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**Determinants of the application of personalised
nutrition and associated technologies in dietetic
practice**

- **A mixed methods study of key stakeholders in
personalised nutrition**

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Determinants of the application of personalised nutrition and associated technologies in dietetic practice - A mixed methods study of key stakeholders in personalised nutrition

Keywords: Personalised nutrition, technology, innovation, dietitians, entrepreneur, health, nutrigenomics, nutrigenetics

Abstract

Background: Tech-enabled personalised nutrition is an emerging area that has promise to improve health outcomes, widen access to nutrition expertise and reduce healthcare expenditure, yet uptake by registered dietitians remains low. This research programme aimed to identify levers and barriers that contribute to adoption of personalised nutrition in order to guide practice and policy for registered dietitians, educators and consumers.

Methods: A mixed methods study with a sequential exploratory design was adopted to determine what the barriers to adoption of technologies are, and secondly, what needs to be in place to make tech-enabled personalised nutrition a reality. The research programme was conducted online using qualitative (focus groups and interviews) and quantitative measures (survey and secondary analysis). Thematic analysis, statistical and secondary analyses of data were performed respectively.

Results: Using diffusion of innovation and entrepreneurial theories, findings indicate that barriers to integration of personalised nutrition technologies include intrinsic and extrinsic factors which relate to a low self-efficacy, high perception of risk, low perceived importance and usefulness of technologies to dietetic practice as well as a lack of an entrepreneurial mindset and regulatory environment.

Conclusion: Uptake of tech-enabled personalised nutrition by registered dietitians will require a multi-stakeholder approach. Educational, professional, regulatory and health policies will need to be in place and strategies that open discussion between Registered Dietitians (RD's) at all levels are needed.

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Humble beginnings

“It always seems impossible until it’s done” - Nelson Mandela

This thesis would not have been possible without acknowledging God and a number of significant people in my life.

Firstly, I thank God for blessing me with health, patience, strength and light to guide me through the last four years. Without faith in God and faith in myself, I would not have been able to reach this milestone. I am eternally grateful to my parents Sam and Laura Abrahams, for laying a solid foundation of life-long learning, sharing selflessly and making an impact by lifting up those around us who may not have a voice. Thank you for the encouragement and supportive words despite the distance. To my loving, patient, ever-present and tolerant husband Luis, my children Arnaldo and Aria, I cannot thank you enough for standing by me over these last four years. Thank you for loving me despite the mood swings, the late nights and the distant looks whilst I was caught up and focused. Last but not least, I would like to thank my supervisors Barbara, Ellie and Lynn for your patience, expert guidance, the kind and encouraging feedback and the vibrant disagreements, it has made my PhD journey an



interesting and unforgettable one!

I dedicate this PhD to my nephew and godchild Tristan, who left us this year.

Your light is our blessing, rest in peace.

Mariette Abrahams

Publications and activities related to PhD

Publications

Paper 1:

Abrahams, M., Bryant, E., Frewer, L., Stewart-Knox, B. Factors determining the integration of nutritional genomics into clinical practice by Registered Dietitians.

Trends in Food Science Nov 2017 <https://doi.org/10.1016/j.tifs.2016.11.005>

Paper 2:

Abrahams, M., Bryant, E., Frewer, L., Stewart-Knox, B. Perceptions and experiences of early-adopting registered dietitians in integrating nutrigenomics into practice.

British Food Journal April 2018

<https://www.emeraldinsight.com/doi/full/10.1108/BFJ-08-2017-0464>

Paper 3:

D'Auria, E., Abrahams, M., Zuccotti, V., Venter, C. Personalised nutrition approach in food allergy: Is It prime time yet?

Nutrients 2019; <https://doi.org/10.3390/nu11020359>

Paper 4:

Abrahams, M., Bryant, E., Frewer, L., Stewart-Knox, B.

Personalised nutrition technologies and innovations: A cross-national survey of registered dietitians

Public health genomics (2019) – [doi: 10.1159/000502915](https://doi.org/10.1159/000502915)

Accepted poster abstracts

Registered dietitians in the genomic era – a qualitative study

International Congress of Dietetic Association - Granada (Spain) 2016

Risk perceptions and attitudes towards personalised nutrition technologies

Food & Nutrition Expo (FNCE) – Washington (US) 2018

doi: 10.1016/j.jand.2018.06.248

Contributing book chapters

Trends in Personalised Nutrition- published June 2019 (Elsevier)

Personalised nutrition chapter in new book “Is butter a carb? - unpicking fact from fiction in the world of nutrition” – published June 2019 (Piatkus)

Contributing articles in dietetic practice magazines

Tech-enabled personalised nutrition evaluation of an intensive module to develop an entrepreneurial mindset and creativity skills in nutrition and dietetics students. *Complete Nutrition Magazine CN Vol.18 No.5 November 2018*

How important is technology in your dietetic practice? *Dietetics Today 42-42 March 2019*

Conference speaking & moderating

Personalised nutrition in the food and beverage industry

Food/Health Ingredients Frankfurt 2017/8

Personalised nutrition and the role of healthcare professionals

Personalised nutrition summit - Amsterdam 2016

Personalised nutrition seminar stream

Food Matters Live London 2015 - 2018

Personalised nutrition expert panel

Food & Drink expo Birmingham UK 2018

Personalised nutrition, technology and dietetics- where are we now

BDA Live – London 2018 (British Dietetics Association)

Global trends and market developments in personalised nutrition

Personalised Nutrition & Innovation summit San Francisco and London 2018

Personalised nutrition trends in food and retail

Personalised nutrition workshop - Brussels 2017

Personalised nutrition in obesity management

BDA obesity specialist group – Manchester 2016 (British Dietetics Association)

Our digital future- how new technologies are impacting nutrition practice

*Nutritionists in Industry and Association of Nutritionists (AfN) annual conference
- London 2017*

The future of food KED talk

Kellogg's UK Headquarters – Manchester 2017

Educational webinars & training

Key essentials on personalised nutrition and nutrigenomics for nutrition professionals Nutrition Society (UK) 2015 – ongoing

Freelance dietitian training day on nutritional genomics – British Dietetics Association May 2015

Guest lecturing - business innovation, creativity and entrepreneurship in personalised nutrition

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Awards

Pat Brereton award – to attend International Society of Nutrigenomics & Nutrigenetics conference in 2015 Tel Aviv (Israel)

GET award – To present poster at FNCE 2018 in Washington (US)

WEIT – Selected to attend workshop for women leaders in health tech innovation leadership course - Barcelona 2018

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Glossary

DNA	Deoxyribonucleic acid
DNA testing	Also known as genetic testing, referring to analysing inherited variations in the human genome
EA (Early adopter)	Individuals who typically are some of the first to adopt new technologies or innovations
Food4me	A 9-European country wide study that aimed to consumer acceptance and perceptions to personalised nutrition
Genome sequencing	A process that involves the sequencing of an organisms chromosomal and/or mitochondrial DNA
Internet of things	Is defined as the extension of internet connectivity to devices and objects
Metabolomics	Is the study of metabolites that are intermediates and products of metabolism
Microbiome	The host of the trillions of gut bacteria
Nutrigenetics	The study of the impact of genetic variation on dietary response to food and beverages. The focus of this field is on health promotion and personalising diet and lifestyle
Nutrigenomics	The study of the impact of food and bioactive molecules on gene expression

Nutritional genomics	The overarching term which encompasses nutrigenomics and nutrigenetics,
Nutritionist	A healthcare professional with a qualification in human nutrition. Registered nutritionists have a degree in nutrition, they differ from registered dietitians by not having completed a clinical practice placement to manage conditions and therefore do not provide medical nutritional therapy. The title “nutritionist” is not protected by law
Personal genome testing	DNA testing of the human genome
Personalised nutrition	The provision of personalised dietary recommendations based on various parameters such as dietary preferences, religion, culture, medical conditions, genetics, microbiome
Precision health	The provision of more comprehensive and dynamic nutritional recommendations based on real-time data
Registered Dietitians	The only legally protected term for expert nutrition professionals who have a minimum educational level and practice education. All dietitians are regulated by a Healthcare professions council
Systems nutrition	The multidisciplinary scientific approach of the impact of diet and lifestyle on the body
Tech-enabled personalised nutrition	The use of technology to develop personalised nutritional recommendations

List of Abbreviations

A.D.A	American Dietetic Association
A.N.D	Academy of Nutrition and Dietetics
A.I	Artificial Intelligence
BDA	British Dietetics Association
CPD	Continuous Professional Development
DNA	Deoxyribonucleic acid
DTC	Direct-To - Consumer
Dr	Doctor
EA	Early adopter
EC	European Commission
EU	European Union
FDA	Food and Drug Administration
GDPR	General Data Protection Regulation
HCP	Healthcare Professional
HCPC	Health and Care Professions Council
ICREP	International Confederation of Registers for Exercise Professionals
INCP	International Nutrition Care Process

IFM	Integrative and Functional Medicine
IoT	Internet of things
NGx	Nutritional genomics
NHS	National Health Service
PKU	Phenylketonuria
PN	Personalised Nutrition
RD	Registered Dietitian
RDN	Registered Dietitian - Nutritionist
SPSS	Statistical Package for the Social Sciences
STEM	Science, Technology, Engineering, Maths
TPB	Theory of Planned behaviour
UK	United Kingdom

Chapter 1

General introduction

1.1 Introduction

Nutrition has long been regarded as important for human health and well-being, as famously quoted by Hippocrates “Let food be thy medicine, and medicine be thy food”. Centuries later this has not changed, only as molecular science has evolved, the intricate relationship between food and health can now be explained through pathways, networks and signals (van Ommen *et al.*, 2017). Nutritional science has become a ‘hard’ science, and good nutritional advice to prevent and treat disease, is in high demand (Kohlmeier, 2018).

The dietetic profession is less than 100 years old, yet it has experienced tremendous growth and evolution (Morgan *et al.*, 2018). Since the inception of the profession, Registered Dietitians (RD’s) have worked to improve health of the nation through the industrial era, war and now the technological revolution, by providing nutrition advice to individuals whilst contributing to the development of national nutritional policies (Mozaffarian, 2016).

RD’s around the globe are the only nutrition professionals with a ‘protected title’ which means that the title can only be used if specific knowledge and practice criteria have been met (HCPC, *Article 39(1) of the Health and Social Work Professions Order 2001*). RD’s are also regulated by a professional body, meaning that dietetic practice is governed by a strict ethical code (ICDA, 2010). RD’s enjoy a wide variety of roles within hospitals, community settings, public health, the food industry and the media, to name a few (Hickson *et al.*, 2018).

It is important to emphasize that RD's and registered nutritionists differ because the former have completed a clinical placement period. The title "nutritionist" is however not a protected title and therefore can be used by any individual irrespective of the number of study hours completed. The terms registered dietitian and registered nutritionist are country-specific, but are herein referred to as the nutrition professionals that have met the required criteria. Only registered dietitians are licensed to provide nutritional therapy. Over the last two decades the numbers of registered dietitian/nutritionist across the globe have increased from 135,000 in 1996 to 209,362 in 2016 which translates to a staggering increase of 55% (ICDA, 2016). The European Federation of Dietetic Associations (EFDA) has reported a membership of approximately 40,000 registered dietitians, demonstrating an increased awareness of healthcare providers of the role of nutrition in health.

The dietetic profession has evolved from being an exclusively referral-based service (by a medical professional), to becoming a self-referral and highly specialized service (Stein, 2017). However, we are currently in the midst of a digital era where the Internet of things (IoT), social media, mobile technologies and the promise of big data are infiltrating our everyday lives and now healthcare too (Rathore *et al.*, 2016).

Healthcare systems around the globe are crippling under the pressure of dealing with an epidemic of preventable lifestyle diseases, such as type II diabetes, and are increasingly looking for innovative solutions that can improve prevention, promote early detection and increase level of knowledge on long-term health (Tambo and Ngogang, 2018). This has meant that adoption of new technologies that enable self-care and the emergence of precision medicine

(Aronson and Rehm, 2015) are crucial drivers for future nutrition and dietetic practice; therefore, acceptance, attitudes and perspectives towards these new technologies requires investigation.

1.1.1 Genetic testing & personalised nutrition technologies

Genetic testing for monogenetic disorders such as Phenylketonuria (PKU) an inherited condition that leads to increased levels of the amino acid phenylalanine in the blood (Guthrie and Susi, 1963), has been included in screening programmes for decades (Rose and Wick, 2016). However, it is only recently that genetic testing has increasingly gathered interest for personalising nutritional recommendations to optimise health and prevention using nutrigenetic, personal genome or DNA testing (Stewart-Knox *et al.*, 2009). These technologies are available through home testing kits available directly to consumers or via healthcare professionals (Bloss *et al.*, 2011). These kits generally consist of a saliva collection tube, instruction leaflet and consent form. Once a sample has been taken by the consumer, these are sent back via pre-paid envelopes to the DNA testing company. DNA results are provided either directly by the company in the form of a physical or digital report, or via a healthcare professionals.

Nutrigenetic testing (or DNA-testing) was one of the first tech-enabled solutions first commercialised after the completion of the human genome project in 2003 (Wellcome Trust Case Consortium, 2007). Nutrigenetics is the study of how genetic variations influence dietary requirements and response, whilst nutrigenomics is the study of how food and bioactive molecules impact gene

expression (Ferguson *et al.*, 2016). However, in the literature these terms are at times used interchangeably. The overarching term for both fields is known as nutritional genomics (Ferguson *et al.*, 2016), however for the purpose of this research, focus is placed on nutrigenetics as the technology available direct to consumers and healthcare professionals.

Two key drivers for the recent uptake of genetic testing, has been consumer interest in health and nutrition, and the rapidly falling cost in technologies such as genome sequencing, which has made direct-to consumer testing accessible to the masses (Ronteltap *et al.*, 2013). Large projects such as the 100,000 Genome Project in the UK, have been set up to identify genetic variations implicated in rare diseases such as Acromicric Dysplasia and cancer (Turnbull *et al.*, 2018).

Despite the early excitement, there is considerable debate in the scientific community as to whether genetic testing is ready to be integrated into practice or not (Drabsch *et al.*, 2018; Ordovas *et al.*, 2018;). The lack of regulatory oversight of genetic tests has further contributed to heightened concerns (Evans and Watson, 2015). The genetic testing market, nevertheless, continues to experience double digit growth year on year, and this is predicted to continue (*Nutrigenomics Market Research Report - Global Forecast till 2023*, 2017).

Important developments in the tech-enabled personalised nutrition industry over the last few years have included the expansion from nutrigenetic testing only, into other areas such as: the microbiome which is the composition of our gut based on the bacteria present; remote blood testing; artificial

intelligence; machine learning which is a technology that is able to identify patterns in a set of data which is generated by the user and big data analytics, which involves analysis of a combination large datasets in order to identify patterns and associations (van Ommen *et al.*, 2017). This means that knowledge, awareness and importance of these technologies to dietetic practice is crucial in understanding how, why and when these should or should not be used, yet currently no research on attitudes, perspectives, awareness and importance to RD's exist.

1.1.2 Personalised nutrition and the public

Public interest in personalised nutrition services was confirmed by the recent European-wide consumer Food4me study across nine countries (including the UK) which demonstrated that consumers are receptive to personalised nutrition services, are willing to pay for them, and trust dietitians to deliver them (Poinhos *et al.*, 2017; Fischer *et al.*, 2016; Stewart-Knox *et al.*, 2009). However, clear challenges relating to the best strategy, format and funding to deliver personalised nutrition services persist (O'Sullivan *et al.*, 2018; de Toro *et al.*, 2013; Ronteltap *et al.*, 2013). Therefore, research that can add to the evidence base and provide guidance to dietetic and healthcare organizations to develop structures and policies are needed.

1.1.3 Registered dietitians and personalised nutrition

RD's are ideally placed ahead of any other healthcare profession to deliver personalised nutrition services owing to their expert knowledge in food science, food behaviour, nutrition, physiology, biochemistry, chronic disease prevention as well as their skills in health and behaviour change (Rozga and Handu, 2018; DeBusk, 2009). RD's are the only nutrition professionals to translate science into actionable nutrition plans that are individualised to the person based on consideration on: culture; religion, budget, skills, nutrition literacy, activity and lifestyle to name a few. In addition, RD's are the only nutrition professionals that can provide both health promotion and medical nutrition therapy. In essence, all dietitians are nutritionists, but not all nutritionists can call themselves a registered dietitian. The addition of genetic information could therefore add a further layer of personalisation. For instance, an individual who has inherited the risk allele of the MTHFR (Methylenetretrahydrofolate reductase) gene, could be recommended to significantly enhance their intake of folate through consuming green leafy vegetables by eating more salads, soups or casseroles together with an increase in foods rich in vitamin B2. This small piece of information could potentially improve their circulating levels of folic acid and reduce associated risk of stroke, cardiovascular disease and a raised blood pressure (McNulty *et al.*, 2017). The current problem, however, is that despite advances in digital healthcare and evolving healthcare priorities, dietetic and nutrition programmes continue to prepare students for jobs in the hospital and community settings to manage and treat health conditions instead of adapting to a change that focuses on prevention and self-care (Morgan *et al.*, 2018; Augustine *et al.*,

2016) enabled by wearable and digital technologies as previously mentioned (Kushner and Sorensen, 2013). The uptake of new technologies such as mobile apps by RD's, to date remains low (Chen *et al.*, 2017c), and RD involvement in developing new technology solutions is even lower (Chen *et al.*, 2017a).

In order for the dietetic profession to stay relevant in a precision healthcare environment where consumers are increasingly more informed (Berezowska *et al.*, 2015), it is inevitable that RD's will need to work seamlessly alongside technologies and play a key role in creating them (Chen *et al.*, 2017b). As consumer interest grows, so does the demand for healthcare professionals who can translate genetic testing results (and other diagnostic tests) into actionable advice to prevent disease and improve health (Murgia and Adamski, 2017; Wright, 2014) in view of a global move towards self-care.

The question is, whether the dietetic profession is ready to handle an increase in consumer demand for adequately trained practitioners in view of a current lack of knowledge, exposure and confidence among the profession (Mlodzik-Czyzewska *et al.*, 2018; Augustine *et al.*, 2016; Bouchard-Mercier *et al.*, 2016;; Collins *et al.*, 2013; Oosthuizen, 2011).

1.1.4 The potential societal benefits of personalised nutrition

The impact of providing more personalised care is potentially huge and it is estimated that wide adoption of personalised care could result in reduced health care expenditure of 13% equating to €385bn per year (Marsh and McLennan, 2014).

Uptake of new personalised nutrition technologies provides the opportunity to drive down cost and improve quality of healthcare by focusing on targeted personalised nutrition strategies such as counselling, behaviour change, nutrition education and early detection for disease prevention to promote self-care (Celis-Morales *et al.*, 2016; Livingstone *et al.*, 2016). The ability of technology to reach the population at large (Macready *et al.*, 2018) has potential to widen and increase access to quality and evidence-based personalised information to impact public health, and a move away from a “one-size-fits all” approach (Celis-Morales *et al.*, 2017).

1.2 The research idea

The idea for this research originated from my own work experience, as well as excellent research conducted by other researchers (Li *et al.*, 2014; Collins *et al.*, 2013; Ronteltap, 2008; Ronteltap and van Trijp, 2007). After following a traditional career path as a clinical dietitian, then specialist dietitian and dietetic manager, I was more interested in business and new health technologies that could solve the problems I witnessed in my day-to day work. Instead of undertaking a Masters in Science, I started a Master in Business Administration (MBA), which equipped me with new ways of thinking, seeing and learning, and put me on a new path driven by curiosity and inspiration.

Once I was able to “see”, I could envisage the opportunities that integration of new technologies such as genetic testing and smartphones could have on managing conditions as well as communicating and engaging with patients remotely. Yet, I was baffled by how dietetic practice maintained its traditional approach despite rapid advances in technology. As the tech-enabled

personalised nutrition industry started to grow, I could see through my work that RD's were key agents operating between new technologies and consumers, and that research in this area was clearly and desperately lacking. While there has been an increase in the number of seminars and events covering nutrigenetics, this increased RD knowledge had not led to an increase in uptake of new technologies (Collins *et al.*, 2013) for reasons that are not clear. There was therefore a need to investigate factors, barriers and beliefs that may influence adoption of new personalised nutrition technologies among the RD profession.

1.3 Aims and objectives of research programme

Personalised nutrition presents an opportunity for a modern healthcare system that could benefit society as a whole, however before this can happen, we need to understand personalised nutrition from the perspective of practicing dietitians (Chapter 4). Existing literature on personalised nutrition, genetics and genomics amongst the dietetic profession has been limited to English-speaking countries only (United Kingdom, United States, Canada, Australia, South-Africa) (Collins *et al.*, 2013; Li *et al.*, 2011). Finally, to my knowledge, no research exists on the perspectives of RD's with regards to new personalised nutrition technologies beyond genetic testing or in developing countries.

The aim of this applied research was to guide current practice and policy with regards to the future of personalised nutrition. The main objective of this research programme was to; first explore the key issues hindering and enabling the uptake of personalised nutrition technologies by RD's (Chapter 3 – 5) and secondly, to determine what needs to be in place to enable dietitians to integrate personalised nutrition into practice (Chapter 6).

1.4 Overview of the thesis

The research programme is outlined below over the course of 7 chapters, and a diagram showing how the chapters interlink is illustrated below (Figure 1) to answer research questions:

1. what are the potential barriers and drivers to adoption of personalised nutrition technologies?
2. what needs to be in place to encourage uptake of personalised nutrition technologies?

Chapter 1 (General introduction) Provides background into the rapidly growing area of tech-enabled personalised nutrition, why it is relevant, how it impacts the dietetic profession, why dietitians play such a key role in the field and the idea for this research. I also describe in detail the societal benefit of personalised nutrition and how the field is expanding.

Chapter 2 (General methodology) Provides a general overview of the mixed methods approach, the advantages and disadvantages as well as the theoretical framework for this research programme. It also provides a high-level overview of the potential risks and ethical considerations for the research programme.

Chapter 3 (Literature review) The aim of this chapter was to address and outline the current state of play and potential barriers in terms of the personalised nutrition, and the use of associated technology in practice amongst RD's through a literature review. This review highlighted the specific research gap, as it relates to those who have an opinion or are not using new personalised nutrition technologies herein called non-adopters (NA) versus

those who actually use genetic testing technologies in practice known herein as early adopters (EA).

Chapter 4 (Qualitative study) Findings from the literature review were used for the qualitative study (study 1) to identify the type and importance of potential barriers to integration of technology from the perspective of EA using focus groups and interviews. Studying EA allowed for free expression and identification of themes and topics that were important to them, based on their observation of the state of play, thereby removing my own bias and opinions on the topic. Early adopters from different countries were invited to participate to obtain an international perspective. I moderated the focus groups and conducted the interviews. Data was co-analysed for themes and subthemes by a second researcher.

Chapter 5 (Multi-national survey) Themes and topics identified in the qualitative study (Chapter 4) and the literature review (Chapter 3), were used to develop survey items (Chapter 5). The survey aimed to objectively measure the themes and variables by determining attitude, psychological and personality differences between EA and NA in a cross-section of RD's through survey design in English (United Kingdom, Australia, New Zealand, Canada, Ireland, South- Africa), Spanish (Spain and Mexico) and Portuguese (Brazil and Portugal) speaking countries.

Chapter 6 (Secondary analysis) While previous research has looked at consumer attitudes towards personalised nutrition (Food4me study), there is a lack of research looking at the profile of interested consumers beyond demographics, what level of personalised services they are interested in, their

self-perceived nutritional self-efficacy and health status and how that relates to the healthcare professionals they trust to deliver that service. This chapter, therefore looked at consumer perspectives by identifying consumer profiles associated with trust related to three different healthcare professionals to provide personalised nutrition services (RD, Family doctor and personal trainer) as well as what level of personalisation that would entail through secondary analysis. This chapter addresses the problem of what needs to be in place in order to ensure equitable access to expert personalised nutrition services.

Chapter 7 (General discussion) Provides a general discussion of the results and a comparison with previous available research. This chapter outlines the strengths, limitations of the mixed-methods approach and the implications of this research with regards to practice, policy and education for dietetic organisations. Finally, it provides direction for future research.

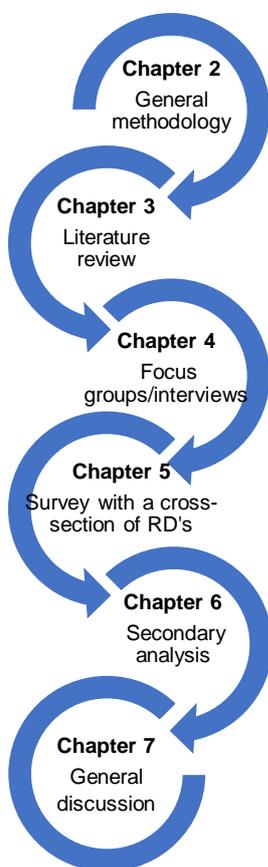


Figure 1. How chapters interlink

1.5 Conclusion

Technology-enabled personalised nutrition is a rapidly growing field owing to phenomenal advances in science, technology and evolving innovative healthcare practices. RD's play a key role as translators of science into actionable information to consumers and patients, however, uptake of technologies is low for reasons that are not entirely clear.

This was a multi-national exploratory mixed methods study with the aim of developing guidance for practice and policy for RD's and associated organisations currently providing nutritional services in the midst of a digital age.

Chapter 2

General methods

2.1 Overall research overview and design

This was an exploratory mixed-methods study driven by my curiosity into the phenomenon of uptake of personalised nutrition technologies into practice by registered dietitians across selected countries (UK, Ireland, Canada, US, Australia, South-Africa, Mexico, Portugal, Spain, Israel). Countries were selected based on previous research as well as personal knowledge of the current marketplace for personalised nutrition technologies and practice. The overall design of the study was exploratory sequential in nature, with the ultimate goal of generating recommendations for social action. The study was conducted mostly online which included qualitative (interviews, documents) and quantitative (surveys) methods to address the research questions. Qualitative data was analysed using thematic analysis and quantitative data was analysed using parametric statistical tests.

2.2 Theoretical framework

2.2.1 Epistemology

This research programme takes an epistemological post-positivist realist approach with inductive reasoning. A realist approach is of the view that there is a reality independent of our thinking that can be studied through objective means and theory that is revisable (Bhaskar, 1975). For this research programme, an inductive approach was adopted to focus on studying observable facts. It is an acceptable approach to develop in-depth descriptions and to illuminate social phenomena and human experience such as in this case,

where an in-depth understanding of the topic, motivations and perceptions for integrating technology was required (Creswell, 1998). Being mindful of the current discussions and controversies around mixed method research (Tobi and Kampen, 2018), I have adopted a complementary strengths stance which means that the weakness prevalent within one theoretical perspective can be offset by the inherent strengths of another perspective (Teddlie and Tshakkori, 2009).

2.3 Theoretical approach and contribution

2.3.1 Diffusion of innovation theory

Using diffusion of innovation theory (Rogers, 1962) the research programme set out to identify potential barriers that may hinder uptake of personalised nutrition technologies and to propose solutions that could encourage uptake of technologies and services amongst practitioners and consumers. The diffusion of innovation theory is a well-established theory that attempts to explain how new innovations are adopted by different segments of the population at different time points. The theory predicts that new innovations are firstly adopted by the early adopter segment. This group tends to be open to new innovations, are comfortable with uncertainty, taking risks and to test new solutions that match their values (Rogers, 1962). The theory supports the concept why different approaches need to be adopted per segment in order to increase trust in new innovations, acceptance and eventually adoption (Rogers, 1962).

EA are therefore considered an important group as they have gone through the different phases which ultimately ends in accepting a new technology or aborting it. They have acquired significant knowledge and experience in

integrating new technology into their workflows and have witnessed the benefits in comparison to their usual practice. Yet with regards to the RD profession, we have no prior research conducted on the topic of personalised nutrition in this important group in order to influence the next segment of users.

The theory was applied throughout the whole programme by:

- obtaining an in-depth understanding and perspective of early adopters, who would influence, persuade and educate the next segment of early majority
- understanding and validating key issues that may hinder uptake of innovations by the early majority of RD's
- understanding key factors that could lead to increased acceptance and adoption of personalised nutrition technologies by consumers.

2.3.2 Entrepreneurial theory

Other theories that were used, included entrepreneurship theory with a focus on human capital, sociological and psychological theories (Simpeh, 2011). Human capital theory focuses on education and experience (Becker, 1975), where the aforementioned attributes are important determinants of opportunity identification and exploitation. The theory implies that the more human capital assets an individual acquires over time, the better and more comfortable they may become in adopting new practices and new behaviours as it relates to their work. Therefore, for this thesis, it was important to determine whether human capital theory bears out when comparing early and non-adopters of new personalised nutrition technologies. Sociological entrepreneurial theory focuses on entrepreneurship which is based on building

relationships in order to instil trust (Reynolds, 1992). Social entrepreneurs are focused on radically improving current conditions to benefit society as a whole. This theory was of particular interest as RD's as healthcare professionals have an interest in helping and supporting society for the greater good. In order to help individuals to change their lifestyle and behaviour, it is crucial for RD's to build trust and relationships with their clients and patients. Social entrepreneurship theory therefore provides a potential explanation for why some RD's integrate new technologies and some don't in the absence (or limited presence) of available evidence. Finally, psychological entrepreneurship theory includes: the role of personality traits, risk, need for achievement (McClelland, 1962), innovativeness (Mohar *et al.*,2007) and locus of control (Rotter, 1966) as potential factors determining entrepreneurial traits and behaviour. This theory poses the idea that some entrepreneurial traits are innate to the individual whereas other can be taught. Therefore, this theory could explain how specific traits could influence adoption of new technologies in order for strategies to be developed to address these. Entrepreneurial theory was used in the development of the survey (Chapter 4)

2.3.3 Theoretical contribution

Recent research from the Food4me project demonstrated that there is consumer interest for personalised nutrition services (Stewart-Knox *et al.*, 2013), yet the profession's readiness for providing these services through digital means is not yet known. Application of the aforementioned theories will aid in examining the phenomenon of adoption of new personalised nutrition technologies by EA and NA within the dietetic profession to ascertain the professions readiness to enter the digital healthcare era. The theoretical

contribution lies in the combination of the two theories to explain RD perception, attitude and ultimately behaviour as it pertains to the integration of new technologies as well as providing new dimensions by the inclusion of RD's from other countries that have a different socio-economic level.

The motivation of this thesis was the limited availability of current research on the topic especially amongst RD's, and to contribute to the current discussions around personalised health, the digitisation of healthcare and changes in healthcare policy towards one that focuses on prevention and self-care. Current literature is not only sparse in terms of the technologies studied, but there is inherent bias in the countries that have been included and the profile of RD's that were involved in previous research. With the evolving role of RD's from providing medical nutrition therapy to disease prevention, this thesis is of particular relevance to key stakeholders such as educators, policy-makers, regulators and dietetic organisations.

2.4 Research design and method

2.4.1 Mixed-methods study design

This was a mixed methods study design (Figure 2), which meant the data collection, data-analysis of both qualitative (focus groups and interviews) and quantitative (survey) data were combined to generalise the findings (Creswell and Plano Clarke, 2011). A mixed method design is considered the best to explore a topic in depth that is not very well understood, such as in this research programme (Halcombe and Hickman, 2015). The strength of a mixed methods approach is to provide deeper unbiased and contextual detail to answer the research questions than a qualitative or quantitative method alone would achieve (Halcombe and Hickman, 2015).

A sequential exploratory design which includes a qualitative study followed by a quantitative study, was adopted to first identify important themes and topics to investigate further (Creswell and Plano Clarke, 2011) and finally, to generate recommendations for social action (Creswell, 2014). This approach was preferred over a sequential explanatory design, which also involves two separate phases but starting with a survey and giving priority to the quantitative data, followed by interviews with participants to understand and contextualize the findings (Creswell, 2003). However, this approach would have restricted the ability to explore the emerging themes in full as there is currently very limited research on the topic.

A second alternative was a concurrent nested design, which involves a single data collection phase where qualitative data collection is integrated into the data-collection instrument (Creswell, 2003). However, although this approach is considered convenient in terms of time saving, it is more difficult to code text fields, and it may not be possible to clarify text with individual participants after data-collection.

Another strength of this approach was that while qualitative data provided deep insights into topics, themes, experiences and observations that were important to early adopter RD's of nutrigenetic tests, the quantitative survey research ensured that the results were unbiased, and facilitated the development and interpretation of the relationship between variables (Flick, 2002). Qualitative and quantitative data were considered of equal weighting and secondary analysis provided potential avenues for social action for nutrition students and consumers.

Studying factors determining uptake of personalised nutrition in RD's by quantitative or qualitative means alone, would not have been sufficiently comprehensive to unravel key issues and themes and allowed for validation of the findings (Creswell and Plano Clarke, 2011).

2.4.2 Online approach

An online approach to data collection was adopted for the research programme. Strengths of using an online format include reduced response time, ease of use for participants as well as control over the format (Granello and Wheaton, 2011). The online approach was deemed the best approach as it allowed for easy global reach of registered dietitians which would otherwise not have been possible without significant resources. However, this method is not without limitations, these include: low response rates as well as a potentially biased sample i.e. those with internet access (Granello and Wheaton, 2011). Despite the potential risks, using an online method was deemed the most suitable for the research programme.

Alternative approaches for the thesis could have included a case-study design or a ethnographic approach which would have involved selecting RD's and carefully study their behaviour and decision-making processes, however it would have been difficult to include RD's from several countries due to time and travel constraints.



Figure 2. Sequential exploratory study design

Having the research design as an online study was a risk on its own, due to the risk of low response rates, potential technical difficulties and access to the internet to name a few (Creswell, 2014). However, the risks of this approach outweighed the benefits due to the far reach and high mobile phone use amongst practitioners and the public in general. In addition, personalised nutrition itself, was and remains a topical and highly controversial issue, and therefore, it was suspected that many RD's would like to share their views (Ordovas *et al.*, 2018; Pavlidis *et al.*, 2016; Grimaldi *et al.*, 2014). The risk of low response rate was overcome by publicising the study online and offline, being responsive to enquiries and regularly networking within the profession through speaking at seminars and conferences on the topic (Publications and activities related to PhD).

In the original research design, the early adopters who were involved in the qualitative study, did not respond for further request for an in-depth interview. This could potentially be due to a lack of time availability, although they were happy to complete the online survey. Therefore, I made the decision to not pursue further interviews and focus on other data collection instead to make the initial data more comprehensive, actionable and meaningful.

2.5 Ethical considerations

Ethical approval was granted by the University of Bradford ethics committee for the qualitative and quantitative study arms of the research (Chapter 4–6). Ethical approval for the secondary analysis of the Food4me survey data (Chapter 6) was obtained by the original academic institutions that conducted the Food4me study. Data were received in anonymised format.

Agreement to use the historic data was obtained from past study researchers via email confirmation (Chapter 6).

2.6 Conclusion

This was a mixed-methods study with a sequential exploratory design.

Theoretical frameworks incorporated in the research programme included primarily diffusion of innovation (Rogers, 1962) and to a lesser degree entrepreneurial theory. The exploratory research programme was multi-national in nature and was conducted predominantly online.

Chapter 3

Factors determining the integration of nutrigenetics into clinical practice by Registered dietitians

(Published- in appendix)

Abstract

Background: Personalised nutrition has the potential to improve health, prevent disease and reduce healthcare expenditure. Whilst research hints at positive consumer attitudes towards personalised nutrition that draws upon lifestyle, phenotypic and genotypic data, little is known about the degree to which Registered Dietitians (RD) are engaged in the delivery of such services. This review sought to determine possible factors associated with the integration of the emerging science of nutrigenetics into the clinical practice setting by practicing RD's.

Scope: Search of online databases (Pubmed, National Library of Medicine, Cochrane Library, Ovid Medline) was conducted on material published from January 2000 to December 2014. Studies that sampled practicing dietitians and investigated integration or application of nutrigenetics and genetics knowledge into practice were eligible.

Key Findings: Articles were assessed according to the American Dietetic Association Quality Criteria Checklist. There has been low integration of nutritional genomics in clinical practice. Application of nutritional genomic approaches to dietary health promotion was associated with knowledge about and confidence in the science, positive attitude towards the field, access to direct to consumer products (DTC) and the working environment.

Conclusions: For dietitians to engage with and integrate nutrigenetics knowledge into practice, more research is required to develop strategies and policies that combine educational knowledge with clinical application. A supportive environment, especially for newly qualified practitioners, which maximises the use of digital technology is urgently needed.

3.1 Introduction

Since the completion of the Human genome project in 2003 (Müller and Kersten, 2003), vast progress has been made in the field of identifying human genetic variations which may play a role in the development of obesity and chronic diseases such as diabetes, cardiovascular disease and dementia (Nielsen and El-Soehmy, 2012). With regards to modernising healthcare, the United Kingdom (UK) government in particular, is aiming to lead genomic research and its application within the NHS (NHS, 2019). According to the 10-year forward review (NHS, 2019), personalised healthcare will be delivered using digital technologies and will be informed by genomic data, which is poised to revolutionise healthcare toward personalised treatment plans. Although personalised nutrition is not explicitly mentioned within the plans, recent reports highlight that diet and lifestyle play a key role in the prevention of non-communicable diseases (WHO). The European Commission has pledged make to personalised diets a priority by 2050 (EC, 2014).

The rapid development in genomic research has led to the emerging field of nutritional genomics (NGx) which encompasses both: nutrigenomics, the study of the impact of diet on gene expression and; nutrigenetics, which looks at how our genetic make-up affects nutrient response (Müller and Kersten, 2003). Rosen *et al* (2006, p1243) defined the application of nutrigenetics (also known

as NGx) as “the interpretation of genetic profile information with subsequent therapeutic prescription of an individualised dietary regimen that was tailored to the prevention or management of one or more specific diseases or conditions identified by the genetic profile”. In addition, the position paper of the Academy of Nutrition and Dietetics (A.N.D) on NGx (hereby referring to the overarching field) states “The application of NGx in clinical practice requires that healthcare professionals understand, interpret and communicate complex test results in which the actual risk of developing a disease may or may not be known” (A.N.D position paper on Nutritional Genomics 2014, p299). The aim of the nutritional genomics field is to enable the delivery of a personalised approach to nutrition intervention which is, or may be based on; lifestyle, genotype and/or phenotype, and in doing so, to prevent or mitigate the development of chronic diseases (Fenech *et al.*, 2011).

The clinical utility of genetic tests to devise personalised nutrition plans have been widely criticised mainly because of a lack of evidence for strong gene-nutrient interactions as well as lack of effectiveness for behaviour change (Hollands *et al.*, 2016; Pavlidis *et al.*, 2015, Burke, 2014, Fraker and Mazza, 2010; Castle and Ries, 2007). On the contrary, there is also mounting evidence, on the potential benefits of a gene-based personalised nutrition approach with regards to lifestyle and behaviour change (Livingstone *et al.*, 2016, Frankwich *et al.*, 2015).

The term ‘personalised nutrition’ has commonly been used interchangeably with ‘nutritional genomics’, yet personalised nutrition has been defined more broadly. The Food4me project was a European wide research effort that looked extensively into public perception of, attitudes toward and

preferences for personalised nutrition as well as explored potential business models for delivering personalised nutrition (Fischer *et al.*, 2016; Rankin *et al.*, 2016; Berezowska *et al.*, 2015; Fallaize *et al.*, 2015; Berezowska *et al.*, 2014; Poinhos *et al.*, 2014; Stewart-Knox *et al.*, 2014; Stewart-Knox *et al.*, 2013; Ronteltap *et al.*, 2012).

Gene-based personalised nutrition was extensively researched in previous large studies such as LIPGENE and PREDIMED, and is already available in the marketplace through various avenues (Ronteltap *et al.*, 2013). For the purpose of the Food4me project, personalised nutrition was defined on three levels: dietary analysis; dietary analysis + phenotypic information (e.g. blood nutrient profile, anthropometry); or dietary analysis + phenotype + genotype (Livingstone *et al.*, 2016).

Despite the uncertainty surrounding the technology, early research from the Food4me project results have indicated a willingness among the European public to pay for a personalised nutrition service which includes some combination of dietary, phenotypic and genotype data (Livingstone *et al.*, 2016; Fischer *et al.*, 2016; Ries *et al.*, 2010). Dietitians (together with family doctors) were identified as among preferred providers of personalised nutrition (Poinhos *et al.*, 2017; Fallaize *et al.*, 2015; Stewart-Knox, 2013). RD's have been providing personalised nutrition plans based on various parameters such as age, medical history as well as blood biochemical data for decades (Sikalidis, 2018; Stein, 2017; DeBusk, 2010). RD's are therefore best placed to deliver nutrigenetics services owing to their expert knowledge on nutrition, disease prevention, medical nutrition therapy as well as behavior change. New technology such as sequencing are generating new type of data which when

interpreted correctly, could be potentially translated into actionable recommendations to improve or optimize health.

Nutrigenetics adds an additional layer of personalisation by including genotypic information. Yet, debate continues as to whether RD's should be delivering gene-based service when there is only limited evidence for links between diet and genetics (Ordovas *et al.*, 2018; Mathers, 2017; Grimaldi, 2014; Görman *et al.*, 2013; San-Cristobal *et al.*, 2013). Professional guidelines therefore, recommend that nutrigenetic testing is not ready for the purpose of routine dietetic practice (Camp and Trujillo, 2014). Meanwhile, there is a growing expectation that RD's should be competent in genetics (HCPC, 2013; BDA, 2013), have a basic knowledge of nutritional genomics (NHS learning outcomes for dietitians on nutritional genomics, 2014) and be prepared to integrate nutrigenetics into their practice (Collins *et al.*, 2013).

There has also been an urgency and education drive of front-line healthcare practitioners to become familiar with genomics (Collins *et al.*, 2018; Martin, 2018; Mlodzik-Czyzewska and Chmurzynska, 2018; Murgia and Adamski, 2017; Health education England, 2016; Daley *et al.*, 2013). Only a few research studies, however, appear to have examined RD's engagement in the field of nutritional genomics (Collins *et al.*, 2013; McCarthy *et al.*, 2008; Whelan *et al.*, 2008; Rosen *et al.*, 2006).

With an interested potential consumer market (Fischer *et al.*, 2016), it is critical to identify and address any barriers that may affect the integration of nutrigenomic science into practice. Any lack of engagement and/or understanding of the science by nutrition providers could impact negatively

upon public perception which could have a knock-on effect on public health. Hence, RD's have an important role to play, in being the bridge between the science and the clients and/or public (Gilbride, 2007). It is also crucial to address any gaps that may exist between potential future demand and supply of practitioners adequately trained in the science at all levels.

The aim of this review, has been to identify and understand factors that are associated with the integration and application of nutrigenetics by RD's in clinical practice. Clinical dietetic practice refers both to advising clients or patients, who may or may not have medical conditions, on nutrition (BDA, 2013). The application or integration of nutrigenetics for this review, is therefore defined as "the interpretation of genetic information, as gained from a commercial or genetic screening test, to assess or evaluate an individuals' predisposition to a nutritional risk, risk of developing a disease/condition, or to determine specific nutrition-related characteristics, to be able to formulate a personalised nutritional and lifestyle plan to achieve or maintain health.

3.2 Method

Firstly, the research question was formulated which was: "What are the factors that have been associated with the integration of nutrigenetics into practice by RD's?". Inclusion criteria included: publications written in English, research including RD's only and human research in any country. Exclusion criteria included: research conducted amongst dietetic students, research conducted in animals, review papers and publications for which full-papers were not available. Search terms were determined owing to differences in spelling of the term "dietitian" across different countries, the interchangeable use of the

terms “nutrigenomics”, “nutrigenetics” and “nutritional genomics” in the literature as well as the practical application into clinical practice.

Databases searched included: Pubmed; Ovid Medline; National Library of Medicine, web of science and the Cochrane library as the most comprehensive sources available. In order to obtain a comprehensive list of publications, an advanced search was performed using the final keyword strategy which included a combination of the terms: Dietitian or Dietician AND Nutritional Genomics OR Nutrigenetics OR Nutrigenomics OR Diet-gene interaction AND Integration OR Application OR Translation OR Involvement OR Attitude OR clinical practice.

All studies published between January 2000 and December 2018 were considered eligible for inclusion. Additional references were found in the bibliography of articles, conference presentations and proceeds of meetings. A total of 91793 articles were found using the databases, most of which were excluded from the search digitally on the basis of: duplication in the different databases used; the title alone; keywords included in the summary or abstract if it did not meet the criteria for the review (see Figure 3).

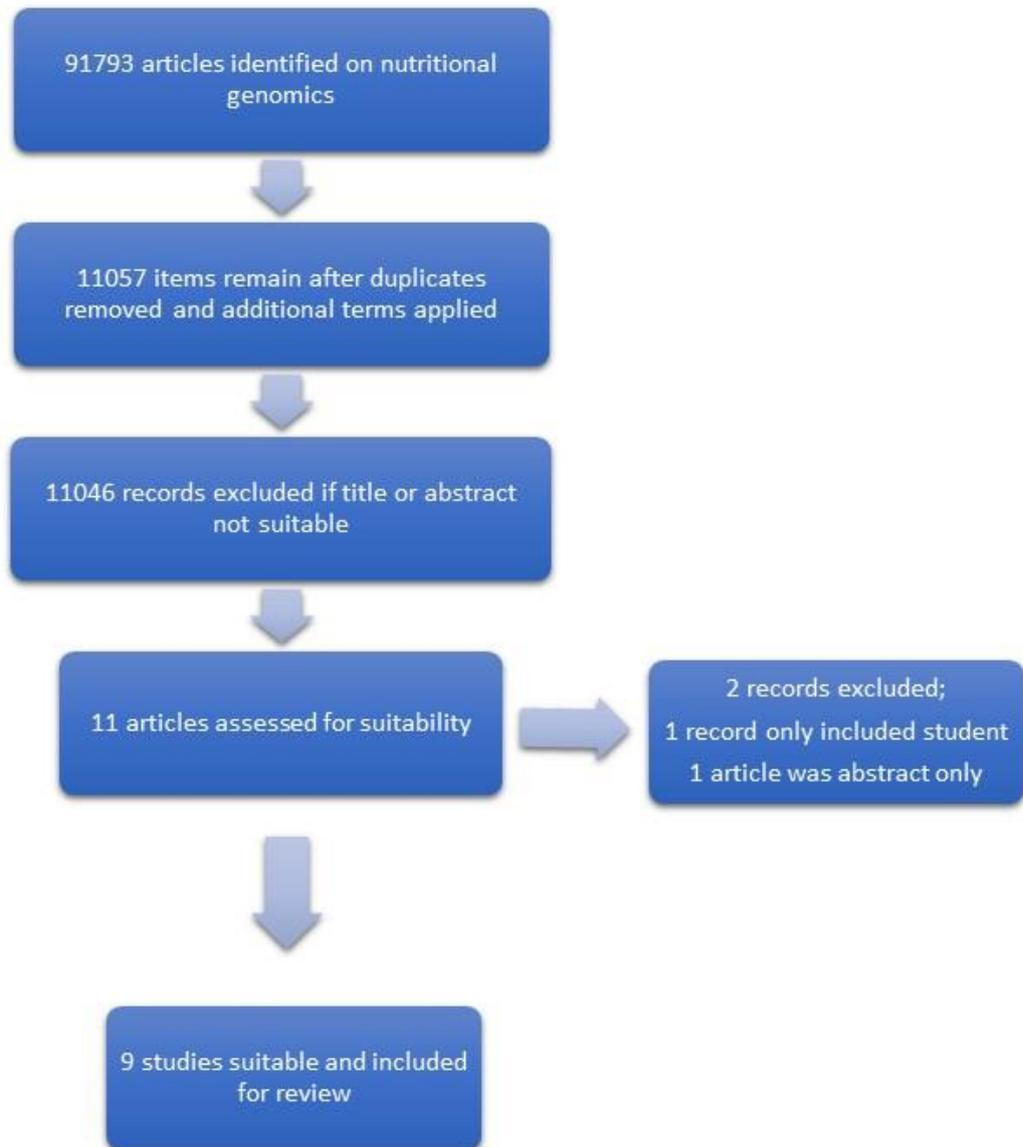


Figure 3 Literature review process

3.3 Data extraction

A total of 9 eligible studies were identified and 1 was added (Bouchard-Mercier *et al.*, 2016) at the end of the thesis write-up phase as a recent publication (Table 1). The full-text versions of the papers that were included in the analysis were accessed using the university online library. Each study was read, analysed for suitability and assessed by myself according to the American

Dietetic Association Quality Criteria Checklist (ADA, 2003). This entailed answering a list of questions with “yes”, “no” or “neutral” related to each study. If most of the answers were “yes”, the study received a positive quality rating, if most of the answers were “no”, the study received a negative rating and if most answers were not applicable, the study received a neutral rating. Overall, the evidence base on the currently available literature is very small but mostly of positive quality as indicated in Table 1. The senior PhD supervisor reviewed all the 11 initial papers and critically reviewed the ADA scoring criteria for each paper before inclusion in the final analysis.

This process was selected in order to increase the rigour of the analysis by using a standardized approach, and to reduce bias by the inclusion of a second reviewer. The strength of this approach is that it improves replicability, however the weakness is that papers or dissertations that are unpublished may have been missed entirely.

3.4 Results

Inclusion criteria as outlined in Table 1 were met by 10 studies. The research included mostly cross-sectional and/or case control studies that were conducted mainly in English-speaking countries including UK, US, Canada, Australia and South-Africa. Seven out of ten studies were surveys (either mailed hardcopies or online), two were mixed-methods (survey and interviews or focus groups) and one was a focus group only. The study designs were mainly cross-sectional in nature, meaning they included dietitians from various clinical backgrounds and specialisations, levels of post-graduate education as well as years of experience. Response rate ranged between 5.8% (Bouchard-Mercier *et al.*, 2016) and 65% (Whelan *et al.*, 2008). The number of participants in each

study ranged between 16 (Li *et al.*, 2014) to 1844 (Collins *et al.*, 2013). As there were a limited number of studies, and the methods across studies were not consistent, a narrative approach was adopted to analyse the findings. The strength of this approach is that it provides a concise summary and synthesis of the highlights of research on a particular topic and can identify gaps in the current research (Cronin, 2008). Weaknesses inherent in this approach include: potential bias when interpreting primary studies in the area of interest in order to support a specific perspective (Green *et al.*, 2006). In addition, a common criticism is that a narrative approach is unstructured which I attempted to overcome by the inclusion of a structured assessment framework that is recognized in the dietetics field.

Other approaches I could have taken included a mapping review, which involves a frequency count to identify patterns and trends, although again owing to the limited number of publications this would not have been appropriate.

3.5 Key factors associated with the integration of nutrigenetics into practice

3.5.1 Involvement of nutrigenetics in the clinical and education setting

Involvement in nutrigenetics was identified as one of the key factors associated with integration into practice (Collins *et al.*, 2013; Oosthuizen, 2011; Whelan *et al.*, 2008). According to Whelan and colleagues (2008) and Collins and colleagues (2014) the term involvement (in nutrigenetics) has been used to refer to eleven clinical, and three different educational activities about genetics and nutritional genomics. These include clinical activities such as “discussing the genetic and dietary basis of disease” or “providing nutrition advice to patients which is specific to the genetic nature of their condition” as well as educational

activities such as “providing training to students or other healthcare professionals on diseases that have both a dietary and genetic component”.

Involvement has been predominantly measured via online surveys using Likert scales (Cormier *et al.*, 2014; Collins *et al.*, 2013; Oosthuizen, 2011; Whelan *et al.*, 2008; Rosen *et al.*, 2006; Christianson *et al.*, 2005). Involvement has been found to be low, such that less than 50% reported engaging in activities associated with nutrigenetics in the clinical setting (Collins *et al.*, 2013; Oosthuizen, 2011; Whelan *et al.*, 2008) which, for instance, includes referring individuals to genetic counselling and 46.1% in the educational setting which included teaching (Collins *et al.*, 2013).

In the multinational online survey study (N=1844) conducted by Collins *et al.* (2013) in the UK, Australia and the United States US, the genetics and nutritional genomics activities were not as clearly separated as was the case in the original paper (Whelan *et al.*, 2008). Given the study was cross-sectional in nature RD’s from various sub-disciplines were included in the study, making it difficult to distinguish between those who were dealing with monogenetic (congenital) disorders and those with polygenetic disorders (chronic diseases).

For the purpose of statistical analysis, the ‘involvement’ variable score was calculated from the sum of clinical and educational activities, therefore, making it difficult to separate out and establish the level of integration into clinical practice. In a Quebec study (Bouchard-Mercier *et al.*, 2016) over 96% of participants had never interpreted the results of a nutrigenetic test despite nearly 60% working in the clinical nutrition in the public sector.

<i>Table 1. Studies included in the literature review</i>					
Study, (Country)	Participants	Design	Quality criteria checklist	Factors influencing integration	Result
Bouchard- Mercier <i>et al.</i> , 2016 (Canada)	Dietitians N=141 (5.8% response rate)	Cross- sectional survey	Positive	Attitude Knowledge Client interest	96.4% had never interpreted results from a nutrigenetic test. Attitude towards discussing nutrigenetics with clients, was strongest TPB construct in predicting intention.
Collins <i>et al.</i> , 2013 (UK, US, Australia)	Dietitians N=1844 (13% response rate)	Cross- sectional survey	Positive	Confidence Knowledge Involvement	Strongest predictor of high involvement for clinical activities was high confidence p<0.001 High knowledge was associated with higher confidence and involvement
Whelan <i>et al.</i> , 2008 (UK)	Dietitians	Postal survey	Positive	Confidence Knowledge	Involvement is associated with high confidence, however involvement was limited

	N=390 (65% response rate)				to discussing diseases with dietary and genetic component (49%) or advising patients where to access information relating to a disease with a dietary and genetic component (33%)
Cormier <i>et al.</i> , 2014 (Canada)	Dietitians N=373 (15.3% response rate)	Online survey	Positive	Experience Perception Knowledge Ethical issues Market need Job role	Less experienced dietitians were more knowledgeable but not applying nutrigenetics into practice. Seniors dietitians were less knowledgeable and more sceptical and concerned about ethical and legal aspects associated with DTC tests. RD's in private practice are more likely to integrate nutrigenetics than RD's in acute and food serve setting.
Weir <i>et al.</i> , 2010 (Canada)	HCP's including RD's n=4,	Focus groups	Neutral	Perceived benefit Confidence	High level of skepticism towards nutritional benefit, lack of confidence to deliver

	nutritionist n=1			Knowledge	nutrigenetic services and lack of knowledge hindered integration
Christianson <i>et al.</i> , 2005 (Australia)	HCP's including dietitians N=235 (response rate 34%)	Cross-sectional survey	Positive	Job role Knowledge Understanding link between diet and genes	71% did not work with patients with genetic conditions. Lack of knowledge and understanding of the link between diet and genes
Lapham <i>et al.</i> , 2000 (US)	Dietitians N=362 (62% response rate)	Survey and focus groups	Positive	Involvement Confidence	Involvement is limited to discussing genetic component of disease problems (67%) and counselling patients with a genetic condition (24.1%) RD's have low confidence in applying genetics in practice
Rosen <i>et al.</i> , 2006 (US)	Dietitians N=995 (40% response rate)	Mailed survey	Positive	Attitude Knowledge and CPD Reimbursement	A positive attitude is associated with greater confidence in the ability to apply knowledge.

				Peer-to peer learning	<p>81% reported lack of knowledge to apply nutrigenetics into practice</p> <p>84% were uncertain about reimbursement for RD's providing nutrigenetic service</p> <p>73% reported a lack of CPD opportunities</p> <p>72% Lack of experts to convey professional expertise</p>
Li <i>et al</i> 2014 (Australia and UK)	<p>Dietitians N=16 (semi-structured interviews)</p> <p>N=7 (focus groups)</p>	<p>Semi-structured interviews</p> <p>Online survey</p> <p>Focus groups</p>	Neutral	<p>Environment</p> <p>Exposure</p> <p>CPD opportunities</p> <p>Relevance to job</p> <p>Evidence</p> <p>Perception</p>	<p>Lack of supportive environment</p> <p>Limited exposure and training</p> <p>Lack of relevance to practice</p> <p>Lack of scientific evidence</p> <p>Too early to integrate the science into practice</p>
Oosthuizen 2011	Dietitians	Cross-sectional survey	Positive	<p>Involvement</p> <p>Confidence</p>	Significant positive association between

(South-Africa)	N=297 (response rate 15.2%)	(online and mailed)		Knowledge	involvement and confidence ($p < 0.001$). Those with higher involvement had higher knowledge and were more confident
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3.5.2 Confidence in Nutrigenetics science and technology

Confidence in the science of nutrigenetics has been identified as one of the strongest predictors of having integrated it into practice. Dietitians with moderate/high level of confidence (54%) were more likely than those with low confidence to be involved in activities relating to nutrigenetics (Collins *et al.*, 2013). Not only did the dietitians lack confidence, but it also appeared that confidence decreased with increasing years of experience (following qualification) (Collins *et al.*, 2013). Another survey (N=995) conducted in the US in 2004 (Rosen *et al.*, 2006) indicated that 60% of RD's had little confidence in their ability to provide nutrition services based on nutrigenetics. According to the multinational (US, UK, Australia) study conducted by Collins *et al* (2013), confidence in nutrigenetics may be associated with involvement, such that those that were involved in nutrigenetics appeared to have more confidence in the science and in ability to apply it to practice (but may not see patients directly). Similar findings were reported in a recent study conducted in Poland (Mlodzik-Czyzewska and Chmurzynska, 2018). This implies that for nutrigenetics to be applied in practice, a sustainable means through which to communicate with RD's on developments in nutrigenetics science on an ongoing basis may be required.

3.5.3 Knowledge of nutrigenetics

Lack of knowledge in nutrigenetics has been identified as a reason for low integration of nutrigenetics into practice. A survey (N=390) conducted in the UK (Whelan *et al.*, 2008) and another, more recently (N=373) conducted in Canada (Cormier, 2014) found that 75.9% of RD's in the clinical nutrition (public healthcare setting) and 62.9% of RD's working as freelance RD's in the private

sector reported that they did not believe that had sufficient knowledge to incorporate nutrigenetics into their clinical practice.

The notion that lack of knowledge deters the application of nutrigenetics is backed up by results of the largest survey study of its kind (Collins *et al.*, 2013) which indicated that only 18.8% (N=1844) of RD's knew the answer to the question "What condition is not associated with the MTHFR 677C→T defect?", which is considered a well research diet-gene interaction. At most, 33.5% could describe what the terms nutrigenomics or nutrigenetics meant. A survey (n=297) of South-African dietitians (Oosthuizen, 2011) found that higher qualifications were associated with greater knowledge and involvement in nutrigenetics. Those with Masters and PhD level education were more likely to be engaged in genetics and nutrigenetics related activities.

This finding, however, has not been borne out in the multinational study conducted by Collins *et al* (2013) who found no association between knowledge of nutrigenetics and involvement. The possibility of any relationship between knowledge and level of qualification was not measured in this study by Collins *et al.*,(2013), but is currently an area of interest (Twohig *et al.*, 2018). Further research may be required to determine the type and level of knowledge required on nutrigenetics by practicing RD's (Bouchard-Mercier *et al.*, 2016).

3.5.4 Attitudes toward nutrigenetics

Relatively few studies have considered the attitudes of RD's toward nutrigenetics. A small mixed-method approach study (n=16) conducted in the UK and Australia by Li and colleagues (2014) found that 50% of dietitians in both countries did not believe that nutrigenetics played any role in informing

their current practice. They also found a general reluctance among RD's to integrate the science owing to a perceived lack of current evidence for its efficacy. Another survey study (N=235) undertaken by Christianson and colleagues (2005) amongst Australian RD's, reported that the majority (71%) attributed the lack of integration of nutrigenetics to not encountering patients with genetic disorders.

This suggests that many RD's have a very limited concept of what nutrigenetics comprises (i.e counselling those with monogenetic disorder) and a neglect of its potential role in the prevention and treatment of non-communicable disease in the general population. Although there were positive views on the potential role of nutrigenetics in preventing the development of chronic diseases, the majority of RD's did not believe that nutrigenetics could improve the quality and relevance of nutritional recommendations they are already providing (Cormier *et al.*, 2014).

This also suggests a need for initiatives to raise awareness of the scope of nutrigenetics and potential for nutrigenetics in public health nutrition (Martin, 2018). A recent study also demonstrated that mHealth use amongst RD's is low (Chen *et al.*, 2017), therefore this may indicate that the aversion to using technology is not just towards nutrigenetics but technology in general (Chen *et al.*, 2017). Another recent study by Bouchard-Mercier et al (2016) found that attitude towards discussing nutrigenetic testing with their clients was the strongest predictor of intention. Overall, this suggests a need for understanding RD attitudes towards technologies, raising awareness and knowledge of nutrigenetics and other personalized nutrition innovations as well as understanding barriers to integration.

3.5.5 Job area and healthcare environment

Quantitative research conducted in Canada, has suggested that RD's in public health/health promotion and food service management may be less likely than clinically based RD's to apply nutrigenetics in practice (Cormier *et al.*, 2014). This finding echoes results of a mixed-methods study reported by Li and colleagues (2014) which found that neither clinically based nor public health RD's (in the UK and Australia), perceived any role for nutrigenetics in providing population level dietary advice. Whereas dietitians in public health failed to see nutrigenetics within the scope of preventative public health, those in the acute (clinical) setting saw nutrigenetics as having a more preventative rather than therapeutic role. The upshot was that neither public health nor clinical dietitians viewed nutrigenetics as relevant to their own area of practice. Other studies (Cormier *et al.*, 2014; Oosthuizen, 2011), meanwhile, have indicated that those engaged in nutrigenetics related activities are most likely to be based in academia, private practice or the food industry. This implies an imperative for research to target RD's practicing in the clinical and public health sectors in an endeavor to better understand the perceived barriers encountered when seeking to engage with nutrigenetics and to apply this understanding to the design of interventions to encourage and support them in providing personalised nutrition services.

3.5.6 Awareness of the field

A US study of N=995 RD's (Rosen *et al.*, 2006) found that 80% of RD's had never encountered nutrigenetics in practice. A possible reason for the lack of integration of nutrigenetics into practice, therefore, could be the lack of exposure in the dietetic curriculum (Li *et al.*, 2014). RD's who are more aware

of this emerging field may be more interested to learn and become involved in activities relating to genetics and nutrigenetics (Li *et al.*, 2014; Collins *et al.*, 2013; Oosthuizen, 2011; Rosen *et al.*, 2006) ;). Although Cormier (2014) found that more than 75%(N=383) of RD's in the Quebec-area (Canada) knew about nutrigenetics, it was not clear from the study whether this high level of awareness led to integration of nutrigenetics into practice.

Raising awareness of nutrigenetics, nevertheless, will require leadership from professional organisations representing dietetics professionals. The latest research on awareness and education on nutrigenetics has identified that genetics and nutritional genomics coverage in the dietetic curriculum is and remains low (Prasad *et al.*, 2019; Collins *et al.*, 2018; Mlodzik-Czyzewska and Chmurzynska, 2018; Beretich *et al.*, 2017; Prasad *et al.*, 2011)

3.5.7 Attitudes toward Direct-to-Consumer (DTC) nutrigenetic tests

Digital technological advances are expected to revolutionise preventative public healthcare (NHS, 2019; EC, 2014) and present an opportunity to digital health technologies directly to the consumer. RD's, however, are purported to hold negative opinions of DTC genetic testing (Cormier *et al.*, 2014; Li *et al.*, 2014; Weir, 2010). RD's appear skeptical of DTC nutrigenetic tests, owing to the perceived lack of scientific evidence for the efficacy of such products (Li *et al.*, 2014; Weir *et al.*, 2010) and this has been put forward as a possible reason for low integration into practice. Research in the area, however, suggests the contrary, receiving personalised genetic information has the potential to increase motivation and commitment to dietary behaviour change (Livingstone *et al.*, 2016; Rankin *et al.*, 2016; Nielsen and El-Soehy, 2014; Saukko, 2013; Bloss *et al.*, 2013, 2011; Green, 2009; Arkadianos *et al.*, 2007).

RD's have also expressed concern that the results of DTC personalised nutrition assessment if conveyed without adequate support and follow-up could cause unnecessary worry in consumers (Cormier, 2014; Li *et al.*, 2014; San-Cristobal *et al.*, 2013; Weir *et al.*, 2010). Individuals could be expected to seek interpretive support from RD's who may be expected to answer clients/patients' questions (Poinhos *et al.*, 2017).

3.6 Discussion

The aim of this review was to identify factors, both barriers and enablers, which may influence the integration of nutrigenetics into practice. Existing studies imply that the apparent reluctance to integrate nutrigenetics into practice is associated with low awareness of nutrigenetics, a lack of confidence in the science surrounding nutrigenetics, and skepticism toward DTC products.

Integration of nutrigenetics also appears to vary among the different dietetics domains (e.g. clinical and public health) and area of practice (e.g. health service versus commercial). All of these factors have potential to respond to education and training initiatives.

Genetics has been designated a compulsory component of dietetics training in the UK since 2008 (BDA, 2013). Nevertheless, nutritional genomics remains only an optional module in undergraduate training in the UK and a module as part of MSc programmes throughout the UK (BDA, 2013). Nutrigenetics and other omic technologies, however, are not yet a part of clinical practice training, which could partly explain the apparently poor knowledge, lack of confidence in the science of nutrigenetics and involvement in

nutrigenetics activities amongst practicing RD's (Mlodzik-Czyzewska and Chmurzynska, 2018; Collins *et al.*, 2014).

RD's involved in managing patients with inborn errors of metabolism were more confident in providing genetic services (Gilbride and Camp, 2004), possibly because this is covered in the undergraduate curricula.

Previous studies have demonstrated that dietitians have a preference for education and training in seminars, workshops or online courses (Morin, 2009; Busstra *et al.*, 2007; Newton, 2007b;), yet the uptake and integration of nutrigenetics following training remains low (Newton, 2007b). This gap in provision of translational education has partly been solved by private companies offering continuous education to various healthcare professionals on the topic (Collins *et al.*, 2018; Ronteltap *et al.*, 2012), however, owing to RD's skepticism towards DTC products and solutions, these opportunities may not be fully exploited.

Digital technological advances may afford the opportunity to integrate the use of digital health technologies which includes big (omics) data on nutrition, into the dietetic curricula (Beretich *et al.*, 2017). Meanwhile, there may be wider issues associated with the lack of interest and involvement in updating skills in nutrigenetics despite the available educational opportunities, which require further investigation (Murgia and Adamski, 2017).

Confidence in the science of nutrigenetics appears to be lowest in those with more years since graduation while knowledge is highest amongst less experienced RD's, possibly because they have had recent training on the topic at undergraduate level (Cormier *et al.*, 2014; Collins *et al.*, 2013; Oosthuizen,

2011; Whelan *et al.*, 2008; McCarthy *et al.*, 2008). This could suggest that RD's who have been out of practice for longer should be afforded continuous education opportunities.

This apparently higher level of knowledge among recent graduates, however, does not appear to translate into clinical practice for reasons that are not entirely clear. It could be that a lack of confidence and lack of a supportive environment are possible explanations (Li *et al.*, 2014). Possible ways on overcoming the confidence gap need to be explored in future research.

Repetition and exposure to clinical situations encourages learning (Banet and Nunez, 2007). However, the current genetics and genomics curriculum in the UK (Dietetic Standards Health and Care Professions Council, 2013) does not appear to follow this approach. Students learn about the science but then do not receive exposure during their clinical placement (Beretich *et al.*, 2017). Reviewing the curriculum to increase knowledge and enhance confidence through clinically based support and training may be necessary to address this (Wright, 2014).

Given the wide range of dietetic roles currently available, a need for change in how we train future dietitians has already been identified (Hickson *et al.*, 2018). The recently published paper on standards of education concluded that "the profession is ready and in need of a change of approach to student training" and that "the sole use of the one-to-one model is neither sustainable nor appropriate and similarly students who only experience NHS acute or community placements do not gain a true understanding of the breadth of dietetic practice" (BDA, practice guidance Dec 2015, p16).

The profession, needs to consider RD's' role and preparation within the 'omics' and digital health technology context (Beretich *et al.*, 2017; Wright, 2014). The core competency in the Learning Outcomes Framework on NGx for Dietitians (The UK National Genetics and Genomics Education Center, 2014: p1) stipulates that: "having a broad understanding of genetics, genomics and genetic testing as it relates to common disorders seen by dietitians, in order that you are able to answer patients' questions".

Professional guidance and RD genomics education websites, however, caution that it is too early to integrate genetic testing to provide genotype-based personalised nutrition advice (Camp and Trujillo, 2014). This renders involvement in nutrigenetics a difficult task, as RD's have both little exposure to nutrigenetics in the dietetic curricula, and a poor perception of DTC products (Cormier *et al.*, 2014; Li *et al.*, 2014;; Weir *et al.*, 2010; Bouwman *et al.*, 2008). I therefore pose the question, if integration is not encouraged, why has previous researched asked the question?

With rapid expansion of the DTC nutrigenetic testing market (Ordovas *et al.*, 2018, Mathers, 2017), the public are likely to seek access to qualified professionals to interpret their results (Critchley, 2015). Whilst nutrigenetic tests have been criticized for lack of clinical utility and validity (Pavlidis *et al.*, 2015) and not ready for prime-time (Grimaldi, 2014; Görman *et al.*, 2013; Bloss *et al.*, 2011), strong market growth indicates consumer interest is growing (Ordovas *et al.*, 2018). According to DTC company websites such as Nutrigenomix (Toronto, Canada <http://nutrigenomix.com>) and DNalysis (Johannesburg, South-Africa <http://dnalysis.co.za>) it is clear that a number of RD's have started integrating nutrigenetics into their practice. So why do some RD's integrate

nutrigenetic testing into their practice and others don't?. Although this may be explained by factors operating within the healthcare environment such as employment in public health services (Government contracted) versus private practice (industry) within which RD's practice, how this operates in practice is currently not clear. RD's are also concerned that DTC results could unnecessarily worry clients and that specific groups, for example, those on lower incomes, could be excluded from accessing such products (Cormier *et al.*, 2014; Li *et al.*, 2014; Weir *et al.*, 2010). Whilst policy needs to consider the needs of the less advantaged members of society (Stewart-Knox *et al.*, 2016) this should not pose a barrier to RD's increasing their knowledge in preparation for responding to questions from patients and the general public (Poinhos *et al.*, 2017; Fischer *et al.*, 2016).

Previous research into the integration of nutrigenetics into practice has only touched upon relevant issues in current nutrigenetics practice such as awareness and education. A possible reason for this, is that the term 'involvement' (in nutrigenetics) has been used in several papers, without it being either fully operationally defined with regard to the application of nutrigenetics or used consistently between studies. A first step toward enabling research on the integration of nutrigenetics in dietetics practice, therefore, would be to define what the integration of nutrigenetics into practice actually means. When looking at the detail within some of the papers (Collins *et al.*, 2013, Whelan *et al.*, 2008), it is evident that none of the activities referred to as "nutritional genomics" actually involved the use of a nutrigenetic test or genotypic information but was limited to a discussion around the role of genetics in disease.

Future research on this topic should provide a full definition of nutrigenetics which encompasses what it entails in practice. Previous studies have indicated some confusion among RD's about what activities are comprised in nutrigenetics beyond the management of inherited conditions (Collins *et al.*, 2014; Whelan *et al.*, 2008). In defining nutrigenetics, therefore, a distinction may need to be made between managing monogenetic disorders (such as inborn errors of metabolic disorders) and personal nutrigenetic testing which relate more to susceptibility to chronic diseases and health promotion (Ferguson *et al.*, 2016).

Most studies were quantitative, mostly on-line surveys and cross-sectional in nature (Collins *et al.*, 2013; Cormier *et al.*, 2014; Oosthuizen, 2011; Weir *et al.*, 2010; Whelan *et al.*, 2008; Rosen *et al.*, 2006; Christianson *et al.*, 2005; Lapham *et al.*, 2000) so there is a need for more in-depth research which could assist in explaining the findings. Some of the surveys suffered poor response rates (Cormier *et al.*, 2014; Collins *et al.*, 2013; Oosthuizen, 2011) and small sample sizes (Li *et al.*, 2014; Weir *et al.*, 2010) the reasons for which are unclear. Only a limited number of countries have been surveyed (Australia, South-Africa, US, UK and Canada) with a lack of research conducted in emerging countries.

3.7 Recent developments (2014-2018)

Since the publication of this review in 2017, only 5 studies have been published: one relating to dietetic students and their perspective on the importance of personal genome testing to dietetic practice (Horne *et al.*, 2016); one study that delved into RD's' intention to discuss nutrigenetics with their patients/clients (Bouchard-Mercier *et al.*, 2016); one study that aimed to identify

current continuous professional development courses on nutrigenetics (Collins *et al.*, 2018), and finally, two on the current state of nutrigenomic education in Poland (Mlodzik-Czyzewska and Chmurzynska, 2018) and the United States respectively (Beretich *et al.*, 2017).

Further recent research has focused on the area of nutrigenetics and behaviour change although this did not include RD's (Horne *et al.*, 2018; Macready *et al.*, 2018; Hollands *et al.*, 2016;; Li *et al.*, 2016) as well as a number of review papers on the topic of nutritional genomics (Rozga and Handu, 2018; Sadeghi *et al.*, 2017) that were not included in this review. The aforementioned publications therefore have not changed the overall picture with regards to integration of nutrigenetics and other personalised nutrition technologies into practice.

3.8 Future directions

There appears to be an association between the perceived importance of genetics and attitudes towards the technology among the dietetic profession and their level of knowledge of nutrigenetics (Bouchard-Mercier *et al.*, 2016; Collins *et al.*, 2013; McCarthy *et al.*, 2008). It is difficult to determine the direction of causation between high perceived importance of nutrigenetics to dietetic practice and actual knowledge of nutrigenetics as neither leads to integration of nutrigenetics into practice and this phenomenon warrants further study. A recent scoping review demonstrates that this is an increasing area of importance for dietitians (Rozga and Handu, 2018).

Existing research has suggested that RD's are concerned that more disadvantaged groups would be excluded from accessing such products,

implying ethical concerns (Cormier, 2014; Li *et al.*, 2014; Weir *et al.*, 2010). Recent research into opinions among the European public on personalised nutrition, however, has suggested that there may be two potential markets: one delivered commercially, and the other through existing health services (NHS) and that in certain circumstances, such as identifying high-risk/low income groups, these types of provision should be synchronized (Fischer *et al.*, 2016; Fallaize *et al.*, 2015; Stewart-Knox *et al.*, 2014;2013). This implies a future where dietetics practitioners work alongside commercial providers of nutrigenetics and that further research is required to determine how best to encourage collaboration between DTC and clinical nutrigenetics service providers (Fallaize *et al.*, 2015).

The limited view of nutrigenetics as the management of genetic conditions rather than the promotion of dietary health and the fact that it is already practiced in areas such as lactose intolerance, could demonstrate a lack of understanding of the links between genes, diet, health and propensity for chronic disease (Martin, 2018; Gilbride, 2007) which will need to be addressed.

With a low response rate of only 13% in the largest study (Collins *et al.*, 2013), however, the results may not be applicable to the wider dietetic profession. As the genomics field affects the dietetic profession as a whole, the divided perception on who should deliver on nutrigenetics, may have wider implications for the education and attitude of future practitioners which could impact upon competence and confidence (Collins *et al.*, 2013). Given that specialisation and area of work could determine interest and integration of nutrigenetics, future policies will need to ensure that nutrigenetics and

potentially other new technologies that are supported by strong evidence are integrated throughout professional practice (Murgia and Adamski, 2017).

No studies appear to have investigated the attitudes and perceptions of RD's who have integrated nutrigenetics into their practice (using the classic definition of nutrigenetics) to provide gene-based personalised nutrition services. The time is right to take the opportunity to conduct research with early adopters and enquire into traits, attitudes and perceptions among this group that could help to determine the factors that are associated with successful integration or rejection of nutrigenetics and to inform the rest of the profession.

3.9 Current research gaps

- how can digital technology be best used to increase knowledge, heighten interest and encourage the inclusion of nutrigenetics into the dietetic education curriculum?
- how much training is currently offered on nutritional genomics in the dietetic curriculum across the globe?
- how has nutrigenetics been integrated into clinical practice and what are the drivers, perceptions and experiences that have influenced early adopters?
- what are the perceived barriers faced by RD's in adopting nutrigenetics into practice?
- has translation of the science and the barriers encountered in doing so, been consistent across countries?
- what are the views and practices of dietitians in non-English speaking and emerging countries?

3.10 Conclusions

Owing to limitations in previous research, very few conclusions can be drawn from studies of nutrigenetics integration especially in a limited number of countries. At present, there is global variation in how nutrigenetics is integrated at the clinical practice level, with the majority of RD's abstaining (Li *et al.*, 2014). This implies that more research is required into drivers, barriers and challenges the profession faces with regards to integration.

More clarity is required in terms of how RD's are to use genotype information and how this translates into practice when dealing with client's questions as well as at policy and strategic levels (Beretich *et al.*, 2017; Wagner *et al.*, 2015). There appears to be a gap between what RD's are expected to know and do, and what actually happens in practice. Further in-depth research is required to determine and understand the reasons why.

It is clear that more needs to be done to ensure that more experienced RD's become familiar with the science, its application and the potential professional opportunities this could present (Murgia and Adamski, 2017; Li *et al.*, 2014; Wright, 2014; Collins *et al.*, 2013).

Measures also need to be taken to ensure that less experienced RD's are encouraged to remain interested in the field once they leave university and are afforded the opportunity to integrate nutrigenetics and other new technologies into their practice to establish a confident and competent workforce that is prepared for changes the genomic and digital revolution may bring (Hickson *et al.*, 2018). How much emphasis is placed on nutrigenetics in clinical practice by educators, senior practitioners and professional

organisations, therefore, could play a major role in the integration of nutrigenetics into dietetic practice (Li *et al.*, 2014).

The future of modernized healthcare relies heavily on prevention and personalisation (Dang and Vialaneix, 2018; Mutch *et al.*, 2018; van Ommen *et al.*, 2017). Whilst genetic contribution of individual single genetic variation to disease susceptibility is small 0-10% (Minihane, 2013) and correlations between gene-environment interactions are still being unraveled (Drabsch *et al.*, 2018; Fenwick *et al.*, 2018)), advanced skills and knowledge in genomics and systems biology may open up new opportunities in the food industry for the development of functional food, as well as digital health programs and academia (Ordovas *et al.*, 2018; Mathers, 2017; van Ommen *et al.*, 2017).

RD's are ideally positioned to bridge the gap between suppliers of new personalised nutrition technologies and innovations and consumers (Martin, 2018; DeBusk, 2009), but in order to achieve this goal, a tremendous effort is required at the policy and educational level to integrate nutrigenetics at all levels (Stewart-Knox *et al.*, 2016). Equally, there is an opportunity to foster links between industry and academia in terms of training, to satisfy demand for personalised nutrition products that can mitigate disease and promote health (Stewart-Knox *et al.*, 2015; Fenech *et al.*, 2011).

Chapter 4

Attitudes, perceptions and experiences of registered dietitians who are early adopters of nutrigenetic tests into clinical practice.

(Published article- in appendix)

Abstract

Background and research objective: The use of nutrigenetic testing has become increasingly popular among a select group of registered dietitians (RD's) globally, yet this group despite being integral to the application of nutrigenetics has not been previously studied. The research objective therefore has been to determine the attitudes, perceptions and experiences of early adopters of the technology in different countries.

Method: RD's (N=14) were recruited from the UK, Canada, South-Africa, Australia, Mexico and Israel to participate in six interviews and two focus groups conducted online using a conference calling platform. Transcripts were recorded, transcribed and thematically content analysed.

Results: Early adopters were highly qualified and experienced, communicated high levels of self-efficacy, highly positive experiences in using nutrigenetic testing with clients and as such felt empowered to deliver personalised nutrigenetics. They were highly motivated and optimistic about the future of nutrigenetics in dietetic practice. Nutrigenetics was considered an extension of current practice and as such they had the skills to deliver it. Among the barriers to widening integration of nutrigenetics were perceived risk aversion and skepticism of nutrigenetics and its efficacy among the wider dietetic community. The proliferation of unregulated websites offering tests and diets were

considered a barrier to dietetics fully embracing nutrigenetics. Another perceived barrier was the lack of a sustainable public health model for the delivery of nutrigenetics. There was a consensus that education and policies were needed to address this.

Conclusions: Early adopters of nutrigenetic tests are an important group to study to determine what needs to be considered for future dietetic training provision, policy development and service delivery models as their views, attitudes, experiences and perspectives appear to be consistent irrespective of the country in which they practiced.

4.1 Introduction

Nutritional genomics is an emerging and exciting field that looks at the interplay between food, nutrition and genes (Kaput, 2008). The field has developed rapidly since the completion of the human genome project, and many researchers have contributed to novel findings between gene-nutrient interactions that may play a role in health and disease (Casas *et al.*, 2016; Stover *et al.*, 2008).

Apart from a lack of disease-related outcome associated single nucleotide polymorphisms (SNP's), many single SNP-nutrient interactions have been observed (Corella *et al.*, 2016; Stover *et al.*, 2008). For instance, the APOA2 -265 G>C, interacts with saturated fat and increases body mass index (BMI) by 6.4%, but only in CC- Allele carriers in the presence of a high saturated fat intake (Corella *et al.*, 2009). This has been replicated in different populations (Corella *et al.*, 2011; Smith *et al.*, 2008).

The recent Food4me project, used 5 gene variants (FTO, FADS1, MTHFR, TCF7L2, APOA2), all associated with strong scientific evidence for interaction with nutrition (Celis-Morales *et al.*, 2016). The results illustrated how gene-based personalised nutritional recommendations could potentially be delivered online to the wider public (Celis-Morales *et al.*, 2016).

There is a growing market offering genetic tests either direct to consumers or via healthcare professionals. The tests can deliver information of relevance to diet and disease, lifestyle, weight or improved fitness (Covolo *et al.*, 2015; Bloss *et al.*, 2011; Ries and Castle, 2008). Yet, nutrigenetic testing remains a highly controversial topic discussed extensively in the literature (Ordovas *et al.*, 2018; Pavlidis *et al.*, 2015) as well as amongst practitioners.

Whilst most academic experts agree that the field is in its infancy, consumer interest is high and demand for trained practitioners is expected to increase (Berezowska *et al.*, 2015). RD's have been identified as key professionals for translating the science of nutrigenomics into practice (Abrahams *et al.*, 2017; Stewart-Knox *et al.*, 2016; Stewart-Knox *et al.*, 2013; de Busk, 2009).

Indeed, it is expected that a precision approach using omics technology such as metabolomics, lipidomics and transcriptomics, is the future of healthcare in terms of providing a highly personalised and targeted approach for treatment and prevention (Sun *et al.*, 2016). This approach has already been demonstrated for disease outcomes such as cardiovascular disease and the benefits of the consumption of a Mediterranean diet (Fitó *et al.*, 2016). A position paper by the Academy of nutrition and dietetics (Camp and Trujillo,

2014), however, has warned that the area is not ready for routine practice (Camp and Trujillo, 2014). It is known that application of nutrigenetics is low amongst the nutrition profession (Collins *et al.*, 2013; Whelan *et al.*, 2008).

Whilst two large multinational European studies (LIPGENE and Food4me) have examined at consumer perceptions and attitudes towards personalised nutrition services (Stewart-Knox *et al.*, 2016; Poinhos *et al.*, 2014; Stewart-Knox *et al.*, 2013; Tierney *et al.*, 2011; Stewart-Knox *et al.*, 2009), to our knowledge no research has investigated the attitudes, perceptions and experiences of RD's who are already delivering such services (Abrahams *et al.*, 2017). This group is of particular interest because, previous research has indicated a preference for personalised nutrition services delivered by dietitians (Berezowska *et al.*, 2014; Stewart-Knox *et al.*, 2013) and also because this group of early adopters of innovation are most likely to lead the integration of nutritional genomics into society.

The research presented here aims to understand the perceptions, experiences and characteristics of the type of registered dietitians who have integrated genetic testing into their practice, despite the rapid developments in current research. In addition, in view of precision healthcare on the agenda of many governments (NHS, 2019), it is imperative to understand which skills, whether translational, business or other, this stakeholder group possesses that may be crucial to prepare the next generation of practitioners.

The research objectives, therefore, were to explore: 1. whether there was a particular profile description for the early-adopter RD and 2. to understand their attitudes, perceptions and experiences to date in applying nutrigenetics

into practice; 3. to understand practitioner perception's regarding barriers towards integrating nutrigenetics in practice, and 4. to capture early adopter perspectives and thoughts on the future for RD's with a specific focus on personalised nutrition.

4.2 Method

4.2.1 Sampling

Potential study participants were approached through the managing directors (MD's) of three Direct-to-Consumer (DTC) genetic testing companies (Genovive (USA), Nutrigenomix (Canada), DNALysis (South-Africa) all of whom work with registered dietitians (RD's) using genetic testing in their practice. These companies are established companies in the nutrigenetic testing industry and are known to provide nutrigenetic testing kits to healthcare professionals including dietitians across the globe. This was therefore the basis to choose participants from UK, Canada, South-Africa, Australia and Mexico. The study details were explained to the MD's via email. The study information sheet (Appendix B) was then sent by the company directors as an attachment to be mailed out to appropriate practicing RD's on their database.

Inclusion criteria for the study was any RD's that were actively using nutrigenetic testing in their practice for at least 6 months prior to the study and from the aforementioned countries. They also needed to be fluent in English, have access to the internet and be able to join an online conference call. Out of 20 invitations sent, a total of 12 RD's responded (60% response rate) and were happy to participate. No reminder emails were sent. Once volunteers were recruited, the study information sheet, consent forms and topics for discussion

were sent to each individual RD via email ahead of the scheduled interview date. Participants returned their consent forms via email with an added digital or wet signature. Participants received no gifts or remuneration to be involved in the study. Participant numbers, country of origin and whether they participated as part of a focus group or as an interview are detailed in Table 2.

Table 2. Profiles of the participating RD's

	Total Number (N=12) All female
Years since graduation	
0 - 9 years	1
10 - 19 years	6
20 -29 years	3
>30 years	2
Level of education	
BSc	5
Masters	6
PhD	1
Other qualifications	
CPD in Nutritional genomics	12
Food science	1
Sport science	1
Medical herbalism	1
Business and management	2
Clinical research	1
Job role	
Mix of lecturing and private practice	4
Mix of business and private practice	4
Private practice only	4
Country of residence	United Kingdom 2

	Australia	3
	South-Africa	2
	Canada	3
	Israel	1
	Mexico	3

4.2.2 Materials

The interviews were conducted using the Citrix platform (Citrix Systems Inc) which is an secure online platform with video recording capabilities. This method was chosen over telephone interviews due to their low cost, easy access, secure environment and potential to share online documentation or conduct video interviews if needed. Another alternative would be to conduct face-to face interviews which was not possible owing to distance. The strength of this approach lies in the ability to continually re-analyse the recorded transcripts which is not possible with in-person or telephone interviews alone. The discussion was initiated and moderated by myself. Participants did not have access to the questions in advance as I wanted the discussion to take a natural course. However, main topics discussed included: experience of using nutrigenetic tests in practice; attitudes and perception towards the emerging field; perceived barriers of integration from peers, any challenges and drivers experienced whilst integrating; education and training opportunities and needs; skills required to successfully integrate nutrigenetic testing; and, future directions for RD's and the profession as a whole. Open-ended questions were used to initiate the discussion which included: "tell me about how you got started in the field" and "what has your experience with using tests with your clients been so far?", and "How do you think you are perceived by your dietetic

colleagues?”(Appendix B). Open-ended questioning are considered the best approach to engage and gather unprompted insights on a topic or issue (Creswell, 2003).

The risk of open-ended questioning is that the discussion can go into unexpected tangents which may reduce the ability to elicit useful information, however as I was experienced in moderating panel discussions and conducting group therapy sessions, this risk was mitigated.

4.2.3 Procedure

Prior study approval was obtained from the research ethics committee of the University of Bradford.

A pilot study was conducted with two (UK) RD's (N=2). The two RD's were professional contacts of the main author. The information sheet and consent form were sent by email in advance of the interviews. This was followed by an email explaining the aim of the discussion and outlining the topics for discussion. Both conference calls were recorded. As there were technical problems with the video during the first pilot interview, it was decided to conduct the second pilot interview using audio only. The participant in the second pilot interview appeared more relaxed and verbal when there was no camera. Given this, and the technical problem experienced during the first interview, it was decided that video would not be used for the main study. In addition, during the pilot interviews, it became clear that professional skills required to deliver gene-based personalised nutrition, was an important topic for discussion, and which should be included in future focus groups and interviews.

For the main study, RD's who agreed to participate were contacted via email at which point the information and consent forms were sent. As RD's were dispersed throughout countries, but some worked in the same private practice, it was initially decided to proceed with focus groups. Interviews were scheduled according to availability with individual RD's. Where a focus group was not possible because of time constraints, time zone differences and diary clashes, individual interviews (n=6) were conducted despite the fact the RD's may have been in the same country. Once a date and time was agreed, dial-in details to access the conference calling facility was sent via email. One final email reminder was sent a day before the call. On the day of the interview, participants would access the online conference room with details sent previously, they could talk and hear each other whilst in the chatroom.

A total of 6 individual interviews and 2 focus groups (Mexico N=3, and Canada N=3) were held between February and April 2016 ranging between 30-60 minutes in length. All participants (N=12) were female, and able to understand and speak English fluently. Discussion was led by myself, and as these were RD's practicing in the field of nutrigenetics already, there was no need to provide an introduction to the actual field of nutrigenetics. Data was analysed and transcribed at the end of each interview. Data saturation was reached after 12 participants (see country of residence as outlined in Table 2). The point of saturation was determined when no new insights were gathered and when common overarching themes were identified. At this point data collection was concluded.

4.3 Thematic content analysis

The recordings of all the interviews were anonymized and transcribed verbatim by an assistant. Thematic content analysis was used to identify potential themes and subthemes (Vaismoradi *et al.*, 2013). The first step in the analysis process involved the analyst re-listening to all the recordings to ensure that no colloquialisms, voice intonations and important pauses in responses were missed. All the transcripts were read and re-read to allow the researcher to become fully immersed in the data.

The next step involved inductive coding of main themes and categorised further into subthemes and interpreted. This process involved the identification of main themes by highlighting key words, sentences or phrases from all of the transcripts and summarizing with a short description. Once initial main themes were identified and coded, further analysis involved re-reading the transcripts to further cluster phrases, keywords and sentences into sub-themes. Suitable quotes were selected for each theme and sub-theme for validation. All themes and sub-themes were documented in table format and main themes were named. To assure rigour, consistency and reliability of the coding and analysis, the senior PhD supervisor who is an experienced qualitative researcher and academic in the field of behavioural science and psychology, checked all the transcripts against the coding framework, to confirm selected quotes provided an accurate description of the themes identified after which discrepancies were discussed and where needed, new quotes were coded and selected. The strength of this approach is that it added rigour to the coding and the analysis. Alternative methods for analysis include: frequency count of key terms, words and phrases used by respective participants.

4.4 Results

4.4.1 Participant profile

RD's who participated in the study were all female, tended to have over 10 years of working experience, have additional qualifications/certifications beyond nutrition and tended to have worked in both the private and public sector. All RD's had access to the internet and were comfortable in using online technology for the call.

4.4.2 The systems practitioner

Overall, 4 main themes emerged: 1. The systems practitioner; 2. Empowerment in clinic; 3. Translation into practice 4. Future proofing the profession and practice (Table 3).

Within the first theme 'the systems practitioner', three subthemes were identified which were around self-efficacy, risk-taking behaviour and optimism. These were related to the main theme in terms of the traits the RD's possessed, as well as the attitudes and views they held about their peers.

For the second theme 'Empowerment in clinic', sub-themes of credibility and accuracy, motivation, confidence and skills were identified. These were related to main theme in terms of how using tests impacted their own beliefs and practice, as well as the perceptions held by their clients.

The third theme "translation into practice" included perceived barriers to integration of which the subthemes included: science vs pseudoscience; lack of regulation; translational research; knowledge and education and data ethics.

The final theme related to 'future perspectives' contained sub-themes relating to: training and education; business and strategy; practice and policy and

translational research. These provided insight into the future through their lens, their opinions and views on how clinical practice and training will and should evolve, as well as how best to deliver these services in the future.

Table 3. Main themes identified and were used as the organizing themes for the respective sub-themes

Research Objective	Themes	Subtheme
Practitioner attitude and profile-	The systems RD– a proactive and technology savvy practitioner who integrates the latest scientific advances into practice	Self efficacy Scope of practice and risk-taking Optimism
Perceptions and experience in practice	Empowerment in clinic	Credibility & accuracy Confidence & skills Attitudes towards the science
Perceived barriers to integration of nutrigenetics into practice	Translation into practice	Science vs pseudoscience Lack of regulation Translational research Knowledge & education exposure Data protection and ethics
Future perspectives	Future–proofing the profession	Training & education Business and strategy Practice and policy Translational research

For the first research outcome, I wanted to determine whether a profile exists for the early adopters RD's of nutrigenetics. I wanted to better understand what made them decide to integrate nutrigenetics into their practice, what the drivers and barriers were, any challenges experienced in integrating the technology and how they perceived themselves in relation to their peers and the perceived norm among the profession.

4.4.2.1 The Systems practitioner

It was clear from demographic data (Table 2) that nutrigenetics RD's were highly trained and/or highly experienced. It was also evident that RD's who had integrated this service were not in a traditional hospital or community clinic setting but rather were self-employed within a private practice, working in a clinic employed by a General Practitioner (GP) for clients who were self-insured, or had their own companies.

Self-efficacy

Participants referred to interests beyond dietetics which widened their knowledge and view of the world as well as their skill set and which ranged from technology and sport science to complementary medicine and business management.

"I was busy with the herbal medicine degree and I started getting a lot of publishing or papers on nutri genomics and (erm) it did spark my interest".(IV1, South-Africa)

"And, moving forward, this is gonna be a very valuable tool, for me as a sport dietician, and to improve athletic performance where our marginal gains are what matter."(FG2, Canada)

“I’ll be opening up my practice again in July of this year in the holistic medical practice. I’ll be— they use functional medicine and a more holistic approach towards lifestyle management.” (IV6, South-Africa)

The RD’s discussed having engaged in activities that were perceived to require high levels of motivation and self-confidence and which enabled them to learn more about the science.

“Passion for the subject, I think, is the main skill”(IV6, South-Africa)

“It’s just the only skill they need is self-confidence – that they are qualified to do it.”(IV4, Australia)

Activities included continuous professional development courses and attendance at scientific conferences that were not traditionally dietetic in nature.

“And (erm) I was hooked with (erm) the nutrigenomics organization in the Netherlands they started putting on conferences that were near to my home. So in 2013 I went to one I think it was either in Spain.”(IV2, Israel)

“And, unless you’re involved in it and you’re looking at the research, and it’s part of your practice, you’re really not aware of what is, um you know, what’s coming out, weekly practically so that’s important too. And the research is just surging right now. And I think, those who of us in it are really embracing that and excited because it’s – uh, yeah – we’re not losing the pace of research, it’s growing.”(FG2, Canada).

Engaging in these outreach activities was seen to give them an edge and social prestige, to make them ‘stand-out’.

“And it worked. It kind of made me stand out a bit because I was one of the first ones to actually venture down this route.”(IV6, South-Africa)

“Yes, we do like at the end of the day we are giving menus and we are all doing the same kind of approach with the patients of giving one on one visits and everything. I think what makes us different it is that we used a DNA test.”(FG1, Mexico)

“I was one of the first dietitians to get involved in it. And, I sort of fell into the area in a way that I was coming up to the end of a job. And I was looking around for new work opportunities.”(IV3, Australia)

Perceived professional scope of practice and risk- taking

Despite an apparent awareness of lack of support from both their peers and their professional organisations, this was not considered a barrier for the advancement of their own careers. They perceived the willingness to accept to integrate nutrigenetics into practice as a professional risk, which was worth taking.

“We have to be so evidence-based and anything in the periphery, you’re gonna lose as far as your credibility and your reputation. And large dietetic associations don’t want to take that risk neither just the individual in their practice.”(FG2, Canada)

There was a perception amongst the RD’s, that the profession was limited in terms of their scope in practice and that this could threaten the sustainability of the profession. Nutrigenetics was seen as a positive force in dietetics. Adding nutrigenetics services to the offering had potential to keep dietetics ‘relevant’.

“Because, I think we all feel that we have our wings clipped in terms of the efficacy and the eventual effect we have on the population in terms of nutrition. So unless we have got something else under our belt, it’s a bit difficult to say – to become more relevant. And I think that is the biggest issue with nutrition here. That it becomes irrelevant.”(IV1, South-Africa)

Optimism

In order to express their views about their peers and the profession in general towards nutrigenetics, words such as “conservative”, “fear”, “not qualified enough”, “scary”, “lack of awareness”, “confused”, “less flexible” were used across all the interviews. They perceived their peers to be inflexible, lacking adventure and unresponsive to emerging scientific movements affecting nutrition science and practice.

“Overall I think the dietetic professionals tend to be a little bit–uh, what’s the word I’m looking for? They tend to be a bit less adventurous in terms of finding out what works for a patient. They’re less flexible.” (IV1, South-Africa)

“Um, but I think that they’re just, they kind of, they like to go with the flow so they wait until majority have adopted before they adopt.”(IV4, Australia)

This perceived conservatism among professional bodies and peers was attributed to fear of novel technologies which was fuelled by concerns about safety and efficacy.

“I think they’re scared, scared that it is a completely new avenue.”(IV6, South-Africa)

“People are still fearful that maybe it’s not accurate. Erm, I can see that in about any kind of method really.”(IV2, Israel)

“The response has always been, “Well, that’s not something that we necessarily learned.” and ‘how scientifically proven is it?’ and you know, they’re always second guessing it”(IV6, South-Africa)

“I think that it’s more of fear of not knowing how to interpret the science and maybe not understanding genetics and nutrigenomics. And, potentially lack of training, they feel like they’re not qualified.”(IV4, Australia)

Participants felt that there was a sense among their peers that learning about nutritional genomics was perceived as a huge learning curve, and whilst it is not critical to their nutrition practice at present, there was no apparent urgency among the wider profession to integrate nutrigenetics into current practice. They felt that as a result, they could be ‘left behind’ as the science advances.

“I think for a lot of dietitians it’s a sort of scary area. So they’re not even exposing themselves.”(FG2, Canada)

“And people right now, I don’t think they feel that they are being left behind by not including it in practice. But, you know, they’re wrong”(FG2, Canada)

“They should study while we have a little need to study. If they keep being behind, one day it will be a lot of studying to do, if you want to like in 5 years or even a year later, if you want to go coming to nutrigenomics there’s been more and more information. And the barrier would be that yes you have to study.”(FG1, Mexico)

Participants were very optimistic about the future, and expressed excitement at the prospect of new opportunities and challenges.

“And I’m very confident, I’m very excited about this field.”(FG2, Canada)

“I think it’s very promising and I think it is gonna be an essential tool and it’s gonna be common place in the years to come.”(FG2, Canada)

“So I think it has a very strong future. And I’m lucky to be in it early.”(FG2, Canada)

4.4.2 Empowerment in clinic

4.4.2.1 Credibility and accuracy

For the second research outcome (perspectives and experiences), empowerment in clinic came out as a strong theme.

The RD’s have been encouraged in their practice by good client adherence and response to nutrigenetics based advice

“It gives me more credibility and it confirms for me them that this is the way to go. And maybe, that improves their compliance, I think.”(FG2, Canada)

“I find that the compliance is one of the largest benefits and as dietitians, we know behavioural changes as one of the biggest barriers to improving ones diet. I find that a lot of my clients are very committed after learning something so personalised”(FG2, Canada)

“They’re motivated to change behaviour from one consult. It’s amazing and it’s across the board.”(IV4, Australia)

4.4.2.2 Confidence and skills

The RD's also felt that by using nutrigenetic testing with clients, it in turn enhanced their own confidence, made them practice differently, and become more motivated and engaged as RD's.

"Because I have more confidence in the exact recommendations I'm giving them. I might actually be counseling differently – for whether they had a nutrigenomics test or not."(FG2, Canada)

"It might be that I'm changing the way that I practice based upon nutrigenomics vs no nutrigenomics."(FG2, Canada)

"So, I think nutrigenomics in itself is very motivating but I think it's how the health care professional delivers that. It's the key (erm) variable that would result in change or not."(IV4, Australia)

Additional skills required to integrate nutrigenetic testing into practice.

Participants were unanimous in their opinion that whilst nutrigenetic practice was something new, RD's were in fact already doing it, and as such required no new skills apart from a basic understanding of genetics.

The Mexican RD's felt that counselling skills were a necessary addition to current skills.

"...that you need to build up the behaviour like what behaviourists do."(FG1, Mexico)

"So in terms of skill level of the dietitian I'm not sure that you need any different skills because the skill has always been to translate the persons medical or

social or other issues into something practical that they can use to improve their nutrition.”(IV5, Australia)

“And so we’re experts at constructing diet and with helping people with behavioural changes, and with the nutrient content of their diet and practical tips and – so that’s where we’re an expert so all of the other science that goes into why someone would need to change their diets, I think it’s separate and I think where dietitians are not understanding – that they’re already doing this.”(FG2, Canada)

4.4.2.3 Attitudes towards the scientific evidence- base

Participants all confirmed that although the science was in its infancy, there was enough evidence for its efficacy, and agreed that it was important for RD’s to get familiar with the science and to raise the profession’s profile and in doing so, to secure opportunities for future RD’s to apply nutrigenetics principles in various sectors and industries.

In addition, they expressed that owing to the complexity of the science and uncertainty with regards to gene-gene and gene-environment interactions, and movement towards the nutritional systems biology approach (Badimon *et al.*, 2016), that it was easier to start learning the topic now, rather than waiting and having to catch up later.

“So, I believe right now that the science and the research is at a point where we can definitely utilize it and it is valuable and it is actionable. But, certainly we need uh, a lot more.”(FG2, Canada)

“you know, you’re meant to be evidence-based but you’re not being evidence-based.” Because the evidence is there, why not adopt it? I find they’re not quite interested.”(IV4, Australia)

4.4.3 Translation into practice

4.4.3.1 Science versus pseudoscience - perceived relationship of nutrigenetics to current practice

Owing to an increasingly competitive marketplace, RD’s felt that they were seen by potential clients to be the more scientifically credible option amongst a sea of other often less-qualified nutrition practitioners, therefore enhancing their own image

“I think we’re facing a huge challenge in the social media space where anyone who’s a celebrity can say (erm) “Look at me this is the diet I follow. Isn’t this fantastic?” you know the most ridiculous and people promoting the most ridiculous diets and people believe them over traditional dietitians or (erm) science, true science.”(IV5, Australia)

Nutritional genomics was considered one way of counteracting this pseudoscientific culture and to raise their own profile as the regulated fully qualified nutrition professionals. RD’s felt that by incorporating nutrigenetic services, they were not only able to offer a more scientifically accurate service, but also to add value to what they were already offering their clients.

“So it’s not like, “Wow, nutrigenomics is the solution of all things in dietetics.” But it’s an add-on service that is quite useful if the right person uses it.”(IV4, Australia)

Participants were of the opinion that there has been considerable skepticism among their peers who felt that nutrigenetics was largely untested and, therefore, pseudoscience, but that this perception may be slowly changing.

“So, when I first started out, the perception was incredibly poor. Mostly, I was, um you know, I felt that a lot people would be like, oh, you know, “that’s a bit of a dodgy space, isn’t it?” (laughing). Erm, as times moved on, the acceptance or the realization that actually, this is an area, an actual area of science, and it’s important for nutrition as a whole. It’s definitely—that perception has definitely grown.”(IV3, Australia)

“I think there’s a lot of skepticism, is this yet another fad? And there are companies that are doing really obscure stuffs in all sorts of areas.”(IV5, Australia)

4.4.3.2 Lack of regulation

All participants were highly critical of the unregulated sale of nutrigenetic tests and were very particular about the companies they chose to work with.

“And I guess it doesn’t help with having so many pseudo companies out there – doing dodgy things.”(IV4, Australia)

“See who’s behind the company and that’s – that is important because there’s a lot of pop-up centers just looking to make buck – they see that this is popular and they don’t really understand.”(FG2, Canada)

There was an apparent consensus amongst the participants that nutrigenetics was an inevitable future, and whilst “causing no harm” was a core belief, that

they were offering a service that was recognized as being well within their scope of practice.

4.4.3.3 Knowledge and education

There was a perceived gap between the body of research and how to apply it, which together with a lack of knowledge, was viewed as a contributing factor to the lack of integration into practice.

“But what I find lacking is the translation into practice or the interventions – what to actually do about it.”(IV3, Australia)

It was felt that nutrigenetic testing, which is focused around personalising diets, was often confused by peers with disease risk prediction and reduction, which is associated with disease outcomes and therefore not within their scope of practice.

“But I think a lot of them are just not - they don’t understand the science. And they feel that it’s not within their scope of practice. And they’re just not aware of it.”(FG2, Canada)

“And then some people just really not knowing what it’s about at all. And I – uh – or thinking that it’s too much about predicting disease, which it’s not. And I think there’s a lot of confusion. Education is huge here.”(FG2, Canada)

“We’re just trying to make a diet more precise according to your DNA. We’re not taking on the whole, you know, preventing major illnesses.”(FG2, Canada)

4.4.3.4 Data protection and ethics

Participants were of the opinion that the financial costs associated with nutrigenetics presented a potential barrier to perceived uptake by more economically disadvantaged clients and which could deter integration of nutrigenetics into the work of practitioners working in the public health sector.

“And another thing I think for a lot of people – it is more costly, right? So if you think of - like a community health center type setting, where you may have a lower socio-economic group of patients, you know it’s not realistic for some practitioners. For others, definitely it is realistic and there’s other reasons why they’re not using it. But I think that also plays a role.”(FG2, Canada)

“But I mean, they [clients/patients] have a good chunk of money that can go towards the dietitian and I think that coverage is important.”(FG2, Canada)

Perceived lack of data security and the possibility of information sharing was also a concern, especially where employers or insurance companies could request or access genetic results which may deter clients to buy a test.

“Um you know, “who has access to the genetic results?”, “are there personal identifying information link right on that test tube, and saliva, and things like that?” That might be a barrier for some people.”(FG 2, Canada)

“I mean, people think as soon as your DNA is out there, we know everything about you and we test for everything. And we’re gonna be able to tell, you know, if you have had children like the rest of your offspring.”(FG2, Canada)

4.4.4 Future proofing the profession

For the fourth research outcome, preparing for the future, participants were asked about their views and perspectives about the future. Discussion centered on educational needs, application in practice and new models of service provision.

4.4.4.1 Training, education and recognition

Participants expressed that their interest was sparked at undergraduate lectures, which they then continued to pursue after graduation. Whilst exposure to the topic differed from between 2 hours to 1 semester, they felt strongly that nutritional genomics should be part of the undergraduate core curriculum and delivered by content experts. There were concerns that not enough emphasis was placed on the relevance of nutrigenetics to dietetics practice as it was not adequately covered in the curriculum.

“You know, if you think of the – four years that we study, it’s kind of like mentioned in passing in one of the lectures. And, because it’s not part of the standard teaching, dietitians think that would – the fresh ones just out of varsity, think that it is irrelevant.”(IV1, South-Africa)

“And so anything that we’re not sort of exposed to formally in our course work, we think, “well, maybe it hasn’t quite yet been proven.”(IV5, Australia)

“No one ever spoke about training, no one ever mentioned it. You know, it was kind of like 30, 40 years in the future that would happen.”(IV6, South-Africa)

This lack of exposure to nutrigenetics in undergraduate education was considered a threat to being able to translate the science or practice in a safe environment before graduation. RD’s also expressed that the current curriculum

needs to find a way to integrate newer scientific advancements which overlap with nutrigenetics such as metabolomics, proteomics and metagenomics. Internships were also offered as a potential solution to bringing the research/practice gap.

“We don’t have experts yet or we don’t have many experts. And so, who’s gonna teach this?.”(FG2, Canada)

“But if they do learn that in school, I think that’s a value that they can – from the get go, they can offer it. Where right now, that’s gonna be a future step for them because they don’t have that solid foundation coming out of university from their internship.”(FG2, Canada)

“Yeah, I would agree that this is the future of dietetics. I feel like it’s going to be the younger generation that really picks up on it. And I do see it becoming a more common component of the curriculum at the undergraduate level and having it more into internships and things like that.”(FG2, Canada)

Participants also felt that possibly owing to a lack of awareness and education that there was a lack of recognition by the scientific and medical community about nutritional genomics.

“Um, and then also, another barrier is recognition from the scientific community or other medical community”(FG2, Canada)

“And it’s, for me it’s, the barriers are mainly lack of knowledge.”(IV4, Australia)

RD’s were also perceived to play a key role in raising awareness, education amongst the public as well as being a reliable information source.

“The public have a very poor understanding of what Nutrigenetics – or what current evidence-based nutrigenetics test can actually tell them. So I get a lot of comments or queries about you know, “I’m interested in a genetic test, to tell me what foods I can and cannot eat.” Or “what foods or what genes are causing my symptoms or my illness?.”(IV3, Australia)

4.4.4.2 Translational research led by RD’s

Participants also felt that the only way to learn about the science was to practice it and were of the view that for personalised nutritional science to advance, research and practice should be integrated as far as possible.

“Someone’s gotta jump first, right? Cause you won’t have evidence until people are jumping. It’s like you can’t expect there to be enough evidence if people aren’t using it. And at the end of the day, as long as it does no harm, why not?.”(IV4, Australia)

“And, unless you’re involved in it and you’re looking at the research, and it’s part of your practice, you’re really not aware of what is, um you know, what’s coming out, weekly practically so that’s important too.”(FG2, Canada)

The RD’s saw themselves as playing a crucial role in ensuring that translational research is conducted by RD’s, and to help in building the evidence- base.

4.4.4.3 Need for practice guidelines

Integrating nutrigenetics services was not without challenges and participants felt that there was a need for clear practice guidelines and consistent use of genomics terminology across countries.

“What I find challenging is the lack of guidelines of best practice out there because the results they’re not “one-size-fit-all”. They still depend on the

context of it—the health context of the patient themselves. I mean, the environment plays such a large role.”(IV3, Australia)

4.4.4.4 New business models for delivering personalised nutrition services

When participants were asked about potential new models for service delivery in practice, participants’ preference was a model that embraced a team approach to service delivery whereby clients/patients would first be seen by a systems RD who would go through their genetic, metabolic and other profiles using a precision nutrition approach, followed by a counselling RD who would help them to make the behaviour change. In other words, RD’s are at the centre of a gene-based personalised nutrition service.

“Or nearly when the nutrigenomics dietitians to work with other more traditional dietitians. When they come in and they do that consult and then the other dietitians takes over. That would be a better model.”(IV4, Australia)

“Yeah, so I think nearly the best way forward is to let the early adopters and the people that are motivated who love it (nutrigenetics), work with dietitians who can’t be bothered, because they really like their clients to reap the benefits of the DNA testing.”(FG2, Canada)

However, linked to the above subtheme, there was apparent discomfort about the conflict of interest associated with dietetics becoming integral to commercial offerings.

“And then, if anyone affiliated with the company, perhaps? there’s that—it’s seen as a bit of a conflict of interest on those mistrust because we know a lot of, you know, industry partnerships have turned out badly. And I think the public and

professionals, including dietitians, are very hesitant about things that are seen to be, you know commercialised.”(FG2, Canada)

4.5 Discussion

To my knowledge, this is the first study to have investigated RD’s who have integrated nutrigenetic testing into their practice, and to compare opinions and attitudes of RD’s between different countries. The aim of the study was to get a better understanding of the experiences, attitudes and perspectives of RD’s who are already offering a nutrigenetics service. Four research questions were explored through qualitative means.

4.5.1 Practitioner attitude and profile

The first research outcome was to describe and characterise RD’s who have applied nutrigenetics into their practice. What typifies an early adopter of nutrigenetics? These data showed that this group of RD’s, (whom I shall call systems RD’s), were highly experienced and trained practitioners who conveyed positive experiences of using nutrigenetics tests in practice. They were self-driven in actively seeking new knowledge and availing of opportunities to network as well as willing to share their knowledge with interested professions outside of dietetics. Interestingly, previous research also found positivity, skills and experience as well as personal value-fit were associated with pre-adoption (Aarons *et al.*, 2011). This finding is in stark contrast with recent cross-sectional survey studies that found that RD’s lack confidence, knowledge and involvement in nutritional genomics (Collins *et al.*, 2013; Oosthuizen, 2011; Whelan *et al.*, 2008). These early adopters appear to have a wide skill-set into various ancillary fields that may make them competitive in the

marketplace (see Table 2), but may also be more tolerant to operating in an emerging and ambivalent field such as genomics. This fits in with the concept of tolerance to ambiguity and early adoption of new technologies (Aarons, 2011; Greenhalgh *et al.*, 2004). This finding could represent a shift in professional opinion and an increase in the number of RD's engaging with nutrigenetics an assumption that will need testing by quantitative means. This finding also highlights the importance of sampling and studying in-depth those who are actively practicing in the field, as this had not been done before.

4.5.2 Attitudes toward nutrigenetics

With regards to attitudes toward nutrigenetics, RD's felt strongly that their practice should be evidence-based and cause no harm, a notion which is supported by recent research indicating that genetic testing has not caused negative effects in clients (Covolo *et al.*, 2015) nor triggered any increase in medical visits (Krieger *et al.*, 2016).

This study also found that systems RD's believed that nutrigenetic testing was of low risk because in their view, it was not targeted towards disease risk reduction but rather toward the promotion of health. Low risk perception of an innovation has previously been shown to increase pre-adoption (Mitchell *et al.*, 2010; Greenhalgh *et al.*, 2004). However, they viewed their peers very differently. There was the perception that the wider peer group comprising RD's were uncertain whether the science was a fad or pseudoscience, which could indicate that they perceived the use of the technology as high-risk. A previous study by Li *et al.*, (2014) echoes this view.

This study found that system RD's felt confident in using the new technology. This is in contrast to what was found in a multinational survey which found that RD's lacked confidence, knowledge and involvement in nutrigenetics (Collins *et al.*, 2013) It is known that innovativeness, propensity towards risk-taking and tolerance to ambiguity are positively associated with adoption (Aarons *et al.*, 2011; Greenhalgh *et al.*, 2004). It is therefore plausible, that these trainable traits could potentially be considered for integration into the curriculum or continuous professional development modules, to prepare the next generation of practitioners to deal with risk, ambiguity and innovation.

The process of adoption of a new technology starts with an acknowledgement that a need exists and is then followed by a search for a solution (Wisdom *et al.*, 2014). In this study, RD's reported that integration of genetic testing technology was driven by clients' interest and their own personal motivation. In contrast, previous research has suggested that for non-adopters, this lag was perceived to be driven by a lack of awareness of the technology (Li *et al.*, 2014; Whelan *et al.*, 2008), a lack of urgency to upskill (Weir *et al.*, 2010) or a lack of appreciation of the research (Solomons and Spross, 2011).

4.5.3 Drivers and challenges

Whilst previous research on RD's has suggested that integration of nutrigenetics into practice may be commercially driven by being able to sell tests and therefore boost income (Cormier *et al.*, 2014; Li *et al.*, 2014), it appears that for this group of early-adopters, however, it was their keen interest in technology and innovations, passion for the subject, and desire to add value to what they offered their clients, as the key drivers for integration. The gene-based personalized nutrition service was perceived as both a response to

consumer push as well as a need to advance the nutritional recommendations they were providing.

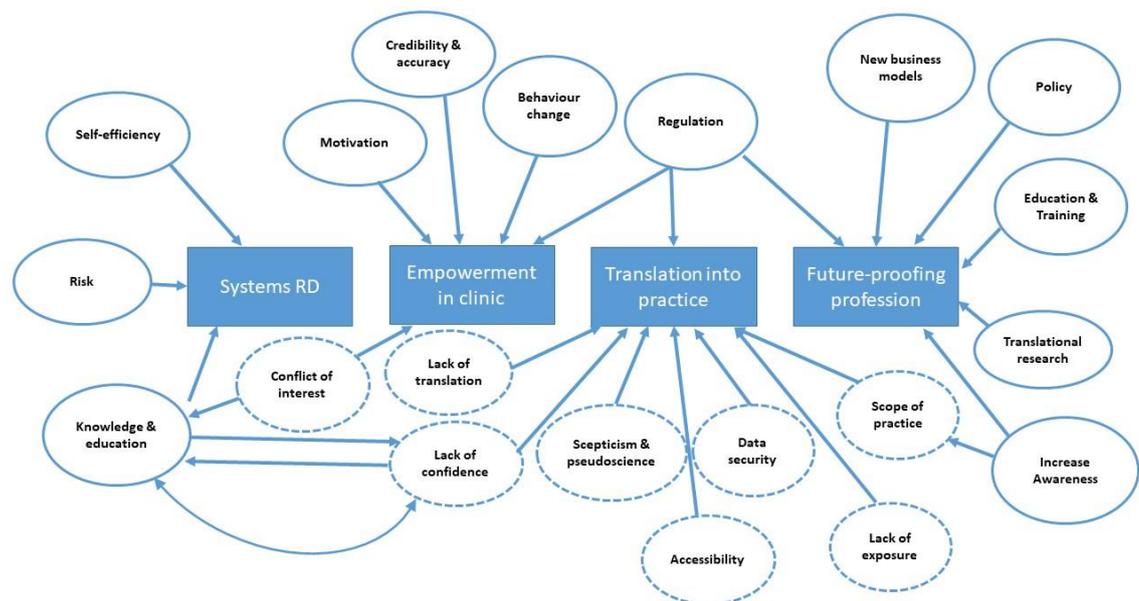
Whilst there was agreement, among participants that the science was (at the time of data collection) in its infancy (Camp and Trujillo, 2014) and the clinical validity of which had been questioned (Castle *et al.*, 2007), systems RD's felt that there was sufficient evidence to make actionable recommendations at the present time. However, at the same time, they were realistic that with rapid developments in research, these recommendations could change. Systems RD's were also very clear and could articulate how nutrigenetics was highly relevant to nutrition practice, which contrasts with previous qualitative research where clinical RD's expressed that nutrigenetics was not relevant to them (Li *et al.*, 2014; Christianson *et al.*, 2005).

The perception that their peers viewed nutrigenetics as not scientifically valid or evidence-based, highlights the need for leaders of the professional organization to ensure that advances in the science are regularly communicated. In fact, the International Society of Nutrigenomics and Nutrigenetics recently published position and guideline papers to ensure that the field is reflected scientifically and accurately (Ferguson *et al.*, 2016; Kohlmeier *et al.*, 2016) which could be included as mandatory reading for all undergraduates to ensure that the message is transmitted early on in their studies.

The words some participants used to describe themselves as well as the field such as: "exciting", "lucky" and "fortunate" indicated an enthusiasm for nutrigenetics and optimism about the future. In contrast, when they were

describing their peers, words associated with “lack of confidence”, “fear” and “reluctance” were used, which may indicate that there is a distinct difference in attitude and possibly personality between early adopters and other RD’s which requires further investigation. Despite the challenges early users experienced by integrating nutrigenetics into their practice from both peers and medical professionals, system RD’s remained determined and optimistic, which is another key trait of early adopters (Wisdom, 2014).

Figure 4. Attitudes, perspectives and experiences of early users, thematic content analysis



4.5.4 Behaviour change

An interesting finding was the perception that using nutrigenetic tests greatly influenced behaviour change in their clients. Whether this was perceived to be a response to the actual level of personalised detail provided in terms of nutritional recommendations, or the style of delivery by the RD, is not clear.

Behaviour change is a hotly debated topic when it comes to disease risk communication (Pavlidis *et al.*, 2016; Li *et al.*, 2016; Hollands *et al.*, 2015), yet

papers addressing the impact of behaviour change specifically in personalised nutrition are few (Stewart-Knox *et al.*, 2015). A recent paper from the Food4me study highlighted how genotype-based information delivered online, improved adherence to a Mediterranean-type dietary pattern (Livingstone *et al.*, 2016).

Considering behaviour change from a practitioner's perspective, a few system RD's expressed how they practice differently and are more engaged depending on if a client had a test or not. Previous studies found an association between involvement and confidence in nutrigenetics activities (Collins *et al.*, 2013; Oosthuizen, 2011; Whelan *et al.*, 2008). It is therefore likely that the more clients early-adopting RD's have, the more confident and engaged they become which ultimately drives the observed behaviour change in their clients. This relationship, however, requires further exploration.

Whilst we have an understanding of propensity towards changing behaviour through personalised nutrition (Rankin *et al.*, 2016), more research is required to separate the message (genotype) from the messenger (practitioner) in terms of genotype-based information on behaviour change as it relates to nutrition, but it is clear that the healthcare professionals do play an integral role (Solas *et al.*, 2015; Sanderson *et al.*, 2013).

4.5.5 New business models

Another interesting insight was that systems RD's enjoyed the initial contact with clients to explain the genetic results and provide nutritional recommendation, but would prefer to hand over the long-term counselling to ensure behaviour change, to another RD. This approach would appear to fit with the proposed business models outlined in the Food4me white paper

(Ronteltap *et al.*, 2013) where RD's (as an example) act as "connectors" for other health professionals. Hubs of practitioners would then interpret and translate the science and provide support to generic healthcare professionals. The viability of such a service would need to be assessed. From a policy perspective, this could mean that results should be communicated by a qualified healthcare professional and not online, as well as that personalised nutrition should be reimbursed, especially for at-risk groups in addition to available commercial services (Stewart-Knox *et al.*, 2016).

4.5.6 Regulation

Regulation was a top concern for the practitioners who took part in the current study and has been raised as a key concern for consumers as well (Fischer *et al.*, 2016). Systems RD's appear to be very particular about which nutrigenetic testing companies they work with. Whilst it may be easy for systems RD's to know and identify more reputable companies, more guidance is required for new starters in the field to equip them with the necessary know-how. It highlights a need to match researchers and innovators with students in order to elaborate on how a technology is developed (Wisdom, 2014).

4.5.7 Education of other professionals and the public

With regards to education for the future, participants felt very strongly that nutritional genomics as part of a systems approach, should be taught at undergraduate level, but that courses should be delivered by content experts who have practical experience in the field of delivery and prevention to ensure that the translational aspect is addressed and included during clinical placements (Wright, 2014). This agrees with a recent paper which also highlighted the need for a more integrative and functional approach to the

dietetic curriculum (Augustine *et al.*, 2016). It has previously been shown that the incorporation of innovations into the curricula and communication about innovation is positively associated with the adoption phase (Mitchell *et al.*, 2010; Greenhalgh *et al.*, 2004) and that pre-adoption of a new technology is contingent of the user having knowledge, skills and application (Aarons *et al.*, 2011; Greenhalgh *et al.*, 2004) which highlights the need to expose dietetics students early during the clinical placement stage.

Recent research has also highlighted that the benefits associated with a personalised nutrition approach should be promoted in order to encourage the uptake of personalised nutrition services to promote health and wellbeing (Poinhos *et al.*, 2016).

4.5.8 Work setting and social network

All of the participants were either self-employed or working in a private practice setting where the use of nutrigenetics was supported. Early adoption of the technology, therefore, was unsurprising in view of the diffusion of innovation theory whereby those with more control to create change, are more likely to adopt innovation than those with less control over their choices (Rogers, 1962). This could potentially explain the low integration and application of nutrigenetics as many RD's are employed in public health organisations (Collins *et al.*, 2013; Whelan *et al.*, 2008) meaning that most strategic decisions regarding practice would be centrally managed. Top-down leadership is negatively associated with adoption (Backer *et al.*, 1986). With growing fears around health inequalities and social exclusion, however, it is imperative that the benefits of precision nutrition approaches reach those who might need it the most (Kohlmeier *et al.*, 2016; Castle and Ries, 2007a).

The healthcare system which operates in each country, therefore, could play an important role in how nutrigenetics tests are used, with potential policy implications to provide publicly funded personalised nutrition services (Fallaize *et al.*, 2015). For instance, in the UK where most RD's are employed by the National Health Service and where health services are free at the point of contact, RD's may be less likely to be approached for a test as UK clients expect personalised nutrition to be provided free of charge (Fischer *et al.*, 2016; Fallaize *et al.*, 2015).

4.6 Strengths and limitations

As with all qualitative research, these results are not generalisable to the general dietetic population. As all the interviews were conducted online, there was no way to gauge non-verbal communication apart from pauses and voice intonation which is a limitation of the study. It was clear early in the pilot study, however, that participants were more forthcoming with unprompted information when there was no camera. The invitation to participate was sent by the company CEO to whom they thought would be most appropriate, and therefore, this could have brought in bias. In addition, all participants were female. Whilst males make up a smaller percentage of the dietetics profession (HCPC, 2017), they may have a different perspective and are worthy of study. Owing to time zone differences, some participants were interviewed individually, whilst others were part of a group, which could have affected the type of information conveyed. It is well known that participants' responses may be influenced by groupthink or a dominant voice (MacDougall and Baum, 1997) Lastly, as an early adopter, this could have introduced bias in interpretation of the comments, although this was minimised through the inclusion and thematic content analysis by the senior PhD supervisor who was not an RD. I was known to

some of the interviewees, which could have positively influenced how forthcoming participants were with information, however this could have also influenced the responses by attempting to answer in a “correct” way. A further limitation is that just because EA adopters perceived their NA peers to be and behave in a particular way does not mean that this is a true reflection of reality, however making this an opportunity for further research.

This study contributes to the nutritional genomics literature for practitioners, by providing a novel insight into the attitudes, perceptions and experiences of the field through the eyes of practicing RD’s who have embraced the latest technologies. This is also the first study that collaborated with RD’s in other countries (Mexico, South-Africa, Israel) where nutrigenetics has been integrated into practice already, but not been studied, thereby providing a more global perspective. As data saturation was reached with only 12 participants from 6 different countries, it is unlikely that further novel insight could have been found by including more countries or more participants.

4.7 Conclusion

Early adopter RD’s are highly motivated, educated and experienced practitioners who have immersed themselves in the wave of recent incredible genomic developments. Eventhough integration of gene-based services has come with numerous challenges, early adopter RD’s have remained optimistic, resilient and determined to raise awareness of the field, share their knowledge, educate the public and carve out a niche in terms of their nutrigenetics expertise. Whilst DNA-based advice is still seen to be the most medicalised form of personalised nutrition (Stewart-Knox *et al.*, 2016), these RD’s report to have had very positive experiences with providing gene-based personalised

nutrition services, especially in relation to lasting behaviour change with their clients, and elevating their own social status which requires further study.

As the prospect of a precision health era becomes likely (van Ommen *et al.*, 2017), early adopter RD's with their interest in innovations are the most likely group to adopt these technologies first. More research is required into understanding the trainable traits, skills and perspectives of this group which can be passed onto the next generation of practitioners to future-proof the profession and to understand the barriers that need to be addressed through policy and regulation.

Chapter 5

Personalised nutrition technologies and innovations: a cross-national survey of registered dietitians

(Published – final draft in appendix)

Abstract

Background: Commercial technology-enabled personalised nutrition is undergoing rapid growth, yet uptake in dietetics practice remains low. This survey sought the opinions of dietetics practitioners on personalised nutrition and related technologies to understand facilitators and barriers to its application in practice.

Method: A cross-section of Registered Dietitians were recruited in the US, UK, Australia, Canada, Israel, Mexico, Portugal, Spain and South Africa. The questionnaire sought views on risk of genetic technology, ethics of genetic testing, usefulness of new personalised nutrition technologies, entrepreneurship and the perceived importance of new technologies to dietetics. Validated scales were included to assess personality (Big 5) and self-efficacy (NGSEI). The survey was available in English, Spanish and Portuguese. Regression analyses were performed to identify factors associated with integration of nutrigenetic testing into practice, and to identify factors associated with the perceived importance of bio, information and mobile technologies to dietetic practice.

Results: A total of 323 responses (response rate 19.7%) were analysed. Dietetic practitioners who had integrated personalised nutrition technology into practice perceived technologies to be less risky ($P=0.02$), biotechnology to be more important ($P<0.01$), and professional skills to be less important ($P=0.04$) than those who had not. They were also more likely to see themselves as entrepreneurs ($P<0.01$) and to perceive lower risks to be associated with

technology ($P < 0.01$). Practitioners of nutrigenetics were lower on neuroticism ($P < 0.01$) and higher on self-efficacy ($P < 0.01$), extraversion ($P < 0.01$) and agreeableness ($P < 0.01$). Higher perceived importance of biotechnology to dietetic practice was associated with higher perceived usefulness of omics tests ($P < 0.01$). Perceived importance of information technology was associated with perceived importance of biotechnology ($P < 0.01$). Mobile technologies were perceived as important by dietitians with the highest level of education ($P = 0.02$).

Conclusions: For dietitians to practice technology-enabled personalised nutrition, training will be required to enhance self-efficacy, address risk perceived to be associated with new technologies and to instil an entrepreneurial mindset.

5.1 Introduction

Technology enabled personalised nutrition has developed rapidly alongside advances in precision healthcare (Market research future, 2017). Potential benefits of a personalised approach to dietary health promotion include reduced healthcare spend, improved efficiencies and better engagement by end-users (Ordovas *et al.*, 2018). At the same, some societal concerns have been raised (for example in relation to personal data privacy) which may impede its adoption (Stewart-Knox *et al.*, 2016; Poinhos *et al.*, 2014). The personalised nutrition industry is expanding rapidly with an annual growth of 17% for genetic testing in response to the falling price of home testing kits and fuelled by advances in 'omics' technologies such as nutrigenetics (Ordovas *et al.*, 2018). Other new technologies associated with personalised nutrition to generate nutritional and lifestyle recommendations for an individual include microbiome and metabolomics tests that can be offered online direct-to-consumer or via a healthcare professional (Ordovas *et al.*, 2018; van Ommen *et al.*, 2017).

Guidelines for interpreting scientific nutrigenetic studies have been recently published with the aim of encouraging international standardization (Grimaldi *et al.*, 2017). Rising consumer interest in health and wellness has encouraged companies to also develop personalised products and offerings including applications (apps) and platforms enabled by data generated from wearables (e.g. with apps to assess diet, heart-rate, blood pressure and physical activity) and telehealth enabling technologies such as artificial intelligence and chatbots (Corbett *et al.*, 2018; Ordovas *et al.*, 2018; Rosenbaum *et al.*, 2018).

Although dietitians from various countries have ventured into this emerging area of technology-enabled personalised nutrition, and have integrated personalised nutrition technologies into practice (Abrahams *et al.*, 2018), application across the dietetic profession remains low (Pray, 2018; Abrahams *et al.*, 2017; Chen *et al.*, 2017; Collins *et al.*, 2013). Possible reasons suggested by previous research which has focused on adoption of personalised nutrition, by nutrition professionals as part of their practice, are low confidence in genetics technology, lack of knowledge of the role of genetics in chronic diseases, and concerns about Direct-to Consumer (DTC) tests (Collins *et al.*, 2013; Weir *et al.*, 2010).

Results from the recent “Future Dietitian 2025” project (Hickson and Child, 2018), highlighted a need for skills training and recommended, *inter alia*, that dietitians should be provided with continuous professional development and training to keep abreast of technological advances, raise awareness of novel technologies and to widen the use of personalised nutrition in dietetics (Hickson and Child, 2018). Indeed, there has been a lack of research which has studied factors determining uptake and non-uptake of personalised nutrition

technologies in relation to dietetics practitioners (Abrahams *et al.*, 2017). Whilst the genomics field is considered to be of increasing importance (NHS, 2019; NHS, 2019; Davies, 2018; Bray *et al.*, 2016; Ferguson *et al.*, 2016), many concerns have been raised in relation to the technology-enabled personalised nutrition field which relate to ethics of genetic testing (San-Cristobal *et al.*, 2013), reliability of tests (Roberts and Ostergren, 2013), scientific validity (Grimaldi *et al.*, 2017), clinical utility (Ordovas *et al.*, 2018; Caulfield, 2015) and efficacy of this emerging technology (Horne *et al.*, 2018; Ordovas *et al.*, 2018). This research, therefore, will consider factors determining uptake of personalised nutrition amongst dietitians.

Qualitative research (Abrahams *et al.*, 2018) has provided a voice for dietitian practitioners who *have* integrated personalised nutrition technologies into practice. Entrepreneurial traits, an appetite for lifelong learning, high tolerance to risk associated with technology and an optimistic view of the future were perceived to be important factors determining if they applied personalised nutrition. Previous research on university students of entrepreneurship has also pointed to the intricate relationship between risk-taking behaviour, personality, self-efficacy and entrepreneurial traits (Barbosa *et al.*, 2007; Zhao and Seibert., 2006; Judge and Ilies, 2002; Chen *et al.*, 1998). Propensity for entrepreneurial and risk-taking behaviour, personality and self-efficacy, therefore, could also be associated with adoption of personalised nutrition and related technologies (Kerr *et al.*, 2017; Barbosa *et al.*, 2007; Zhao and Seibert., 2006; Judge and Ilies, 2002; Sitkin and Pablo, 1992; Chen *et al.*, 1998). According to human capital theory, the greater knowledge, skills and capabilities an individual acquires, the higher the chances of attaining performance outcomes (Becker,

1964; Mincer, 1958). In line with this, meta-analysis (Martin *et al.*, 2013) has established a relationship between human capital assets (the acquisition of skills and knowledge) and entrepreneurial outcomes, which could be an important consideration in the adoption and perceived importance of personalised nutrition technologies in practice.

The Diffusion of Innovation Framework devised by Rogers (1962), considers how new technologies are adopted by different stakeholders. According to diffusion theory, adoption of new innovations or technologies is initiated by “innovators”, who are followed by “early adopters” (individuals who represent opinion leaders), the “early majority” (individuals who adopt new innovations before the majority), the “late majority”, (individuals sceptical of innovations, “laggards” (individuals sceptical of change) and “non-adopters” (individuals who will not adopt new innovations)(Rogers, 1962). Early adopters must believe and trust a new technology in order to influence the next customer segment (Rogers, 1962). As new personalised nutrition technologies become available, they will impact on the way that personalised nutrition is delivered and practiced (Khoury *et al.*, 2016). This implies that early adopters, in this case dietitian practitioners who have integrated personalised nutrition technologies into practice, are appropriate to study and compare with late adopters within the occupational group in order to understand factors determining application of personalised nutrition in practice.

The aim of the research presented here has been to identify barriers to, and facilitators of, adoption of personalised nutrition and related technologies by dietetics professionals. Psychological factors that distinguish between dietitian

practitioners who have, and have not, integrated personalised nutrition and associated technologies into their practice, have been analysed.

The first hypothesis is that higher self-efficacy, perceived importance of new personalised nutrition technologies, and professional skills, as well as levels of self-perception as an entrepreneur, and lower, perceived risks of genetic testing are associated with early adopters together with differences in personality that could determine whether dietitians integrate personalised nutrition testing into their practice.

Second, it is hypothesized that the perceived importance of three types of technologies (biotechnology, information technology and mobile technology) to dietetic practice will be associated with higher self-efficacy, perceived usefulness of omics technology, perceived importance of professional skills and lower perceived risk of genetic testing, ethical considerations, personality traits (such as extraversion), and high perception of self as an entrepreneur/innovator. For this reason, the type of technology will be used as the independent variable but “whether nutrigenetics has been integrated” will be excluded as a variable as this relates more to a behaviour and is therefore not relevant.

5.2 Method

The study was of a cross-sectional design by which data were gathered online by self-reported questionnaire. Participation was on a voluntary basis. A cross-sectional survey methodology was chosen as the most suitable design given time constraints and the spread of RD's across countries.

5.2.1 Questionnaire

The final questionnaire consisted of 62 questions which took an average of 8-10 minutes to complete. The first section asked about demographic information. The design of the remainder of the survey tool, including selection of validated scales was informed by prior qualitative research (Abrahams *et al.*, 2018). As implied by the qualitative research, and in keeping with diffusion of innovation (Rogers, 1962) and entrepreneurial theories (Kwabena and Simpeh, 2011), questions focussed upon technologies associated with personalised nutrition. Items tapped into perceived risk of genetic technology, views on the ethics of genetic testing, perceived usefulness of new personalised nutrition technologies, perceived importance of new technologies/skill area to dietetic practice, and the perception of self as an entrepreneur/innovator (Table 4).

Remaining sections asked questions about self-efficacy and personality traits. The construct of self-efficacy was originally developed by Bandura (1986), which refers to the belief in one's own capability to attain a particular goal in a specific domain. Self-efficacy was assessed using the New General Self-Efficacy Instrument (NGSEI) originally developed by Schwartzer and Jerusalem (1995)³ and then amended and re-validated by Chen, Gully and Eden (2001). The scale comprised eight questions, for which responses were on a 5-point scale. Each of the items were equally weighted, so were summed, and a mean score was calculated per participant.

Personality has frequently been assessed using the "Big-5" framework, which assumes that differences in personality between individuals can be identified by looking at 5 broad traits: extraversion; openness; conscientiousness; agreeableness; and neuroticism (Costa and McCrae, 1992).

Although personality is yet to be linked to entrepreneurship (Kwabena and Simpeh, 2011), the justification for assessing personality in the current context was to determine whether differences in adoption of personalised nutrition technology among dietitians were associated with personality. For the purpose of this study, the 10-item version of the “Big 5 Inventory” developed by Gosling *et al* (2003) was used. The 10-item version has demonstrated adequate levels of reliability and convergence with the full 44-item inventory (Gosling *et al.*, 2003) and has been found to retain 85% of the test-re-test reliability (Rammstedt and John, 2007). Previous authors have recommended its use in research where data need to be collected from individuals in a short time (Gosling *et al.*, 2003). The scale has also been validated (Rammstedt and John, 2007; Gosling *et al.*, 2003). The scale consists of ten questions, two to measure each trait, and for which responses were on a 5-point scale.

Also included were questions, the content of which were derived from findings of the prior qualitative study (Abrahams *et al.*, 2018), and for which responses were provided on a 5-point Likert scale. Two questions asked about perceived risks of nutrigenetic testing. Two questions asked for views on the ethics of nutrigenetic testing. Four questions asked about perceived usefulness of tech-enabled personalised nutrition technologies (microbiome, metabolomics, food allergy and food sensitivity). Questions on the perceived importance of nutrition technologies (biotechnology, information and mobile technology), and skill areas related to the field of dietetics (research, business, entrepreneurship, creativity, training) were also included, as were perceptions of self as an entrepreneur or innovator.

5.3 Procedure

Ethical approval for the study was granted by the University of Bradford Ethics Committee (E598)

5.3.1 Sampling

Based on an alpha of 0.05, power of 0.9, and a potential effect size of 0.8, an estimated total sample size of $n=122$ was required (Schwarzer and Jerusalem, 1995). Dietitians were accessed between May and June 2017 through dietetic associations, and through dietetics-related social media networks (Facebook 1K, LinkedIn 1K, European Federation of Associations of Dietetics 2.6K, Association of Nutrition and Dietetics 2K) based in English, Spanish and Portuguese speaking countries. Personal invitations were also sent via LinkedIn to Registered Dietitians (RD's), to which only one person declined. One dietetic association (South-Africa) posted the information about the study in their weekly newsletter (1.5k). CEO's of companies that provide nutrigenetic testing kits to healthcare professionals for use in practice were contacted and requested to distribute the survey to their database of RD's (Nutrigenomix, Genovive, DNAlysis). No reward or gift was offered for participation. Information about the aims of the research, and the study itself was provided on the first page of the survey questionnaire. A separate information sheet was made available as an attachment upon request *via* email. The only exclusion criterion was that unqualified individuals, or students of nutrition and/or dietetics programmes, should not participate. Consent was obtained at the start of the survey and the researcher's contact details were provided. Potential volunteers were then invited to participate by being sent an

email containing an on-line link to the survey. Participants could withdraw their responses at any time, although no such requests were received.

5.3.2 Survey

The questionnaire was translated from English into Portuguese and Spanish by a professional local translation service, and back-translated to ensure consistency, accuracy and clarity. The survey was administered using the SurveyMonkey™ platform (SurveyMonkey.com, LLC, Palo Alto, CA, USA, 2014). The questionnaire was initially piloted on UK based dietitians (N=3) using the test function on SurveyMonkey™ to which participants could add comments and questions. Minor changes were made to the questionnaire based on the feedback received. To the question about gender, “non-binary” was added as an option. The term “non-profit” was changed to “not-for-profit”. The survey was made available over a five-week period, during which time one reminder mail was sent *via* the social media platforms.

5.4 Data Analysis

5.4.1 Treatment of missing data

At the end of five weeks, the total number of completed questionnaires was 383. Participants with more than five demographic entries missing (10% of the survey), as well as those who identified themselves as students (N=2, 0.5%), were removed from the database. Also excluded were 65 responses where participants provided demographic information but did not complete any of the scales.

5.4.2 Treatment of included data

All the variables are summarised in Table 5. Responses to the two free-text questions “number of years in practice” and “age” were rounded up to the nearest whole number. Initial responses to the question “have you integrated nutrigenetic testing into your practice?” were coded as ‘yes’, ‘no’ or ‘at some point’. Owing to the small number of responses in the cell “at some point”, the categories “yes” and “at some point” were combined to create a dichotomous yes /no variable. Reasons for stopping were completed by 10 participants in the free text box which included: high cost to clients (n=3); job change (n=2); lack of knowledge; testing discussed but not used (n=2); and, concern that the underpinning science was not yet ready for practice (n=2).

Scores for self-efficacy (Schwarzer and Jerusalem, 1995) and personality (Big 5) (Gosling *et al.*, 2003) were calculated according to how scales had been validated. Specific items on the self-efficacy and 10-item Big 5 scales were reverse-scored (Chen and Gully, 2003; Gosling *et al.*, 2003; Schwarzer and Jerusalem, 1995; Costa and McCrae, 1992). Missing data were replaced with the series means.

Cronbach’s alpha implied very good reliability and high internal consistency for the self-efficacy tool ($\alpha=0.87$). For the 10-item personality scale, the 5 traits Cronbach-alpha reliability tests were found to be: $\alpha=0.70$ (extraversion); $\alpha=0.22$ (agreeableness); $\alpha=0.45$ (conscientiousness); $\alpha=0.54$ (neuroticism); $\alpha=-0.43$ (openness). Whilst the Cronbach- alpha score for openness was low, I decided to keep it as part of the analysis.

Principal component analysis (PCA) was performed on the un-validated scales (perception of risks of genetic testing, ethics of genetics testing, usefulness of omics, usefulness of food testing, perceived importance of skill area, perceived importance of biotechnology/information technology/mobile technology). A factor loading threshold of 0.4, and eigenvalue >1 was used to identify factors. PCA indicated that the two items on genetic testing: “Gene-and other omics-based technologies represent a risk to me professionally”; and “Gene-based Personalised nutrition represents a risk to my patients and clients”; loaded onto one factor (eigenvalue of 0.94). The Cronbach alpha for this variable labelled as “perceptions of risk”, showed good reliability ($\alpha=0.78$). PCA indicated that the two items: “Genetic testing poses an ethical dilemma to me”; and, “Genetic testing should not be available direct to consumers” (which were reverse scored); loaded onto one factor but with low reliability ($\alpha=0.44$). This factor was labelled “ethics”. Items on the usefulness of: the microbiome; metabolomics; food allergy; and, food sensitivity testing; (supplementary table) loaded onto two factors each with an eigenvalue of 0.90. These were labelled “usefulness of omics” (microbiome/metabolomics) ($\alpha=0.84$) and “usefulness of food testing” (food allergy/food sensitivity) ($\alpha=0.73$).

Items “I see myself as an entrepreneur” and “I see myself as an innovator” were entered as separate variables into the analysis.

Items that followed on from the question “Please rate the importance to dietetics of each area below”: genomics; functional and integrative nutrition; food engineering; bioinformatics; artificial intelligence and machine learning; chatbots; microbiome testing; metabolomics; virtual and augmented reality;

telehealth and wearable technology (supplementary tables); loaded onto three factors creating new variables labelled: 'biotechnology' ($\alpha=0.85$); 'information technology' ($\alpha=0.84$); and, 'mobile technology' ($\alpha=0.61$).

Items assessing the perceived importance of: "creativity; innovation and entrepreneurship"; "business and marketing"; "research"; and, "teaching and training"; loaded onto one factor with "creativity, innovation and entrepreneurship" contributing to the highest weighting of 0.80 and with adequate reliability ($\alpha=0.51$). All four items were combined into a single variable labelled "Importance of skill area".

Pearson correlation (supplementary tables) was used to check for intercorrelations between the independent variables: "age"; "years in practice"; "sector of work"; "highest level of education gained", "mean self-efficacy"; "perception of risks of genetic tests"; views on "ethics of genetic testing"; "usefulness of omics"; "usefulness of food testing"; perceived importance of "bio, information and "mobile technology"; "importance of skill area"; "extraversion"; "openness", "conscientiousness"; "agreeableness"; "neuroticism"; "perception of self as an innovator"; "perception of self as an entrepreneur"; and "have you integrated nutrigenetic testing into practice".

Significance level was set at $p < 0.05$. Effect size was measured using Cohen's d where $d= 0.2$, $d= 0.5$ and $d= 0.8$ equated to a small, medium and large effect respectively (Cohen, 1988). Power analysis was performed using G*3-power software version 3.1.9.2 (Faul *et al.*, 2007)

Model 1 calculated the factors that determine integration of personalised nutrition technology into practice to test the first hypothesis: "age"; "gender";

“sector of work”; “country”; “number of years working”; “mean self-efficacy”; “extraversion”; “openness”; “agreeableness”; “neuroticism”; “conscientiousness”; “I see myself as an entrepreneur”; “I see myself as an innovator”; “usefulness of omics”; “usefulness of food testing”; importance of “bio/IT/mobile technology”; “importance of skill area”; “ethics of genetic testing”; and, “perceptions of risk” of genetic testing; as independent variables and “having integrated nutrigenetic testing into practice” as the dependent variable.

Model 2 calculated factors that determined perceived importance to dietetics of different types of technology to test the second hypothesis. Explanatory (independent) variables were: “age”; “number of years in practice”; “sector of work”; “highest level of qualification gained”; “UK or other”; “I see myself as an entrepreneur”; “I see myself as an innovator”; “ethics of genetic testing”; “perception of risk” of genetic testing; and, “importance of skill area to dietetic practice”; as independent variables. With perceived “importance of biotechnology”, “information technology” and “mobile technology” entered as dependent variables respectively. As integration of nutrigenetics into practice is considered a behaviour, it would have been inappropriate to include this as both a dependent and independent variable and therefore was removed from the regression model. SPSS© (IBM) version 24 was used to analyse data.

A test for multicollinearity was performed. A VIF (variance inflation factor) score of below 5 was considered acceptable (Hair *et al.*, 1995).

5.6 Results

5.6.1 Sample description

The final sample comprised 323 registered dietitians from the countries as outlined in Table 4. The questionnaire was distributed to approximately 8000 registered dietitians, implying a response rate of 19.7%, which correlates well with the 16% response rate of a previous online survey conducted amongst dietitians (Collins *et al.*, 2013). The sample consisted mainly of females (93.8%) with only 5.6% male and non-binary gender 0.2% (Table 4). Age ranged from 21 years to 72 years with a median age of 37.5 years. There was no significant difference between dietetics practitioners who had and had not integrated personalised nutrition technology into practice in terms of age ($t(321)=-0.63$, $P=0.53$), or highest level of education attained ($t(321)=1.63$, $P=0.11$). More than half (57%) held a BSc (with or without postgraduate diploma), 36% an MSc and 6.5% a Doctorate. More than a third (37%) worked in the public sector (37%) and more than half (52%) in the private sector. One participant was retired. There was no significant difference between the two groups in terms of the sector where they worked ($t(321)=-0.14$, $P=0.76$) or number of years worked ($t(321)=-0.29$, $P=0.78$). The number of years working ranged from 1 up to 50, with a median of 12 years and a mean of 10 years. Of dietetic practitioners of personalised nutrition (84%) were based in: the UK =7(14%); Australia =1(2%); Canada=6(12%); USA =12 (24%); Israel =1(2%); Mexico =9 (18%); Portugal=4 (8%); South-Africa=7(14%); UAE=1 (2%); Norway =1(2%).

Table 4: Sample characteristics (N=323)

	N (%)
Gender	
Male	18 (5.6%)
Female	303 (93.8%)
Non-Binary	2 (0.2%)
Age	N=323 (100%) Range = 21-72 yrs
Education	
BSc	59 (18%)
Degree/Diploma	126 (39%)
Masters	117 (36%)
Doctorate/PhD	21(6.5%)
Place of work	
Public sector	119 (37%)
Private sector	168 (52%)
Non-profit/Third sector	4 (0.01%)
Non-clinical	23 (7%)
Public /Third	2 (0.62%)
Public/Non-clinical	1 (0.3%)
Third sector/Non-clinical	1 (0.3%)
Public/Third sector/Non-clinical	2(0.62%)
All	2 (0.62%)
Unemployed	1 (0.3%)

Country of employment	
United Kingdom (UK)	133 (41%)
Australia	6 (1.86%)
Canada	23 (7%)
United States	39 (12%)
Israel	1 (0.3%)
Mexico	9 (2.78%)
Spain	1 (0.3%)
Portugal	42 (13%)
South-Africa	44 (13.6%)
Belgium	1 (0.3%)
Ireland/Republic of Ireland	13 (4.0%)
UAE	2 (0.6%)
Saudi Arabia	1 (0.3%)
Italy	1 (0.3%)
Greece	2 (0.6%)
Nordics	2 (0.6%)
Netherlands	1 (0.3%)
St Helena	1 (0.3%)
Egypt	1 (0.3%)
Years in practice	323 (100%) Range = 1-10 years
Integrated nutrigenetic testing into practice?	
Yes	49 (15%)
No	274 (85%)

Table 5. Survey questions and associated variables

Questions	Variable, scoring, reference
<p>Please indicate the answer that most accurately describes you</p> <p>-I will be able to achieve most of the goals that I have set for myself</p> <p>-When facing difficult tasks, I am certain that I will accomplish them</p> <p>-In general, I think that I can obtain outcomes that are important to me</p> <p>-I believe I can succeed at most endeavours to which I set my mind</p> <p>-I will be able to successfully overcome many challenges</p> <p>-I am confident that I can perform effectively on many different tasks</p> <p>-Compared to other people, I can do most tasks very well</p> <p>-Even when things are tough, I can perform quite well</p>	<p>Mean self-efficacy</p> <p>Likert scale (1-5)</p> <p>Schwarzer and Jerusalem (1995)</p>
<p>Please indicate the answer that most accurately describes you</p> <p>Gene-and other omics based technologies to personalise nutrition represent a risk to me professionally</p> <p>-Gene-based Personalised nutrition represents a risk to my patients and clients</p>	<p>Perception of risk (towards genetic testing)</p> <p>Likert scale (1 – 5)</p> <p>Abrahams <i>et al</i> 2018</p>
<p>Please indicate the answer that most accurately describes you</p> <p>I consider myself to be an innovator</p>	<p>Perception of self as Innovator</p> <p>Likert scale (1-5)</p> <p>Abrahams <i>et al</i> 2018</p>
<p>Please indicate the answer that most accurately describes you</p> <p>I consider myself to be an entrepreneur</p>	<p>Perception of self as entrepreneur</p> <p>Likert scale (1-5)</p> <p>Abrahams <i>et al</i> 2018</p>

<p>Please indicate the answer that most accurately describes you</p> <ul style="list-style-type: none"> -Genetic testing poses an ethical dilemma to me -Genetic testing should not be available direct to consumers 	<p>Ethics of genetic testing</p> <p>Likert scale (1-5)</p> <p>Abrahams <i>et al</i> 2018</p>
<p>Please indicate the answer that most accurately describes you</p> <ul style="list-style-type: none"> -Microbiome testing is useful to personalise diets -Metabolomics is a useful tool to personalise diets 	<p>Usefulness of omics</p> <p>Likert scale (1-5)</p> <p>Abrahams <i>et al</i> 2018</p>
<p>Please indicate the answer that most accurately describes you</p> <ul style="list-style-type: none"> -Food allergy testing is a useful tool to personalise diets -Food sensitivity testing is a useful tool to personalise diets 	<p>Usefulness of food testing</p> <p>Likert scale (1-5)</p> <p>Abrahams <i>et al</i> 2018</p>
<p>How well do the following statements describe you?</p> <p>I see myself as someone who;</p> <ul style="list-style-type: none"> -Is reserved -Is generally trusting -Tends to be lazy -Is relaxed, handles stress well -Has a few artistic interests -Is outgoing, sociable -Tends to find fault with others -Does a thorough job -Gets nervous easily -Has an active imagination 	<p>Personality traits</p> <p>Likert scale (1-5)</p> <p><i>Gosling et al (2003)</i></p>

<p>Please indicate how you rate the importance of each area below to dietetic practice</p> <p>Research</p> <p>Creativity, innovation & entrepreneurship</p> <p>Business & Marketing</p> <p>Teaching & training</p>	<p>Perceived importance of skill area</p> <p>Likert scale (1-5)</p> <p>Abrahams <i>et al</i> 2018</p>
<p>Please indicate how you rate the importance of each area below to RD's to dietetic practice</p> <p>Genomics</p> <p>Microbiome testing</p> <p>Metabolomics</p> <p>Functional & Integrative nutrition</p> <p>Food engineering</p> <p>Bio-informatics</p> <p>Artificial intelligence and machine learning</p> <p>Chatbots</p> <p>Virtual and Augmented reality</p> <p>Telehealth</p> <p>Wearable technology</p>	<p>Perceived importance of;</p> <p>Biotechnology</p> <p>Information technology</p> <p>Mobile technology</p> <p>Likert scale (1-5)</p> <p>Abrahams <i>et al</i> 2018</p>

5.6.2 Factors associated with integration of personalised nutrition into practice

Traits that were positively correlated with having practiced personalised nutrition were (Table 3): higher extraversion ($r(321)=-0.11$, $P<.05$); lower neuroticism ($r(321)=0.14$, $P=0.01$); higher self-efficacy ($r(321)=-0.14$, $P=0.01$); lower perception of risk of genetic testing ($r(321)=0.31$, $P<0.01$); higher perceived importance of biotechnology to dietetic practice ($r(321)=-0.24$, $P<0.01$); higher perception of self as an entrepreneur ($r(321)=-0.22$, $P<0.01$); higher perception of self as an innovator ($r(321)=-0.13$, $P=0.02$); lower perceived impact of ethics of genetic testing ($r(321)=-0.18$, $P=0.001$); higher perceived usefulness of omics ($r(321)=-0.21$, $P<0.01$) and food testing technologies ($r(321)=-0.13$, $P<0.01$).

Table 6. Mean and SD scores for dietitians who have and have not integrated nutrigenetic testing into practice

	Early adopters N=49 (15%)		Non-adopters N=274 (85%)	
	Mean	SD	Mean	SD
Perception of risk of genetic testing	3.41	1.53	4.70	1.41
Importance of technology				
Biotechnology	17.31	2.34	15.35	2.95
Information	16.96	3.40	17.05	3.53
Mobile	7.63	7.79	7.79	1.58
Importance of skill area	18.20	1.97	18.53	1.62
Mean self-efficacy	4.27	0.49	4.08	0.46
Personality				
Extraversion	7.73	1.47	7.17	1.98
Agreeableness	7.92	1.30	7.47	1.66
Neuroticism	5.00	1.79	5.73	1.88
Openness	6.57	1.47	6.50	1.46
Conscientiousness	8.70	1.36	8.63	1.48
Perception of self				
Entrepreneur	4.10	1.01	3.45	1.03
Innovator	3.96	0.84	3.65	0.88
Usefulness of				
Omics technology	7.67	1.45	6.88	1.36
Food testing	7.73	1.87	7.07	1.81
Ethics of genetic testing	7.06	1.87	6.24	1.57

*Significance level at $p < 0.01$

Table 7. Factors associated with integration of personalised nutrition into practice (N=323)

	Unstandardized coefficients		Std. coefficients Beta	P-value
	B	Std. Error		
(Constant)	1.651	.362		.000
Gender	.094	.070	.072	.179
Age	.005	.004	.141	.195
Highest level of qualification gained	-.016	.023	-.038	.482
Sector of work	.009	.011	.043	.405
Mean number of years working	-.007	.004	-.192	.078
I consider myself to be an innovator	.023	.026	.057	.383
I consider myself to be an entrepreneur	-.062	.023	-.181	.007
Mean self efficacy score	-.048	.048	-.062	.320
Extraversion	-.014	.010	-.077	.161
Agreeable	.002	.012	.009	.874
Neuroticism	.015	.011	.078	.165
Openness	.000	.013	.001	.980
Conscientious	.009	.015	.036	.548
Country (UK and other)	-.105	.042	-.144	.014
Importance of skills area	.028	.013	.128	.037
Perception of risk of genetic testing	.044	.014	.184	.002
Ethics of genetic testing	-.004	.012	-.019	.738
Usefulness of omics	-.009	.016	-.036	.554
Usefulness of food testing	.003	.011	.016	.778
Importance of mobile technology	.003	.013	.012	.841
Importance of information technology	.018	.007	.177	.012
Importance of biotechnology	-.033	.009	-.269	.000

*Significance level at $p < 0.05$

The regression model 1 (see Table 7) of factors predicting the integration of personalised nutrition technology testing into practice explained 49% of the

variance between dietetic practitioners who had and had not integrated personalised nutrition testing into practice, and was statistically significant ($F(3211, 3212) = 4.41, P < 0.01, 95\% \text{ CI } 0.94\text{--}2.36$). Factors which predicted whether an individual had integrated personalised nutrition and associated technology into practice were: higher “perception of self as an entrepreneur” ($B = -0.06; t = -2.73, P < 0.01, 95\% \text{ CI } -0.12\text{--}-0.02$) (which was the strongest predictor with an effect size of $d = 0.64$); lower “perception of risk” associated with genetic testing technologies ($B = 0.04; t = 3.14, P < 0.01; 95\% \text{ CI } 0.02\text{--}0.07$) (effect size $d = 0.88$); higher perceived “importance of biotechnology” ($B = -0.03, t = -3.54, P < 0.01, 95\% \text{ CI } -0.05\text{--}-0.02$) (effect size $d = 0.74$); lower perceived “importance of skill area” ($B = 0.03, t = 2.09, P = 0.04, 95\% \text{ CI } 0.00\text{--}0.05$) (effect size $d = 0.18$); and, lower “perceived importance of information technology” ($B = 0.02, t = 2.54, P = 0.01, 95\% \text{ CI } -0.01\text{--}0.03$) (effect size $d = 0.02$).

Table 8. Factors predicting perceived importance of biotechnologies amongst cross-section of dietitians

	Unstandardized Coefficients		Std coefficients	P-value
	B	Std.Error	Beta	
(Constant)	-.553	2.031		.785
Highest level of qualification gained	.259	.142	.074	.068
Sector of work	.046	.067	.027	.492
Mean number of years working	-.036	.012	-.120	.003
I consider myself to be an innovator	.020	.164	.006	.902
I consider myself to be an entrepreneur	.003	.139	.001	.982
Mean self efficacy score	-.222	.298	-.035	.457
Extraversion	-.025	.063	-.016	.696
Agreeable	.082	.073	.045	.263
Neuroticism	.016	.066	.010	.813
Openness	.037	.079	.018	.644
Conscientious	.023	.090	.011	.801
Importance of professional skills	.297	.078	.169	.000
Perception of risk of genetic testing	-.334	.085	-.170	.000
Ethics of genetic testing	.115	.076	.064	.131
Usefulness of omics	.516	.093	.245	.000
Usefulness of food testing	.144	.066	.090	.031
Importance of mobile technology	.100	.081	.053	.220
Importance of information technology	.333	.040	.397	.000

*Significance level at $p < 0.05$

Table 9. Importance of information technology to dietetic practice amongst cross-section of dietitians

	Unstandardized coefficients		Std. coefficients	P -value
	B	Std.Error	Beta	
(Constant)	-4.645	2.630		.078
Highest level of qualification gained	-.147	.185	-.035	.430
Sector of work	-.122	.087	-.060	.159
Mean number of years working	.027	.016	.077	.082
I consider myself to be an innovator	.302	.213	.076	.158
I consider myself to be an entrepreneur	-.016	.181	-.005	.928
Mean self efficacy score	.142	.388	.019	.714
Extraversion	.022	.081	.012	.788
Agreeable	.118	.095	.055	.217
Neuroticism	-.026	.086	-.014	.762
Openness	.021	.103	.009	.842
Conscientious	-.219	.116	-.091	.061
Importance of professional skills	.486	.100	.232	.000
Perception of risk of genetic testing	.124	.113	.053	.273
Ethics of genetic testing	-.057	.099	-.027	.561
Usefulness of omics	.071	.127	.028	.576
Usefulness of food testing	-.090	.087	-.047	.302
Importance of mobile technology	.423	.103	.187	.000
Importance of biotechnology	.564	.067	.474	.000

*Significance level at $p < 0.05$

Table 10. Importance of mobile technologies to dietetic practice amongst cross-section of dietitians

	Unstandardized coefficients		Std. coefficients	P - value
	B	Std. Error	Beta	
(Constant)	1.539	1.424		.281
Highest level of qualification gained	.219	.099	.119	.028
Sector of work	.043	.047	.048	.355
Mean number of years working	.000	.008	.001	.987
I consider myself to be an innovator	.016	.115	.009	.888
I consider myself to be an entrepreneur	-.040	.097	-.027	.679
Mean self efficacy score	.251	.209	.076	.231
Extraversion	-.010	.044	-.012	.826
Agreeable	-.054	.052	-.057	.292
Neuroticism	.025	.047	.031	.590
Openness	.022	.056	.020	.699
Conscientious	.181	.062	.170	.004
Importance of professional skills	.038	.056	.042	.493
Perception of risk of genetic testing	.077	.061	.075	.205
Ethics of genetic testing	.062	.053	.066	.245
Usefulness of omics	-.081	.068	-.073	.240
Usefulness of food testing	-.061	.047	-.072	.191
Importance of biotechnology	.049	.040	.094	.220
Importance of information technology	.123	.030	.279	.000

*Significance level at $p < 0.05$

5.6.3 Factors associated with the perceived importance of new technologies

Three regression models were created to determine the perceived importance of each of three types of personalised nutrition technologies identified in the PCA analysis, and which were labelled 'biotechnology', 'information technology' and 'mobile technology' (Tables 8-10). The strongest predictor of perceived importance of biotechnology was higher perceived "usefulness of omics tests" ($B=0.52$, $t=5.55$, $P<0.01$, 95% CI 0.33-0.70), followed by higher perceived "importance of information technology" ($B=0.33$, $t=8.39$, $P<0.01$, 95% CI 0.26-0.41), higher "importance of skill area" ($B=0.33$, $t=3.82$, $P<0.01$, 95% CI 0.14-0.45), lower "perception of risk" of genetic testing ($B=-0.33$, $t=-3.952$, $P<0.01$, 95% CI -0.50- -0.17) and lower "mean number of years working" ($B=-0.04$, $t=-3.02$, $P<0.01$, 95%CI -0.06- -0.01). This model explained 75% in variation between variables and was significant ($F(3211, 3212) =21.43$, $P<0.01$, 95% CI -4.55–3.443).

The strongest predictor of perceived "importance of information technologies" was higher perceived "importance of biotechnology" ($B=0.56$, $t=8.39$, $P<0.01$, CI 0.43–0.70), followed by higher perceived "importance of skill area" ($B=0.49$, $t=4.87$, $P<0.01$, 95% CI 0.29–0.68) and, whether "mobile technologies" were also perceived as important ($B=0.42$, $t=4.09$, $P<0.01$, 95% CI 0.22-0.63). This model explained 69% of variability between variables and was significant ($F(3211, 3212) = 15.16$, $P<0.01$, 95% CI -9.82–0.53). Factors that determined perceived "importance of mobile technologies" were "highest level of education gained" ($B=0.22$, $t=2.20$, $P=0.03$, 95% CI 0.02-0.41), higher "conscientiousness" ($B=0.18$, $t=2.90$, $P =0.01$, 95% CI 0.58–0.30) and, higher perceived "importance

of information technology” (B=0.12, t=4.09, P<0.01, 95%CI 0.06-0.18). This model explained 46% of the variability between variables (F3211, F3212=4.58, P<0.01), 95%CI -1.26–4.34).

Test for collinearity indicated that the two independent variables “age” and “number of years working” had a VIF score of 4.5 and 4.5 respectively indicating that these may influence the models. All the other independent variables had a VIF score of below 2 which is considered good.

Furthermore, comparison between the perception of EA and NA of different technologies indicated that EA rated the importance of omics and functional and integrative nutrition significantly higher in comparison to NA (Figure 5).

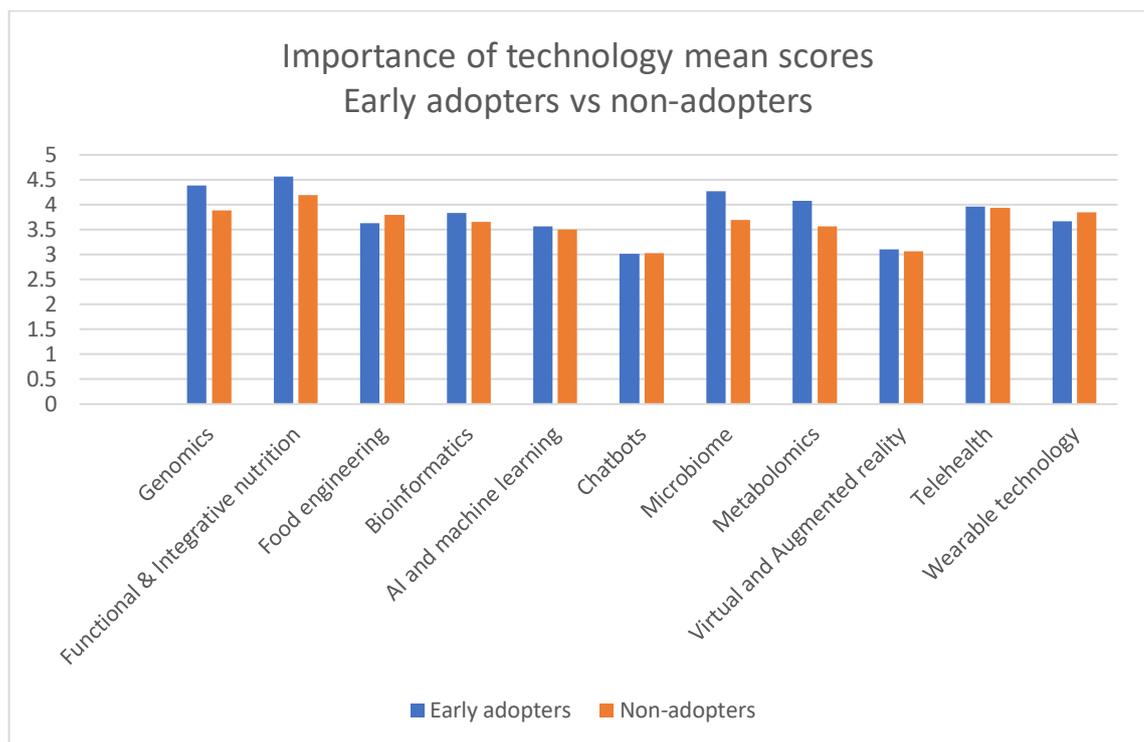


Figure 5. Importance of different technologies that may impact dietetic practice between early adopters and non-adopters.

5.7 Discussion

The purpose in this research has been to identify barriers to, and facilitators of, adoption of personalised nutrition and related technologies by dietetics professionals. In this research we sought to determine what distinguished dietitian practitioners who had, and had not, integrated personalised nutrition technology into their practice. The first finding demonstrated that dietitian practitioners who had integrated personalised nutrition technology into their practice considered themselves to be entrepreneurs, perceived lower risk in genetic testing, rated biotechnology higher and professional skills lower to dietetic practice.

That those who practiced technology-enabled personalised nutrition perceived less risk in genetic testing was as expected. In comparison to the general population, dietitians have been found to have average levels of novelty seeking behaviour and high levels of harm avoidance (Ball *et al.*, 2015; Ball *et al.*, 2014). This implies that more could be done to open up discussion on risk of genetic testing in dietetics practice.

The finding that integration of personalised nutrition technology was also associated with higher perceived importance of biotechnology but lower perceived importance of information technologies would align with predictions made by the diffusion of innovation theory (Rogers, 1964). This implies that more could be done to not only increase awareness of new technologies among those dietetic practitioners who have not integrated personalised nutrition technology, but also increase understanding of how new technologies impact dietetic practice. Perceived importance of “skill area” was not a predictor for integration of personalised nutrition into practice. This is supported by previous

research (Abrahams *et al.*, 2018) and suggests that those who already practice technology-enabled personalised nutrition, do not consider that additional professional skills are required. Hickson *et al* (2017) have recently recommended the need for the development of a career framework which maximises and utilizes the existing skills and knowledge of dietitians.

High perception of self as an entrepreneur also distinguished those dietitian practitioners who had integrated personalised nutrition technology into practice. This may have important implications for policy and practice, as diffusion of new innovations may be accomplished by enabling dietitians to think more like entrepreneurs, without necessarily having to become one.

Also, in keeping with findings of previous research (Corbett *et al.*, 2018), those who practiced technology-enabled personalised nutrition had higher levels of self-efficacy. Self-efficacy has also been associated with personality, such that those who exhibit more pro-active personalities tend to have higher self-efficacy (Judge and Ilies, 2002), greater risk-taking and opportunity seeking behaviour (Krueger *et al.*, 1994), goal orientation and need for achievement (Phillips and Gully, 1997). Self-efficacy has also been closely associated with entrepreneurial intentions and traits (Locke, 2000), entrepreneurial self-efficacy and entrepreneurial intentions (Chowdhury and Endres, 2005; Gatewood *et al.*, 2003; Chen and Green, 1998; Kourilsky and Walstad, 1998). Given that self-efficacy is task and situation dependent and can be increased through learning and experience (Bandura, 1986), future considerations could include specific training directed towards raising levels of self-efficacy among nutrition and dietetics students. Contrary to previous research (Cormier *et al.*, 2014; Li *et al.*,

2014), neither sector of work nor personality were associated with integration of personalised nutrition technology into dietetic practice.

A second objective sought to determine factors associated with perceived importance of personalised nutrition technologies to dietetic practice. The finding that the perceived importance of biotechnology was determined by perceived usefulness of 'omics' technologies indicates that a potential strategy to encourage adoption of personalised nutrition could be to raise awareness of microbiome and metabolomics technology. This could be achieved through case examples, success stories from early adopters, encouraging research as well as addressing the negative perceptions that non-practising dietitians may hold (Rogers, 1962) which include fear of practice- license being revoked, adopting technology that is not evidence-based or endorsed by professional organizations (Abrahams *et al.*, 2018; Abrahams *et al.*, 2017).

The perceived importance of information technology was determined by perceived importance of biotechnology. Recent research has highlighted the importance of sensors, wearable and nutrition informatics technologies in early detection, tracking, monitoring and intervention to produce quality evidence-based personalised recommendations to individuals in real-time (Tambo and Ngogang, 2018). Whilst nutrition informatics competencies for dietitians have already been investigated (Ayres *et al.*, 2012), more research is needed in view of the rapid advances in personalised nutrition technologies (Kuriyan *et al.*, 2014; Khoury *et al.*, 2013). Factors that predicted the perceived importance of mobile technologies included higher perceived importance of information technology, higher conscientiousness, and higher level of qualifications. This

may imply the need for further training in telehealth, wearable and information technologies.

Among the study limitations are those inherent to the use of self-report methodologies and include the potential bias associated with perceived social desirability in responses (Grimm, 2010; Chan, 2009). The online survey methodology meant that compliance was low, although we have estimated that the response rate was comparable to other on-line surveys which used similar recruitment methodologies (Collins *et al.*, 2013), yet the study was adequately powered (0.99). Another potential limitation inherent in the sampling was that the number of dietitians practicing personalised nutrition was small (n=49) relative to those who were not practicing (n=274). Given that this is an emerging area and the research on the potential health benefits of a personalised nutrition approach is limited, we would expect numbers of practitioners of personalised nutrition to be small.

Whilst the number of countries included was large, this reflects current practice and online discussion around the world, as nutrigenetic testing companies make testing kits available across country borders. There may have been between-country differences in responses, which given insufficient numbers in certain countries, were impossible to analyse and which may have impacted upon the findings. Results of the qualitative study implied that attitudes, perceptions and practice amongst early adopters of personalised nutrition were similar irrespective of nationality or country of origin. We cannot therefore be certain that items were understood in the same way by dietitians in the different countries. Future research will be required to determine the degree

to which views on personalised nutrition and related technologies vary between professions based in various countries.

Single items included in the questionnaire (such as that on perception of self as an entrepreneur) may not have been sensitive as multi-scaled validated measures. Existing validated scales, however, would have taken a long time to complete which could have affected compliance. In addition, given that the aim of the study was to measure self-perception of self as an entrepreneur, rather than actually being an entrepreneur, no existing scale would have been entirely appropriate. Another factor which could have affected discriminate ability of the measure was that responses of those who had at one time used nutrigenetic testing, but who had not continued to do so, were combined with those who continued to apply it in practice. Further research is needed with frontline RD's to understand reasons for stopping. Another omission was that respondents were not asked for the reasons why they had not used personalised nutrition technologies in practice or had ceased. Possible reasons which could be explored in future research include organisational culture (NHS, 2019), lack of opportunity or constraints on resources. There may have been between-country differences in responses, which given insufficient numbers in certain countries, were impossible to analyse and which may have impacted upon the findings. Results of the qualitative study (Corbett, 2018) implied that attitudes, perceptions and practice amongst early adopters of personalised nutrition were similar irrespective of nationality or country of origin. We cannot therefore be certain that items were understood in the same way by dietitians in the different countries. Future research will be required to determine the degree to which views on personalised nutrition and related technologies vary between

professions based in various countries. The variable “ethics of genetic testing” had low reliability and the personality trait of “openness” had a negative Cronbach indicating that these results should be interpreted with caution. A final limitation was that there was collinearity between the independent variables “age” and “number of years working” and therefore this should be kept in consideration when interpreting the regression models.

5.8 Conclusion

To my knowledge, this is the first multi-national study undertaken to determine how psychological and personal factors may influence adoption of new personalised nutrition technologies amongst a cross section of dietetics practitioners. These findings therefore have important implications for practice and policy to open-up dialogue on tech-enabled personalised nutrition at a more local, country level. Whilst this study adds to the existing small body of literature on personalised nutrition in practice, future research should seek to obtain a comprehensive insight into how health professionals construe risk around personalised nutrition and associated technologies and understanding how entrepreneurial traits and efficacy can be harnessed in the delivery of personalised nutrition.

Chapter 6

Trust in healthcare professionals, demographic factors, nutritional self-efficacy, perceived health, perceived risk and level of personalised nutrition a secondary analysis using Food4me survey data

(Status – To be submitted as a commentary paper)

Abstract

Background: Whilst the personalised nutrition industry is experiencing rapid growth, the public may place their trust in different healthcare professionals to provide this service. This study aimed to determine the profiles of those who would trust a family doctor, registered dietitian and personal trainer to provide a personalised nutrition service. The study also aimed to determine the type of personalised nutrition service that would be appealing.

Methods and Materials: This study analysed existing Food4me survey data, collected in representative samples recruited in nine EU countries (N=9381). K-means cluster analysis was used to determine groups according to the extent to which they found personalised nutrition appealing based on advice derived from; 1. information on their diet and physical activity; 2. Phenotype; and, 3. DNA. Two clusters were identified, those who found personalised nutrition appealing and those who did not. Those who did not find personalised nutrition appealing (n=3821) tended to be older, have a lower education level, were less likely to perceive themselves as healthy, had lower levels of self-efficacy and were more likely to perceive personalised nutrition as risky. Data obtained from those who found personalised nutrition appealing (n=5253) were entered into multiple regression analysis. Regression models were created to identify what

type of information was most appealing to those who trusted family doctors, dietitians/nutritionists and personal trainers.

Results: Trust in each of three professionals (family doctor; dietitian; personal trainer) was explained by the type of personalised nutrition deemed appealing (food and exercise; blood chemistry; genotype (DNA)). The model explaining trust in dietitians was the strongest. Those who trusted dietitians tended to be female, younger, have a higher education level, higher perceived health, higher nutrition self-efficacy and lower perceived risk in personalised nutrition. They found advice based on food and exercise most appealing and that based on genotype (DNA) least appealing. Those who trusted personal trainers tended to be female, younger, have a lower education level, higher perceived health, higher nutrition self-efficacy and lower perceived risk. They found advice based on food and exercise most appealing and that based on genotype (DNA) least appealing. Those who trusted family doctors tended to be male, older, have a lower education level, higher perceived health, higher nutrition self-efficacy and lower perceived risk. They found advice based on food and exercise and on blood chemistry most appealing and that based on genotype (DNA) least appealing.

Conclusion: People who trust a family dr, RD or PT to provide personalised nutrition differ in their profile in terms of demographics as well as on their self-rated health status, nutritional self-efficacy and perceived risk towards personalised nutrition. Interest in personalised nutrition based on food and exercise is the preferred level of service. These findings need to be considered when engaging with clients and developing services to allow equitable access,

however nutrition training needs for family dr's and PT need to be addressed as a matter of urgency.

6.1 Introduction

Personalised nutrition has the potential to reduce the cost of healthcare and increase motivation and adherence to nutritional recommendations (Celis-Morales *et al.*, 2016; Livingstone *et al.*, 2016). Recent research has indicated that the public is interested in personalised nutrition (Stewart-Knox *et al.*, 2013), are willing to pay for personalised nutrition services (Fischer *et al.*, 2016) and were more likely to improve their dietary habits in comparison to those who received generic healthy eating guidelines (Livingstone *et al.*, 2016). With a global rise in chronic diseases, healthcare systems are searching for innovative ways to increase patient engagement in order to encourage self-care for disease prevention and self-management of their own conditions. This new approach makes patients partners in their own healthcare and decision making in order to increase health literacy, increase satisfaction with healthcare systems as well as improve adherence to treatment plans (Graffigna *et al.*, 2014). In order for individuals to become more engaged in their own care however, they need to be able to have a trusting relationship with their healthcare provider which may require using technology as a tool to engage people in their own health to create healthy communities (Graffigna *et al.*, 2013)

A survey (Poinhos *et al.*, 2017) of representative samples across nine European countries (N=9381) found that trust and preferences in personalised nutrition providers strongly predicted intention to adopt personalised nutrition. Although there was some variation across countries, the family doctors, followed by RD's

were most trusted to provide personalised nutrition advice (Poinhos *et al.*, 2017). This finding is similar to a previous qualitative study conducted in Australia which also found that family doctors were considered to be most trusted and preferred professionals to provide personalised nutrition advice followed by RD's (Ball *et al.*, 2012)

Another group of professionals that are ideally placed to provide physical activity and healthy eating advice, are personal trainers (PT's) (de Lyon *et al.*, 2017; Oprescu *et al.*, 2012). Whilst nutrition is not a primary focus for personal trainers (Barnes *et al.*, 2017), international standards for providing nutritional care for healthy eating and obesity have been established (ICREP, 2013). Recent international research has indicated that personal trainers feel confident in their ability to deliver nutritional advice to promote fitness as well as prevent disease (Barnes *et al.*, 2016). Furthermore, a recent study has demonstrated the potential use of genetic information to improve physical performance (Jones *et al.*, 2016).

According to a recent meta-analysis (Birkhäuer *et al.*, 2017), trust in healthcare professionals is directly linked to health outcomes. A high level of individual self-efficacy has been previously shown to predict adoption and engagement in health behaviours (Gwaltney *et al.*, 2009; Strecher *et al.*, 1986). In addition, previous research conducted in HIV patients found that engagement with a trusted healthcare professional increased levels of self-efficacy, self-esteem and adherence to medication (Chen *et al.*, 2013). However, nutritional self-efficacy and self-rated health status have not been related to trust in healthcare provider to provide personalised nutrition.

It was therefore important to understand how nutritional self-efficacy related to trust in a healthcare provider to provide personalised nutrition advice. Furthermore, perception of risk is negatively associated with adoption and engagement of new health technologies (Schnall *et al.*, 2017). It was therefore important to understand how perceived risk of personalised nutrition related to interest in adopting personalised nutrition advice. Self-rated health measures have been shown to be good predictors of mortality and objective health status (Wu *et al.*, 2013), yet these have to date not been related to the adoption of personalised nutrition offering. With a growing consumer interest in personalised nutrition, clients should be able to choose the professional who provides personalised nutritional advice which may extend beyond RD's. The purpose of this secondary analysis, therefore, has been to determine the profile of those who would prefer the family dr, RD or a personal trainer (PT) to deliver this service, and to inform healthcare professionals on how best to structure their product offering depending on the level of personalisation this advice is based on. The Food4me consumer survey (N=9381) included items on trust in family doctors, dietitians and personal trainers. Whilst RD's are known to provide personalised nutrition services, Family doctors have been shown to also be preferred providers (Poinhos *et al.*, 2016). Personal trainers on the other hand, were not considered to be preferred providers, but they are currently providing nutritional and exercise advice (de Lyon *et al.*, 2017). The Food4me survey also enquired of demographic data and included questions suited to profiling related to nutritional self-efficacy (San-Cristobal *et al.*, 2017); perceived risk of personalised nutrition (Berezowska *et al.*, 2014); self-assessed health status; and, appeal of personalised nutrition services based on food and

exercise; blood chemistry; and/or genetic (DNA) variables not previously analysed.

Based on previous available research, it is hypothesised that the profile of individuals who trust a family doctor, RD or personal trainer (PT) to provide personalised nutrition advice, differ in their preference for the level of personalised nutrition service offered based on their nutritional self-efficacy, self-reported health status, age, gender and risk perception of personalised nutrition.

6.2 Method

This is a part-secondary analysis of data collected as part of the Food4me survey on personalised nutrition for which the method is reported in detail elsewhere (Celis-Morales *et al.*, 2017; Poinhos *et al.*, 2017; Fischer *et al.*, 2016; Poinhos *et al.*, 2014). Data were collected online between February-March 2013. For this study, variables were analysed that were not included in previous Food4me analyses which included: self-perception of health status and preferred level personalised nutrition service (food and exercise; blood chemistry; genotype (DNA)). Approval to analyse the previously anonymised data was granted by the University of Bradford ethical committee

6.2.1 Sampling

Recruitment of participants is documented in a previous publication (Livingstone *et al.*, 2016)

6.2.2 Questionnaire

The questionnaire was developed, tested and piloted previously, for which full details have been documented in Poinhos *et al.*, (2016). Demographic factors analysed were: age, gender and education level. nutritional self-efficacy (San-Cristobal *et al.*, 2017) was measured using a 5-point Likert scale by means of the following question and items: “Please indicate how certain you are that you could overcome the following barriers; I can manage to stick to healthy foods even if I: need a long time to develop the necessary routines; have to try several times until it works; have to rethink my entire way of nutrition; do not receive a great deal of support from others when making my first attempts; have to make a detailed plan”. This scale had a Cronbach level of $\alpha=0.90$ and construct validity of >0.8 which is good.

Perceived risk (Berezowska *et al.*, 2014) of personalised nutrition was measured by means of the following question and items: “Please indicate the extent to which you agree or disagree with the following statements.

Personalised nutrition represents a risk: to me personally; to my family; to an average member of the society in which I live;”. This scale had a Cronbach of $\alpha=0.97$ and a construct validity of >0.96 which is considered good.

On preferences for different levels of personalised nutrition services; “How appealing is personalised nutrition based upon: food and exercise; blood chemistry; DNA”. On trust in health professionals, the following question was used: “Please indicate the extent to which you trust each of the following information sources: (your family doctor; RD; PT), to provide accurate information about personalised nutrition: Reliability estimates for the scale indicated a Cronbach of 0.88 which is considered good. Self-rated health measure was assessed by means of the question: “How healthy do you

consider yourself? (Likert scale 1–5), with 1= very unhealthy and 5= very healthy.

6.3 Data analysis

SPSS © (IBM) version 24 was used to analyse data.

Box plot indicated that responses to the question on trust in providers to provide information on personalised nutrition (family dr; RD's; and PT's) were normally distributed, therefore, parametric tests were used for statistical analysis.

Mean scores were calculated for the nutritional self-efficacy and risk perception scales. Two-step cluster analysis was performed to identify the ideal number of clusters using the following variables: age; education; nutrition self-efficacy; perceived risk of personalised nutrition to: myself; my family; society; perceived health status; appeal of personalised nutrition advice derived from: food and exercise; blood chemistry; DNA. K-means cluster analysis was performed firstly by creating standardized variables for age, education level, nutritional self-efficacy, perceived risk of personalised nutrition, appeal of levels of personalised nutrition (based on food and exercise, blood chemistry, and DNA) and perceived health status. These were used as independent variables. The numbers of clusters were specified as two, number of iterations were ten, and cluster association was selected. Cluster analysis is useful to identify profiles of participants with similar traits and characteristics especially if the data set is large. This had not been done in previous Food4me analyses. For the purpose of this study, I was only interested in those participants who found personalised nutrition appealing at any level and therefore K-means clustering provided the means to separate out the two groups i.e. those who found personalised

nutrition appealing and those who did not. This method was chosen above bivariate analysis (which had been performed in previous research), as this approach provided a more comprehensive picture based on objective (age, sex, education) as well as self-reported data (health status, nutritional self-efficacy) which had not been analysed before.

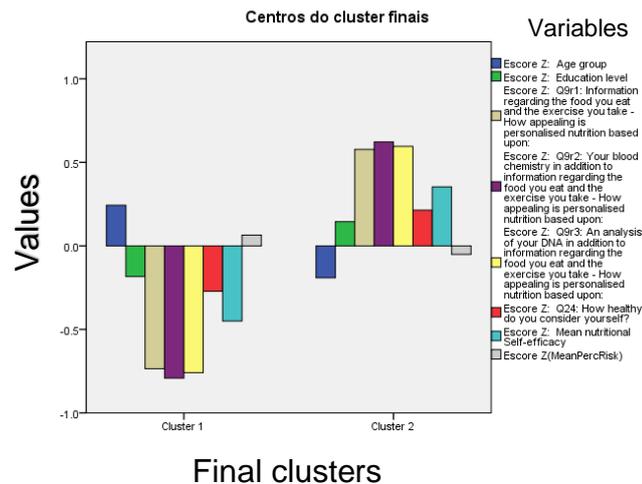


Figure 6. Final cluster analysis of participants who do and do not find personalised nutrition appealing.

Independent T-tests were used to determine the differences between the two clusters in gender, age, education level, nutritional self-efficacy, perceived risk, perceived health status. The goal was to identify if there were any global differences in terms of profiles between those who do and do not find personalised nutrition appealing.

Multiple linear regression analysis was performed to calculate the factors that determined trust in the three healthcare professionals (family doctor, RD, PT) respectively as outcome variables and a level of $p < 0.01$ was used to determine statistical significance. This approach aims to identify which independent variables more strongly influenced trust in the healthcare professional, as well as identify the level of personalised nutrition that was most appealing.

6.4 Results

The full sample consisted of N=9381 (Males =4751, Females =4630), the age group ranged from 18-65 years. Positive values in the cluster analysis (>0) indicate a positive relationship between variable and the cluster, whereas a negative value i.e. <0 , indicates an inverse relationship. Clusters analysis revealed that Cluster 1 (n= 4128) did not deem level of personalised nutrition appealing at any level (Question 9r1, 9r2, 9r3) and cluster 2 (n=5253) deemed personalised nutrition appealing all levels (Figure 6).

Cluster 1 who did not deem any level (food and exercise; blood chemistry; DNA) of personalised nutrition appealing, was significantly different from cluster 2 in that they tended to be older ($F=63.12$, $t=21.37$, $p<0.01$, 95%CI 0.41 – 0.49), had lower levels of education ($F=0.08$, $t=-15.95$, $p<0.01$, 95%CI -0.29 - -0.22), were less likely to see themselves as healthy ($F=174.92$, $t=-24.09$, $p<0.01$, 95%CI -0.42 - -0.35), had lower levels of nutritional self-efficacy ($F=17.19$, $t=-41.87$, $p<0.01$, 95%CI -0.67- -0.61), and had higher risk perception of personalised nutrition ($F=226.20$, $t=5.51$, $p<0.01$, 95%CI 0.07 – 0.14). There were no significant differences in terms of gender.

Table 11. Mean and standard deviations of participants who find personalised nutrition appealing

	Mean	Standard deviation (SD)
Age group	2.33	1.03
Education	2.15	0.77
Trust in:		
Family doctor	3.69	0.82
Registered dietitian	3.40	0.84
Personal trainer	3.81	0.80
Nutritional self-efficacy	3.65	0.70
Perceived risk	2.49	0.95
Perceived health	3.71	0.72
Preference for advice on		
Food and exercise	3.75	0.67
Blood chemistry	3.76	0.71
DNA	3.65	0.85

Multiple linear regression analyses were undertaken on data within cluster 2, who found at least one level of personalised nutrition (food and exercise; blood chemistry; genotype) appealing using trust in each of the selected three healthcare professionals (family doctor, RD, PT) as outcome variables.

Table 12. Regression model for participants who trust RD's to deliver personalised nutrition

	Coefficients				
	B	S.D	Beta	t	p-value
(Constant)	2.616	.119		21.971	.000
Mean nutritional self-efficacy	.046	.016	.039	2.799	.005
Mean perceived risk	-.100	.012	-.117	-8.577	.000
Gender	.101	.022	.062	4.504	.000
Age group	-.024	.011	-.031	-2.256	.024
Education level	.029	.014	.027	2.016	.044
Information regarding the food you eat and the exercise you take	.125	.019	.103	6.564	.000
Your blood chemistry in addition to information regarding the food you eat and the exercise you take:	.073	.021	.063	3.575	.000
An analysis of your DNA in addition to information regarding the food you eat and the exercise you take:	.030	.016	.031	1.955	.051
How healthy do you consider yourself?	.039	.016	.034	2.462	.014

Dependent variable: RD

*Statistical significance at $p < 0.01$

Factors associated with trust in RD's were greater appeal of personalised nutrition based on food and exercise (lifestyle) as the strongest predictor ($B=0.13$, $t=6.54$, $p < 0.01$) and based on blood (phenotype) ($B=0.07$, $t=3.58$, $p < 0.01$). Trust in RD's was associated with being female ($B=0.10$, $t=4.50$, $p < 0.01$), higher level of education ($B=0.03$, $t=2.02$, $p < 0.04$) and younger age ($B=-0.02$, $t=-2.26$, $p=0.02$). Trust in RD's was also associated with lower perceived risk personalised nutrition ($B=-0.10$, $t=-8.58$, $p < 0.01$), higher nutritional self-efficacy ($B=0.05$, $t=2.80$, $p < 0.01$) and higher perceived health

($B=0.04$, $t=2.46$, $p<0.01$). This model contributed to 23% to the difference in variation between the variables and was significant ($F(190, 3309)=33.54$, $B=2.62$, $t=21.97$, $p<0.01$).

Table 13. Regression model for participants who trust family dr to deliver personalised nutrition.

Coefficients					
				t	p-value
	B	S.D	Beta		
(Constant)	3.039	.118		25.784	.000
Mean nutritional self-efficacy	.037	.016	.033	2.304	.021
Mean perceived risk	.003	.012	.004	.301	.764
Gender	-.044	.022	-.028	-2.009	.045
Age group	.053	.011	.068	4.938	.000
Education level	-.050	.014	-.049	-3.518	.000
Information regarding the food you eat and the exercise you take	.096	.019	.081	5.103	.000
Your blood chemistry in addition to information regarding the food you eat and the exercise you take	.049	.020	.044	2.427	.015
An analysis of your DNA in addition to information regarding the food you eat and the exercise you take	-.012	.015	-.013	-.774	.439
How healthy do you consider yourself?	.048	.016	.043	3.042	.002

Dependent variable: Your family doctor. *Statistical significance at $p<0.01$

Factors associated with trust in the family doctor to deliver personalised nutrition were higher ratings on the appeal of personalised nutrition advice based on food intake and exercise ($B=0.10$, $t=5.10$, $p<0.01$) as the strongest predictor and lower ratings on the appeal of personalised nutrition based on blood chemistry ($B=0.05$, $t=2.43$, $p=0.02$) as the weakest predictor. Higher trust

in the family doctor was associated with lower education level ($B=-0.05$, $t=-3.52$, $p<0.01$), male gender ($B=-0.04$, $t=-2.01$, $p=0.05$), and being older ($B=0.05$, $t=4.94$, $p<0.01$). Trust in the family doctor was also associated with higher self-rated health ($B=0.05$, $t=3.04$, $p<0.01$), significantly higher nutritional self-efficacy ($B=0.04$, $t=2.30$, $p=0.02$), lower perceived risk of personalised nutrition ($B=0.01$, $t=-0.30$, $p=0.76$) and lower appeal of personalised nutrition based on DNA ($B=-0.01$, $t=-0.77$, $p=0.44$), which were both non-significant. This model explained 15% of the variation between variables and was found to be significant ($F(77, 3242)=13.96$, $B=3.04$, $t=25.78$, $p<0.01$)

Table 14 Regression model for participants who trust personal trainers to deliver personalised nutrition.

Coefficients					
	B	S.D	Beta	t	p-value
(Constant)	2.330	.123		19.017	.000
Mean nutritional self-efficacy	.092	.017	.077	5.520	.000
Mean perceived risk	-.015	.012	-.017	-1.236	.217
Gender	.089	.023	.053	3.893	.000
Age group	-.091	.011	-.112	-8.244	.000
Education level	-.070	.015	-.064	-4.701	.000
Information regarding the food you eat and the exercise you take	.133	.020	.107	6.825	.000
Your blood chemistry in addition to information regarding the food you eat and the exercise you take	.054	.021	.045	2.541	.011
An analysis of your DNA in addition to information regarding the food you eat and the exercise you take	.036	.016	.037	2.274	.023
How healthy do you consider yourself?	.045	.016	.038	2.754	.006
Dependent variable: Personal trainers					

*Statistical significance set at $p < 0.01$

Trust in personal trainers was associated with (in order of strength of association) greater appeal of personalised nutrition based on food and exercise (lifestyle) ($B=0.13$, $t=6.83$, $p < 0.01$), on blood (phenotype) ($B=0.05$, $t=2.54$, $p=0.01$) and on DNA (genotype) ($B=0.04$, $t=2.27$, $p=0.02$). Trust in personal trainers was associated with younger age ($B=-0.09$, $t=-8.24$, $p < 0.01$), being female ($B=0.09$, $t=3.89$, $p < 0.01$), having a lower education level ($B=-0.07$, $t=-4.70$, $p < 0.01$). Trust in personal trainers was also associated with higher

nutritional self-efficacy ($B=0.09$, $t=5.52$, $p<0.01$), higher perceived health ($B=0.05$, $t=2.75$, $p<0.01$), and lower perceived risk of personalised nutrition ($B=-0.02$, $t=-1.24$, $p=1.24$). This model explained 23% of the variance between the variables and was significant ($F(201, 3504)=33.54$, $B=2.33$, $t=19.02$, $p<0.01$ (Table 14).

6.5 Discussion

The purpose of this study was to determine the profile of people who would trust a family doctor, RD or PT to deliver personalised nutrition services and to determine the type and what level of service most appeal. The goal was not to compare trust amongst professions. The results demonstrated that amongst those to whom personalised nutrition services appealed, profiles differed substantially between those who trusted family doctor, versus RD or PT with respect to age, gender, level of education, perceived health status, nutritional self-efficacy and perceived risk of personalised nutrition. The strongest models were that which profiled those who trusted a RD and PT. Those who trusted RD's tended to be female, younger, educated to a higher level with higher levels of self-efficacy and perceived health. In addition, this group had lower perceived risk of personalised nutrition and a preference for personalised nutrition advice based on food/exercise and blood (phenotype). This implies that RD's are an ideal group to offer personalised nutrition services and that this group would be more open to disease prevention and/or self-care services in view of their high levels of self-efficacy and perceived health status. As reported previously, uptake of technologies remains low amongst the dietetic profession and dietetic care for prevention is still limited (Abrahams *et al.*, 2017). Access to RD's is variable depending on the country (ICDA, 2016).

People who trusted personal trainers were younger, female with lower levels of education. This group had lower self-perception of health, yet high levels of nutritional self-efficacy as well as low risk perception of personalised nutrition. This group preferred personalised nutrition advice based on food/exercise (lifestyle) the most, followed by blood (phenotype) and lastly DNA (genotype). This implies that personal trainers will be expected to provide nutrition and exercise advice for which PT's are ideally placed, especially in view of weight management and disease prevention (Barnes *et al.*, 2016). However concerns have been raised on the level of nutritional education PT's receive on a country-level (Barnes *et al.*, 2017). Research indicates that PT's do not receive adequate training on nutritional care to the same standard across different countries which could pose a risk, particularly in view of young consumer groups who may be vulnerable or subjected to inaccurate or misguided advice such as those identified in this analysis (Barnes *et al.*, 2017).

People who preferred the family dr tended to be male, older, with lower levels of education. This fits with a recent survey conducted in the UK, which demonstrated that even when accounting for reproductive consultations, men visited their family doctor less frequently and were from more deprived areas (Wang *et al.*, 2013). Personalised nutrition based on food intake, exercise and blood appealed the most in this group. Those who trusted doctors had lower levels of nutritional self-efficacy and lower perceived health status. This implies that strategies to increase uptake of personalised nutrition should involve the younger generation of males, as well as ensuring that this group receives ample time and resources to discuss their concerns and goals with their family doctor in order to impact health outcomes. Previous studies (Womersley and

Ripullone, 2017; Cardinal *et al.*, 2015) have suggested that junior doctors felt inadequately trained to provide advice on nutrition and lifestyle. According to another survey less than 27% of US medical schools provided the agreed minimum of 25 hours (Adams *et al.*, 2010) and the same was assumed for medical schools in the UK (Womersley and Ripullone, 2017). A need for increased resources, guidelines and focus on training in nutrition and lifestyle medicine for doctors therefore warranted (Cardinal *et al.*, 2015).

This analysis has implications for practice. Differences in trust in providers of personalised nutrition services need to be kept in mind when designing new products and services (Poinhos *et al.*, 2014). The results also suggest potential in offering personalised nutrition services based on food and exercise (lifestyle) information alone, especially to those with lower education levels or with low nutritional self-efficacy. Results from the intervention study of the Food4me trial suggests that personalised nutrition advice does impact dietary habits (Livingstone *et al.*, 2016). As indicated by our previous work (Abrahams *et al.*, 2018), this is currently the area of focus for early adopter registered dietitians, who are highly experienced and trained professionals, but who are also still a minority (Abrahams *et al.*, 2017).

These findings have practical implications for policy in suggesting that minimal training on nutrition is needed in medical schools as well as for PT's as they are in addition to RD's, perceived to be providers of personalised nutrition advice. Meanwhile, professionals who deal with clients with co-morbidities or chronic diseases should not provide medical nutrition advice that could potentially put consumers at risk in view of the current lack of nutritional training (Barnes *et al.*, 2017; Cardinal *et al.*, 2015). This analysis has provided novel insights in terms

of the profile of individual who find personalised nutrition appealing and their associated trust in different healthcare providers based on the level of personalised nutrition, their perceived health, perceived risk and nutritional self-efficacy. The study suggests that as a self-care approach is increasingly adopted across healthcare systems, individuals will seek out providers they can trust and build relationships with in order to manage their goals.

Among the study limitations is that the sample comprised 5660 respondents who, although representative of the respective countries in terms of gender, age and education, were biased in that they all had internet access. Minority ethnic groups were underrepresented in the Food4me survey, therefore, trust in professionals may not be representative of other ethnic or cultural groups. The limitations inherent in self-reported measures is also well documented as a limitation (Chan, 2009). In addition, data were collected in 2013, therefore none were likely to have had any experience of personalised nutrition.

Another limitation is that healthcare professionals such as “nutritionists”, “nutritional therapists” or “health coaches” who are not regulated professions, but suppliers of nutrition and lifestyle information, were not included on the list of trusted providers, meaning that potentially consumers may have responded differently. As the survey was designed by previous researchers, it was not possible to understand and elucidate the definition of what being a personal trainer entailed. In addition, the construct of “nutritional self-efficacy” was not clearly defined. The constructs of “trust” and “preference” in healthcare providers are complex constructs that are ill-defined (Pearson and Raeke, 2000). Therefore, it was not possible to investigate the previous researchers’

definition of what these constructs meant. Owing to constraints upon the number of variables that could be included in the analysis, it was not possible to compare differences across countries. It is possible that cultural, regional and potentially traditional differences may have impacted upon responses based on previous research by Poinhos *et al* (2017).

6.6 Conclusion

Consumers who trust in providers of personalised nutrition services differ significantly with regards to their profile. These data demonstrate that provision of personalised nutrition services need to cater to different gender, age and education groups who differ in terms of their perceived health, perceived risk of personalised nutrition services and self-reported nutritional self-efficacy.

Policies are required to ensure that all providers have a minimum level of training to ensure that access to personalised nutrition services is equitable.

Chapter 7

General discussion

7.1 Thesis overview

The aim of this chapter is to bring the results of the research programme together through discussion and compare the findings against previous research. A mixed methods approach was adopted to explore in- depth, factors determining the uptake of personalised nutrition technology by registered dietitians. The sequential exploratory design meant that the qualitative study informed the subsequent quantitative study and for this research programme also provided an international perspective by including registered dietitians from different countries (Creswell, 2013). A mixed method approach was chosen as the most suited, because it was necessary to explore, understand and identify qualitatively and quantitatively potential topics and themes that could influence adoption of personalised nutrition technologies by early-adopters and non-adopters on the frontlines (Creswell and Plano Clarke, 2011).

Each study informed and laid the foundation for the next. The literature review identified topics relating to nutrigenetic testing, this highlighted that previous research had only included non-adopting dietitians according to my definition (Chapter 3). This gap in research provided the basis to select early adopting dietitians to explore the topic of nutrigenetic and other personalised nutrition technology integration including potential barriers and levers, through *their* lens, thereby adopting a bottom-up approach (Chapter 4). The themes and issues that were identified in this study, then provided the basis to develop the items for the survey.

Where validated scales existed (such as self-efficacy Bandura, 1963), for example, these were included, and new scales created (Chapter 5) although not all themes were included. Finally, secondary analysis of an existing Food4me database informed recommendations for policy-makers and regulators for social action which could benefit consumers in relation to personalised nutrition services (Fischer *et al*, 2016; Chapter 6).

The advantages of using a mixed-method approach was that the qualitative results provided the means to research the topic in-detail from registered dietitians on the frontline, whilst subsequently comparing attitudes and opinions to non-adopters quantitatively (Creswell, 2013). In contrast to previous research, this approach provided more context and depth into issues that were raised before (Li *et al.*, 2014; Collins *et al.*, 2013). The disadvantages included that it was not easy to translate the qualitative study findings into survey items and owing to advances in personalised nutrition science (Mathers, 2017), it became clear that the original research proposal became outdated very quickly.

The aim of this research was therefore to guide practice and policy regarding the future personalised nutrition amongst registered dietitians for dietetic organizations, policy makers, educators and regulators.

The objectives were to identify barriers hindering the uptake of personalised nutrition technology and propose potential solutions. A second objective was to identify what needs to be in place in order to make personalised nutrition a reality.

The two research questions therefore were; 1. What are the potential barriers hindering uptake? And 2. What policies and practices need to be in place for personalised nutrition and associated technologies to become a reality?

7.2 Theoretical contribution

The focus of this thesis was on theory application with Diffusion of innovation (Rogers, 1962). Diffusion theory partly explained the phenomenon of integration of new personalised nutrition technologies into practice. It fits with respect to the traits, perceptions and behaviours of early adopters of new technologies and explains the reluctance of the early majority to integrate at a later stage. Diffusion theory also helps to provide a practical approach to address challenges in communication with each respective segment. However, diffusion theory is limited in explaining how being an RD in the midst of wider technological, scientific, environmental, organizational culture, societal and health policy shifts further influence adoption of technologies that may influence work. It was therefore crucial to import entrepreneurial theory to provide another dimension to explain why some RD's integrate and others do not.

Entrepreneurial theory helped to explain how early adopters differ from non-adopters by understanding the importance of human capital, by realising how early adopters adjust their workflows in order to offer an even more personalised service to have a long term societal impact and to psychologically have control over one's own career and future.

The theoretical contribution of this thesis therefore lies in the combination of the two theories to examine the factors that encourage or inhibit the uptake of new personalised nutrition technologies amongst RD's and provide insight into the professions readiness to enter healthcare in the digital and precision era. In

addition, applying diffusion and entrepreneurial theory helped to explain why policy changes are necessary to ensure that personalised nutrition services are equitable and accessible.

The thesis aimed to contribute to the current literature around the convergence of key issues such as personalised health, digital health, prevention and cultural mind shifts around healthcare which add new dimensions that extend beyond Diffusion theory.

7.3 What are the barriers preventing uptake of personalised nutrition by RD's?

This research programme sought to obtain views and opinions from both adopters and non-adopters of personalised nutrition technologies. Previous research on members of the nutrition and dietetics profession have implied that a lack of knowledge and confidence in nutrigenetics, the ethical concerns, longer years in practice as well as a lack of scientific evidence are deterrents to adoption of the technology (Cormier *et al.*, 2014; Li *et al.*, 2014; Collins *et al.*, 2013; Oosthuizen, 2011; Whelan *et al.*, 2008). More recently Bouchard-Mercier *et al* (2016) indicated that it was attitude of individual practitioners toward discussing genetic testing as well as client interest that mainly determine adoption. However, none of the aforementioned barriers have been validated in comparative studies between early adopters and non-adopters.

These findings refute the previous research, I did not find that years of practice, ethical concerns or lack of scientific evidence to be determining factors in the integration of nutrigenetic testing technologies. The literature review, qualitative enquiry results and survey findings, taken together, suggest that uptake of

personalised nutrition technologies by the dietetic profession, will require interventions that address both intrinsic and extrinsic factors.

Intrinsic factors are inherent to the individual which include; low self-efficacy, attitudes towards perception of risk genetic technologies pose, a need for professional support and an entrepreneurial mindset. Extrinsic factors that are outside of the control of the individual practitioner will also need to be addressed and the findings together indicate that uptake of new technologies is dependent on a conducive environment which involves; the academic, regulatory and work environment as well as the professional/organizational culture. Integration of new innovations is favourable when there is a strong demand for change, meaning that change is urgent but favourable (Greenhalgh *et al.*, 2017). The current professional environment is not actively encouraging the integration of genetic testing into professional practice (Camp and Trujillo, 2014), the regulatory environment is warning consumers against the accuracy of genetic testing (Evans, 2015) and the educational environment lacks genetics, genomics and other integrative practice in the dietetic curriculum (Augustine *et al.*, 2018; Beretich *et al.*, 2017; Wagner *et al.*, 2015). These findings taken together have answered the research question and imply that the profession is not ready to integrate personalised nutrition technologies into practice. RD's do not trust the technology as they find it too risky owing to the lack of scientific evidence, they lack the necessary digital and technical skills, and the current practice and working environment in terms of regulation, policy and professional culture are not currently conducive to the uptake of personalised nutrition technologies (Chapter 3 – 4).

7.4 What are the enablers encouraging uptake of personalised nutrition by RD's?

Previous researchers indicated that involvement in nutritional genomics which included discussing genetics with clients or teaching it, was determined by higher levels of education and being in academia (Collins *et al.*, 2013; Oosthuizen, 2011). Findings from this research, however, suggest that drivers that contribute to personalised nutrition technology integration include high level of self-efficacy, low risk perception as well as having an entrepreneurial self-perception. Early adopting registered dietitians enjoy agency, report being proactive in seeking evidence-based information on novel (including nutrigenetics) technologies and acquiring skills related to tech-enabled personalised nutrition (Abrahams *et al.*, 2018; Chapter). They are highly engaged and the adoption of new innovations fit in with their personal values (Chapter 4). They have a strong belief in the quality of the technology, and this is reinforced through strong personal and scientific networks who are working at the forefront of personalised medicine. A further demand from clients for personalised nutrition services with positive results and feedback further reinforces this belief that the integration of new technologies can bring to individualised care. One potential assumption is that because early adopters were in private practice, they had more time to move through the knowledge-attitude-practice gap, meaning that they integrated the technology at their own pace, created their own workflows and adapted their way of practising to fit in with what they were already doing(Chapter 4). With integration also came a sense of prestige or social status that they perceived themselves, and in the eyes of their clients to be at the forefront of dietetic practice (Chapter 4).

7.5 What distinguishes early adopters from non-adopters?

Findings show that early adopters demonstrated differences in terms of personality, attitudes and perspectives towards technology as well as possessing entrepreneurial traits (Chapter 3 – 5). Considering diffusion theory, this is not very surprising, however, it does mean that the profession needs to have a better distribution of practitioners at different stages of technology adoption in order for any progress to be made (Chapter 3 - 5), as current research indicates that the majority are non-adopters . Most encouraging was that in this study, the early adopting registered dietitians reported positive experiences with clients who were seen to respond well to tailored advice and able to make healthy dietary behaviour changes (Chapter 4). This was perceived by those dietitians as meaning that they had instilled in their clients, greater confidence in the technology (Chapter 4). As previous research would suggest (Ronteltap *et al.*, 2007), this encouraged them further to use personalised nutrition technologies in their practice, further building on their knowledge and expertise (Chapter 4).

Together this implies that exposure to new technologies and learning through practice and from peers (Bandura, 1969) would enable the profession to engage and become familiar with new personalised nutrition technologies and in turn boost practitioner's confidence in nutrition technologies so that they begin to see them as less risky (Brown *et al.*, 2019; Hickson *et al.*, 2018; Banet and Nunez, 1997).

7.6 How can the needs of RD's with regards to personalised nutrition be addressed?

Previous research has indicated that knowledge is a key factor in involvement in genetics and genomics (Collins *et al.*, 2013; Oosthuizen, 2011; McCarthy *et al.*, 2008; Whelan *et al.*, 2008) and that education should focus on increasing exposure in the curriculum (Collins and Adamski, 2018; Beretich *et al.*, 2016; Wright, 2014). I did not cover knowledge as a variable on purpose, as this had been extensively covered in previous research.

This research, in contrast, suggests that it is crucial to look beyond just acquiring additional technical subject knowledge and that education needs span beyond scientific to entrepreneurial, technological and digital literacy. Findings indicate that education needs of future RD's should address developing an entrepreneurial mindset, encouraging application and developing digital appraisal skills (Chapter 3 – 5) in order to increase knowledge and address attitudes with regards to risk perception and perceived importance to clinical practice.

This would provide an opportunity to share real-life experience and practice, learnings and communicate benefits and disadvantages as well as present potential areas for future research. Entrepreneurship training, has the potential to raise confidence, levels of self-awareness, as well as expose nutrition students to new ways of working alongside technology to reduce perceived risk in personalised nutrition technologies and open new career avenues (Chapter 3 - 5).

7.7 What regulatory policies are needed to encourage uptake?

Previous studies have highlighted RD concerns regarding the ethics, accuracy, and clinical validation of genetic testing (Cormier *et al.*, 2014; Li *et al.*,

2014; Weir *et al.*, 2010) This research did not find ethical concerns to be a major factor in the integration of nutrigenetic testing as it pertains to either their patients or themselves as practitioners. I did not find a significant difference between early and non-adopters, however, non-adopters' biggest concern was the perceived risk genetic testing poses (Chapter 3 and 4). This was both directed at the technology but also the companies and other providers supplying these.

This implies that regulatory policies are needed, to make sure that devices (and associated companies) as well as other new innovations that provide nutrition and/or lifestyle recommendations meet specific quality criteria to instil confidence in their use, confirm clinical validity, scientific accuracy and provide resources to demonstrate that they are evidence-based (Chapter 3 and 4). Together, the results imply that there is a need to open up discussion and to address the concerns of both early adopter and non-adopter RD's about personalised nutrition related technologies, and in doing so to resolve their risk perceptions, barriers and challenges experienced. Training in digital and technological and entrepreneurial literacy could aid in enhancing levels of self-efficacy with regard to the use of new technologies in dietetic practice (Chapter 3-5). Furthermore, regulatory policies need to be in place to ensure equitable access to technological innovations (Chapter 3 and 6) and that professionals providing personalised nutrition services should be trained to a minimal standard in order to build trust and credibility but also to encourage collaborative working to improve societal health (Chapter 6).

7.8 Study limitations

The limitation of a mixed method approach is that it was challenging to turn the findings from the qualitative study into variables for the quantitative arm. This meant that the study took longer to conduct. The qualitative study had technical as well as time zone difficulties which meant that some interviews were conducted individually, whereas others were conducted as focus groups which lend themselves to groupthink, this inconsistency was a limitation. Whether face-to face or alternatively telephone interviews would have been better to elicit information, remains a question. The number of countries selected to participate in the study could have been more extensive to make it more representative of RD's around the world. Since the start of this research, uptake of new personalised nutrition technologies has been growing rapidly. In addition, the category of personalised nutrition innovations was limited to omics, but this could have been wider depending on the definition of players in the market. The survey was available online only, which would have excluded participants who either did not have access to a smartphone, the internet or a computer. This limitation made this research more biased towards RD's who were already comfortable using technology or who were familiar with participating in online research. Future research may include the option to download hardcopies of the survey forms and return by post. The use of single-items in the survey is a further limitation as it does not comprehensively determine a construct. The personality trait of "openness" had a negative Cronbach alpha indicating that as a variable, this result was not reliable. The variable was left in the regression model. The issue of collinearity with the independent variables of "age" and "number of years working" further should be

considered when interpreting the findings as these will have impacted on the regression models.

Another limitation was the study population could have been even more diverse and included countries such as India, Singapore, Nigeria where nutrigenetic testing services are offered to make the study more reflective of the current consumer user base (Chapters 2 - 6). As I did not ask for ethnic background as part of the surveys or qualitative study, a limitation could be that we only obtained perspectives from a largely white dietetic group who have access to the internet, and consumers from developed countries who have easy access to the latest technologies. I would therefore suggest that future studies need to include not only RD's and consumers from different countries but also ethnicities to ensure that personalised technologies and their integration are representative of the populations they serve.

Another limitation is that in general most RD's employed in the public sector which could include schools, hospital, community clinics, catering or nursing homes, may have never been exposed to nutrigenetics or other personalised nutrition technologies, making this researched biased towards those who work in the private or industry setting.

Furthermore it was not possible to clarify items and constructs that were originally developed and included in the Food4me survey, such as the definition of a "personal trainer", the criteria for the term "dietitian-nutritionist", the self-reported item: "Do you consider yourself as healthy?" as well as the construct of "trust". This limitation may impact the findings of the study. The fact the science on tech-enabled personalised nutrition is emerging, a limitation is that at the

time of this research (and currently) integration of technologies is not encouraged by professional organisations and therefore it may be perceived that the research is critical or practising RD's.

7.9 Implications for education

The research programme as a whole, indicates that in order to increase access and integration of personalised nutrition services and technologies in the future, the profession will need to be upskilled. This is because the data indicates that knowledge alone is not enough to action integration (Chapter 4). This will require numerous interventions including; the development of translational practice guidelines (Murgia and Adamski, 2017), highlighting and communicating the benefits/usefulness of tech- enabled personalised nutrition solutions, especially when it comes to biotechnology (Brown *et al.*, 2019), stressing the importance of technology to dietetic practice (Chapter 4) in a digital health future that is already here, as well as highlighting the need for getting RD's involved in new research that include advances in personalised nutrition technologies (Hickson *et al.*, 2018; Chapter 3 – 5).

7.9.1 Implications for managers and leaders

In addition, leaders, educators and those longer in practice need to make sure that they are keeping abreast of new developments and address the organisational culture which poses an important barrier to technology innovations in order to ensure that their decisions are not passed down. The findings also imply that owing to differences between early adopters and non-adopters, the profession will need to consider the adoption of personalised career pathway framework depending on interest and attitude of individual dietitians as suggested by Hickson *et al* (2018). Previous research highlighted

the need for increased collaboration with the integrative medicine departments (Augustine *et al.*, 2018; Wagner *et al.*, 2015) This research however, indicates that for those with an interest in technology, cross-departmental working with computer science department, bioinformatics, technology and business schools will need to be considered.

Early adopters reported that opportunities for training were availed through participation in training courses and attendance at conferences where dietitians could engage with the wider scientific community, ideas exchanged, and skills imparted (Chapter 4). According to the early-adopting registered dietitians, along with the acquisition of new skills, came a certain degree of confidence and belief on utility in the technologies which support the personalised nutrition approach (Chapter 3 and 4).

The perceived importance of professional development, acquisition of new skills, preparing for the future and pro-active development of supportive networks are characteristic of an entrepreneurial mindset, these therefore, are likely to be a key factors determining whether a dietitian will integrate personalised nutrition technologies or not (Chapter 3 - 5). It is also likely that those practitioners who have fewer years in practice are naturally more comfortable with innovations, as technology has been part of their life at an early stage. This implies that personalised nutrition related technology should be embedded in the curriculum, during clinical placements and continuous learning opportunities in a variety of online and offline formats as well as formal and informal structures should be made available (Brown *et al.*, 2019; Collins *et al.*, 2018; Mlodzik-Czyzewska and Chmurzynska, 2018; Wright, 2014). RD's should be taught how to validate the quality and accuracy of new personalised

nutrition and digital innovations in order to build confidence and trust (Digital health academy). Equally RD's should be encouraged and educated on how new technological solutions are developed to increase their involvement and interest. Nutrition education of course also spans beyond just nutritionists and dietitians, and education policies that enforce a minimum level of hours as part of the training for family doctors and personal trainers should be a priority especially across Europe.

7.10 Implications for practice

Successful integration of new tech-enabled personalised nutrition solutions will require a change in practice with a focus of prevention. This means that RD's will need to evaluate the value they bring in view of advances in technologies, by working alongside technology which is client-focused and this may require new ways of working.

Delivery of personalised nutrition services may require varied and flexible models (Fallaise *et al.*, 2015) which means a combination of co-pay or fully subsidised services for at-risk communities, but should include full reimbursement for registered dietitians who are offering the service (Chapter 4). Those that employ a team approach can offer a skills 'bank' from which advice can be sourced and support systems adapted to meet personalised client needs and preferences (Chapter 4 and 6).

The profession will also need to move beyond the commercial model and consider ways of integrating personalised nutrition into public health nutrition (Chatelan *et al.*, 2018; O' Sullivan *et al.*, 2018; Chapter 4 - 6). Meanwhile,

guidance from professional organisations representing nutrition and dietetics professionals will be needed to encourage the profession in the direction of public health directed personalised nutrition and personalised medicine and prevention (Rozga and Handu, 2018; Khoury *et al.*, 2016; Chapter 3 - 6). Placements could also be extended to include companies that create new personalised nutrition technology solutions, to expose students to more potential career opportunities (Chapter 3 and 5). The findings also suggest that consumer differ in their profile in terms of who they trust to provide personalised nutrition (Chapter 6). This means that provision of personalised nutrition service should be tailored to the individual according to their profile and by their provider of choice (Chapter 6), however this should be equitable, and provision should be made to ensure that trusted resources are easily available such as the NHS app library.

7.11 Implications for policy

Ethical, legal, social issues that may hinder access should be addressed by the profession in a multi-stakeholder format. In order to instil trust in personalised technologies, policy changes will need to ensure that the new General data protection regulation (GDPR) is enforced, that new products undergo a validation process, that quality standards are established, and that transparency of data use are communicated widely and become standard operating procedures. RD's will need to be vocal in order to have their voice heard and to have an input into policy papers and position statements in order to represent their view and that of their clients both nationally and internationally. Furthermore, policy changes will be needed to ensure full reimbursement for preventative services provided by experts as well as cost to

end-users which may or may not include technology should be considered, as well as transparent and full credentialing of professionals providing personalised nutrition services (Chapter 3 – 6).

This means that funding potentially needs to be re-allocated from conducting large public health campaigns, to strategies that focus on individualised care, in order to increase motivation and adoption (Stewart-Knox *et al.*, 2016). Policies will need to ensure that registered dietitians services are covered by insurers and health organizations to incentivise healthy lifestyle and behaviours in the long term (i.e. value based) and these should be supported through research. Finally, any policy changes will require the involvement of multiple stakeholders such as supermarkets, pharmacies, farmers and on-line stores (Mathers, 2017) considering their important role in communities.

7.12 Implications for organisations

The mixed method design which provided in-depth insight into important barriers for adoption indicated that best practice will entail treating clients as partners in the design and delivery of personalised dietary services (Chapter 6). This implies that the involvement of health professionals will be crucial to public uptake of personalised nutrition services and technologies in the future (Chapter 5 and 6). Nutrition and dietetic organisations therefore play a crucial role as leaders, stakeholders and change agents.

Meanwhile, there are lessons to be learned from early adopting dietitians in terms of sharing perspectives, best practice, case studies, those who have abandoned providing services and challenges that could be communicated (Chapter 3-4). However, in order for this to happen, the organizations have a

responsibility to the wider dietetic community to be given the opportunity to share their concerns, opinions and perspectives openly so that these can be addressed strategically.

Organisations will need to reflect and approach strategies that can address the concerns, perceived risk and low importance and lack of urgency associated with advances in technologies and their impact on dietetic practice.

Organisations can first lead by example and ensure that technology is embedded at the core of the organisation to set the bar and offer recommendations of resources and guidance on which technologies to integrate into practice. Competencies for practice such as previously developed for genetics and genomics (NHS, 2014) will need to be updated to reflect recent advances, and the International Nutrition Care Process (INCP) which is the accepted standardised language to be used in electronic health records, should reflect advances in technology and practice.

Organisations will need to address the culture and consult the dietetic community on the best ways to increase engagement with technology but also to increase and incentivise digital and entrepreneurial literacy. Leaders and organisations need to explore ways to create enabling environments and networks that encourage exploration, development and risk-taking with regards to new technologies without the threat of professional remorse (Chapter 3). Organisations need to proactively communicate the potential benefits of integrating technologies into dietetic practice where relevant, and encourage co-creation of new solutions. Organisations need to start opening discussions with industry partners to better understand the skills and knowledge required to educate and train the next generation of practitioners and in turn for

practitioners to increase trust. Organisations also have the responsibility to develop and contribute to guidance and ensure that new technologies are integrated into existing workflows in order to encourage uptake which may include the involvement and creation of new networks. Finally, organisations will have to work with stakeholders, policymakers and regulators to ensure that new business models are created which unlock value provided RD's to create a sustainable self-care system.

7.13 Implications for future research

For this study, we only recruited registered dietitians, however there may be registered nutritionists, or even family doctors or nurses who have integrated nutrigenetic testing into their practice, these groups should be included in future studies (Chapter 3 – 4).

We did not get a clear perspective of what the attitudes and perspectives of leaders within the profession are towards the entire personalised nutrition technology spectrum (Li *et al.*, 2014), this will require further investigation. In the same vein, we have limited insight into how policymakers and regulators view registered dietitians' role in the tech-enabled personalised nutrition arena which will also need review.

Further gaps in knowledge exist in terms of how early adopters translate the science into practice as there are currently no guidelines, which will require further exploration with different methods (Murgia *et al.*, 2019). Finally, there is currently a lack of knowledge in terms of what the implications of a personalised nutrition approach means in terms of cost savings and long-term health outcomes.

Future research could adopt a more action-research or ethnographic approach to get a deeper insight into how early adopters think, process information and make clinical decisions to translate these into best-practice guidelines, algorithms or recommendations on when to abandon a new technology. However, with rapid advances in big data analytics, these can be easily mapped and analysed. Future research will need to include additional stakeholders such as retailers, policymakers, regulators and companies that provide personalised nutrition services which seem to be ever expanding.

Lastly, future research will need to consider how these new technologies as well as new skills impact long-term economic benefits, as well as public health outcomes and whether these outcomes are best achieved through a facility, group or online setting (Poinhos *et al.*, 2017). The research was further strengthened by including non-English speaking countries which had not previously been done before (Collins *et al.*, 2013; Oosthuizen *et al.*, 2011; Whelan *et al.*, 2008).

Owing to rapid advances, we are now at a tipping point where these new technologies are impacting and infiltrating areas beyond computer science departments and the potential realized. This means that there is potential to conduct research into identifying who would be better suited to a career as a nutrition entrepreneur, a researcher, clinical dietitian or behaviour change RD for instance, so that the curriculum and career framework can be personalised per student rather than the one-fits all curriculum that currently exist.

Furthermore, while data gathered from wearable sensors and trackers are already creating new ways of conducting research, it is only a matter of time

until other new technologies such as holograms, voice-activation, digital assistants and robots will be discussed in the realms of patient care too (Garg *et al.*, 2018), and therefore future research could evaluate perspectives and RD knowledge of these innovations too.

7.14 Researcher reflections

From the start of this thesis to the end, this work has evolved and changed in sync with market developments in the personalised nutrition industry. Whilst scepticism and interest in this area is high, it has become clear that genetic testing and technologies in healthcare is here to stay (NHS, 2019). In four short years, with high profile studies being published (Fallaize *et al.*, 2018; Gardner *et al.*, 2018; Li *et al.*, 2018), governments see the potential opportunity of cost saving to a point where genetic testing will be offered free on the NHS (NHS, 2019).

Practicing registered dietitians have been particularly interested in this thesis based on the numbers of enquiries received, which can only indicate potential future research will follow (Twohig *et al.*, 2019).

I considered potential alternative explanations for the findings, one of which may be demand characteristics (Nichols and Maner, 2008). I am considered an early adopter, entrepreneur, innovator and public figure in the personalised nutrition industry. This could have influenced participants to respond in a particular way. For instance, early adopters could compare themselves against me and selected responses that reflected that they too were entrepreneurs and innovators with particular personality traits. However, non-adopters would be less inclined to respond similarly if they used me as a benchmark, even if they

were successful innovators and entrepreneurs in their own right albeit in a different environment for instance.

7.15 Conclusion

This is the first exploratory multi-national, multi-lingual mixed methods study that explored topics and themes relating to the uptake of personalised nutrition technologies amongst the dietetic profession. The research programme managed to answer the research questions in terms of what are the barriers to integration of new personalised nutrition technologies, and what needs to be in place in order to encourage uptake. The profession is ultimately not ready for a digital technology future that is already here. Potential barriers to the adoption and uptake of personalised nutrition technology included; intrinsic factors such as low levels of self-efficacy, high perceived risk, low perceived importance to dietetic practice as well as trust in the healthcare provider. Extrinsic factors such as the lack of regulatory oversight, and practice policies that support integration and shortage of educational focus on new technologies contribute to the lack of uptake and low perceived importance. Cultural factors which relate to a lack of organizational leadership, discouraging risk-taking, lack of a supportive innovation environment and lack of an entrepreneurial focus will need to be considered for the integration of new technologies into practice. Gaps in skills and knowledge amongst RD's found to play a role in the uptake of technologies could be closed through an intensive course that focuses on personalised nutrition technologies and developing an entrepreneurial mindset.

This is the first study that provides a comprehensive insight into the perspectives and attitudes of dietetic professionals with regards to new personalised nutrition technologies which is generalisable to the dietetic

population. Findings of this research programme provide the evidence-base for the profession to open honest discussion on the impact new of technology and innovations will, and already has on dietetic practice, and that technological and entrepreneurial literacy will need to be addressed.

In addition, findings can be used to guide organisational strategy which spans education, practice, placement, research and continuous professional development. Finally, professional bodies, regulators and policy makers can use these findings as a starting point to address educational, regulatory and health policy to prepare the next generation of nutrition professionals, and to ensure that the needs of consumers with respect to equitable access to quality, evidence-based products and services through knowledgeable providers of personalised nutrition are met.

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Appendix A –

ADA checklist

Quality Criteria Checklist: Primary Research

Symbols Used

- + **Positive:** Indicates that the report has clearly addressed issues of inclusion/exclusion, bias, generalizability, and data collection and analysis.

- **Negative:** Indicates that these issues have not been adequately addressed.

- ∅ **Neutral:** Indicates that the report is neither exceptionally strong nor exceptionally weak.

Quality Criteria Checklist: Primary Research

RELEVANCE QUESTIONS					
1.	Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (NA for some Epistudies)	Yes	No	Unclear	N/A
2.	Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about?	Yes	No	Unclear	N/A
3.	Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to dietetics practice?	Yes	No	Unclear	N/A
4.	Is the intervention or procedure feasible? (NA for some epidemiological studies)	Yes	No	Unclear	N/A
<i>If the answers to all of the above relevance questions are "Yes," the report is eligible for designation with a plus (+) on the Evidence Quality Worksheet, depending on answers to the following validity questions.</i>					
VALIDITY QUESTIONS					
1.	Was the <u>research question</u> clearly stated?	Yes	No	Unclear	N/A
	1.1 Was the specific intervention(s) or procedure (independent variable(s)) identified?				
	1.2 Was the outcome(s) (dependent variable(s)) clearly indicated?				
	1.3 Were the target population and setting specified?				
2.	Was the <u>selection</u> of study subjects/patients free from bias?	Yes	No	Unclear	N/A
	2.1 Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?				
	2.2 Were criteria applied equally to all study groups?				
	2.3 Were health, demographics, and other characteristics of subjects described?				
	2.4 Were the subjects/patients a representative sample of the relevant population?				
3.	Were <u>study groups</u> comparable?	Yes	No	Unclear	N/A
	3.1 Was the method of assigning subjects/patients to groups described and unbiased? (Method of randomization identified if RCT)				
	3.2 Were distribution of disease status, prognostic factors, and other factors (e.g., demographics) similar across study groups at baseline?				
	3.3 Were concurrent controls used? (Concurrent preferred over historical controls.)				
	3.4 If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?				
	3.5 If case control study, were potential confounding factors comparable for cases and controls? (If case series or trial with subjects serving as own control, this criterion is not applicable. Criterion may not be applicable in some cross-sectional studies.)				
	3.6 If diagnostic test, was there an independent blind comparison with an appropriate reference standard (e.g., "gold standard")?				

<p>4. Was method of handling <u>withdrawals</u> described?</p> <p>4.1 Were follow up methods described and the same for all groups?</p> <p>4.2 Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)</p> <p>4.3 Were all enrolled subjects/patients (in the original sample) accounted for?</p> <p>4.4 Were reasons for withdrawals similar across groups?</p> <p>4.5 If diagnostic test, was decision to perform reference test not dependent on results of test under study?</p>	<p>Yes No Unclear N/A</p>
<p>5. Was <u>blinding</u> used to prevent introduction of bias?</p> <p>5.1 In intervention study, were subjects, clinicians/practitioners, and investigators blinded to treatment group, as appropriate?</p>	<p>Yes No Unclear N/A</p>

5.2	Were data collectors blinded for outcomes assessment? (If outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)	
5.3	In cohort study or cross-sectional study, were measurements of outcomes and risk factors blinded?	
5.4	In case control study, was case definition explicit and case ascertainment not influenced by exposure status?	
5.5	In diagnostic study, were test results blinded to patient history and other test results?	
6.	Were <u>intervention/therapeutic regimens/exposure factor or procedure</u> and any <u>comparison(s)</u> described in detail? Were <u>intervening factors</u> described?	Yes No Unclear N/A
6.1	In RCT or other intervention trial, were protocols described for all regimens studied?	
6.2	In observational study, were interventions, study settings, and clinicians/provider described?	
6.3	Was the intensity and duration of the intervention or exposure factor sufficient to produce a meaningful effect?	
6.4	Was the amount of exposure and, if relevant, subject/patient compliance measured?	
6.5	Were co-interventions (e.g., ancillary treatments, other therapies) described?	
6.6	Were extra or unplanned treatments described?	
6.7	Was the information for 6.4, 6.5, and 6.6 assessed the same way for all groups?	
6.8	In diagnostic study, were details of test administration and replication sufficient?	
7.	Were <u>outcomes</u> clearly defined and the <u>measurements</u> valid and reliable?	Yes No Unclear N/A
7.1	Were primary and secondary endpoints described and relevant to the question?	
7.2	Were nutrition measures appropriate to question and outcomes of concern?	
7.3	Was the period of follow-up long enough for important outcome(s) to occur?	
7.4	Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?	
7.5	Was the measurement of effect at an appropriate level of precision?	
7.6	Were other factors accounted for (measured) that could affect outcomes?	
7.7	Were the measurements conducted consistently across groups?	
8.	Was the <u>statistical analysis</u> appropriate for the study design and type of outcome indicators?	Yes No Unclear N/A
8.1	Were statistical analyses adequately described the results reported appropriately?	
8.2	Were correct statistical tests used and assumptions of test not violated?	
8.3	Were statistics reported with levels of significance and/or confidence intervals?	
8.4	Was "intent to treat" analysis of outcomes done (and as appropriate, was there an analysis of outcomes for those maximally exposed or a dose-response analysis)?	
8.5	Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?	
8.6	Was clinical significance as well as statistical significance reported?	
8.7	If negative findings, was a power calculation reported to address type 2 error?	
9.	Are <u>conclusions supported by results</u> with biases and limitations taken into consideration?	Yes No Unclear N/A
9.1	Is there a discussion of findings?	
9.2	Are biases and study limitations identified and discussed?	
10.	Is bias due to study's <u>funding or sponsorship</u> unlikely?	Yes No Unclear N/A
10.1	Were sources of funding and investigators' affiliations described?	
10.2	Was there no apparent conflict of interest?	
MINUS/NEGATIVE (-)		
<i>If most (six or more) of the answers to the above validity questions are "No," the report should be designated with a minus (-) symbol on the Evidence Worksheet.</i>		
NEUTRAL (Ø)		
<i>If the answers to validity criteria questions 2, 3, 6, and 7 do not indicate that the study is exceptionally strong, the report should be designated with a neutral (Ø) symbol on the Evidence Worksheet.</i>		
PLUS/POSITIVE (+)		
<i>If most of the answers to the above validity questions are "Yes" (including criteria 2, 3, 6, 7 and at least one additional "Yes"), the report should be designated with a plus symbol (+) on the Evidence Worksheet.</i>		

Symbols Used

- +** **Positive:** Indicates that the report has clearly addressed issues of inclusion/exclusion, bias, generalizability, and data collection and analysis.
- **Negative:** Indicates that these issues have not been adequately addressed.
- ∅** **Neutral:** Indicates that the report is neither exceptionally strong nor exceptionally weak.

Quality Criteria Checklist: Primary Research: Non-human Subjects

RELEVANCE QUESTIONS		Yes	No	Unclear	N/A
1.	Would implementing the studied intervention, procedure or product (if found successful) result in improved outcomes for the patients/clients/target population group? (NA for some Epi studies)				
2.	Did the authors study an outcome (dependent variable) or topic that the patients/clients/target population group would care about?				
3.	Is the focus of the intervention, procedure or product (independent variable) or topic of study a common issue of concern to dietetics practice?				
4.	Is the intervention, procedure or product feasible for application in dietetic practice?				
<i>If the answers to all of the above relevance questions are "Yes," the report is eligible for designation with a plus (+) on the Evidence Quality Worksheet, depending on answers to the following validity questions.</i>					
VALIDITY QUESTIONS		Yes	No	Unclear	N/A
1.	Was the <u>research question</u> clearly stated?				
1.1	Was the specific intervention(s) or procedure (independent variable(s)) or exposure factor, process or product of interest identified?				
1.2	Was the outcome(s) (dependent variable(s)) or status or condition of interest clearly indicated?				
1.3	Were the study context and setting specified?				
2.	Was the <u>selection</u> of study subjects/units to be free from bias?				
2.1	Were eligibility criteria (inclusion/exclusion) specified with sufficient detail and without omitting criteria critical to the study?				
2.2	Were criteria applied equally to all units of observation and all study groups?				
2.3	Was the source and other relevant characteristics of units of observation described?				
2.4	Were the selected units a representative sample of the context and setting for application of study findings?				
3.	Were <u>study groups comparable</u> or was an appropriate reference standard used?				
3.1	Was the method of assigning subjects/units of observation described and unbiased? (Method of randomization identified if RCT)				
3.2	Was the distribution of relevant characteristics similar across subjects/units of observation and study groups at baseline?				
3.3	Were concurrent controls used? (Concurrent comparison data preferred over historical data.)				
3.4	If a cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis?				
3.5	If diagnostic, validity or reliability study, was there a comparison with an appropriate reference standard?				
NOTE: Criterion #3 is NA if only one group was studied, comparison groups were not constructed for analysis, and a comparison to a reference standard not made.					

4. Were methods of handling losses from the original sample (withdrawals) described?	Yes	No	Unclear	N/A
4.1 Were follow-up methods described and the same for all subjects/units of observation and groups?				
4.2 Were the number, characteristics of withdrawn units (i.e., damaged specimen, dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for the sample and each group?				
4.3 Were all enrolled subjects/units (in the original sample) accounted for?				

4.4	Were reasons for withdrawal or loss similar across groups?				
4.5	If diagnostic test, was decision to perform reference test not dependent on results of the diagnostic method under study?				
5.	Was <u>blinding</u> used to prevent introduction of bias?	Yes	No	Unclear	N/A
5.1	Were field and research staff and investigators blinded to treatment group, as appropriate?				
5.2	Were data collectors blinded for outcomes assessment? (If the outcome is measured using an objective test, such as a lab value, this criterion is assumed to be met.)				
5.3	In a cross-sectional study, were measurements of outcomes and risk factors blinded?				
5.4	In case control study, was case definition explicit and case ascertainment not influenced by exposure status?				
5.5	In diagnostic, reliability or validity study, were test results blinded to unit of observation history and other test results??				
6.	Was the <u>intervention/treatment regimen/exposure factor, procedure, process or product of interest and any comparison(s) described in detail? Were <u>intervening factors</u> described?</u>	Yes	No	Unclear	N/A
6.1	Were protocols described for all alternatives studied?				
6.2	Was the context (study setting, intervention or exposure details or process, involved personnel, etc) described?				
6.3	Was the intensity and duration of the treatment or exposure factor sufficient to produce a meaningful effect?				
6.4	Was fidelity to the research plan documented and the actual amount of exposure, if relevant, measured, and are data free from bias?				
6.5	Were co-interventions (e.g., concurrent ancillary treatments or procedures, other therapies) described?				
6.6	Were extra or unplanned interventions or environmental influences during the study period described?				
6.7	Was the information for 6.4, 6.5, and 6.6 assessed the same way for all units of observation and all groups?				
6.8	In diagnostic, validity or reliability study, were details of test administration and replication sufficiently described?				
7.	Were <u>outcomes</u> or condition or status of interest clearly defined and the <u>measurements valid and reliable</u>?	Yes	No	Unclear	N/A
7.1	Were key outcomes (including primary and secondary endpoints, if applicable) described and relevant to the question?				
7.2	Were nutrition-related outcomes measures, if included, appropriate to the study question and outcomes of concern?				
7.3	Was the period of follow-up long enough for important outcome(s) to occur?				
7.4	Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?				
7.5	Was the measurement of outcomes or effect at an appropriate level of precision?				
7.6	Were other factors that could affect outcomes (e.g., confounders) measured or accounted for?				
7.7	Were the measurements conducted consistently across units of observation, groups and time periods?				
8.	Was the <u>statistical analysis</u> appropriate for the study design and type of outcome indicators?	Yes	No	Unclear	N/A
8.1	Were statistical analyses adequately described and the results reported appropriately?				
8.2	Were correct statistical tests used and assumptions of test not violated?				
8.3	Were statistics reported with levels of significance and/or confidence intervals?				
8.4	Was there a clear description of subjects/units observed included in each analysis? If appropriate, was there a dose-response analysis?				
8.5	Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?				
8.6	Was clinical or pragmatic significance as well as statistical significance reported?				
8.7	Was a power calculation reported to address adequate sample size to measure effect and avoid type 2 error? (This is especially important if findings are negative.)				

9. Are <u>conclusions supported by results</u> with biases and limitations taken into consideration? 9.1 Is there an adequate discussion of findings? 9.2 Are biases and study limitations identified and discussed?	Yes No Unclear N/A
10. Is bias due to study's <u>funding or sponsorship</u> unlikely?	Yes No Unclear N/A

<p>10.1 Were sources of funding and investigators' affiliations described?</p> <p>10.2 Was there no apparent conflict of interest?</p>	
<p>MINUS/NEGATIVE (-) <i>If most (six or more) of the answers to the above validity questions are "No," the report should be designated with a minus (-) symbol on the Evidence Worksheet.</i></p>	
<p>NEUTRAL (∅) <i>If the answers to validity criteria questions 2, 3, 6, and 7 are "Yes" but several other criteria indicate study weaknesses, the report should be designated with a neutral (∅) symbol on the Evidence Worksheet.</i></p>	
<p>PLUS/POSITIVE (+) <i>If most (six or more) of the answers to the above validity questions are "Yes" (including criteria 2, 3, 6, 7), the report should be designated with a plus symbol (+) on the Evidence Worksheet.</i></p>	
<p>When a validity criteria question is NA <i>If any of the ten validity questions are NA, the report requires a majority of "Yes" answers (including 2, 3, 6, 7, as applicable) for a plus (+), or a majority of "No" answers for a minus (-) rating.</i></p>	

Symbols Used

- +** **Positive:** Indicates that the report has clearly addressed issues of inclusion/exclusion, bias, generalizability, and data collection and analysis.
- **Negative:** Indicates that these issues have not been adequately addressed.
- ∅** **Neutral:** Indicates that the report is neither exceptionally strong nor exceptionally weak.

Quality Criteria Checklist: Review Articles

RELEVANCE QUESTIONS				
1. Will the answer if true, have a direct bearing on the health of patients?	Yes	No	Unclear	N/A
2. Is the outcome or topic something that patients/clients/population groups would care about?	Yes	No	Unclear	N/A
3. Is the problem addressed in the review one that is relevant to dietetics practice?	Yes	No	Unclear	N/A
4. Will the information, if true, require a change in practice?	Yes	No	Unclear	N/A
<i>If the answers to all of the above relevance questions are "Yes," the report is eligible for designation with a plus (+) on the Evidence Quality Worksheet, depending on answers to the following validity questions.</i>				
VALIDITY QUESTIONS				
1. Was the question for the review clearly focused and appropriate?	Yes	No	Unclear	N/A
2. Was the search strategy used to locate relevant studies comprehensive? Were the databases searched and the search terms used described?	Yes	No	Unclear	N/A
3. Were explicit methods used to select studies to include in the review? Were inclusion/exclusion criteria specified and appropriate? Were selection methods unbiased?	Yes	No	Unclear	N/A
4. Was there an appraisal of the quality and validity of studies included in the review? Were appraisal methods specified, appropriate, and reproducible?	Yes	No	Unclear	N/A
5. Were specific treatments/interventions/exposures described? Were treatments similar enough to be combined?	Yes	No	Unclear	N/A
6. Was the outcome of interest clearly indicated? Were other potential harms and benefits considered?	Yes	No	Unclear	N/A
7. Were processes for data abstraction, synthesis, and analysis described? Were they applied consistently across studies and groups? Was there appropriate use of qualitative and/or quantitative synthesis? Was variation in findings among studies analyzed? Were heterogeneity issues considered? If data from studies were aggregated for meta-analysis, was the procedure described?	Yes	No	Unclear	N/A
8. Are the results clearly presented in narrative and/or quantitative terms? If summary statistics are used, are levels of significance and/or confidence intervals included?	Yes	No	Unclear	N/A
9. Are conclusions supported by results with biases and limitations taken into consideration? Are limitations of the review identified and discussed?	Yes	No	Unclear	N/A
10. Was bias due to the review's funding or sponsorship unlikely?	Yes	No	Unclear	N/A
MINUS/NEGATIVE (-) <i>If most (six or more) of the answers to the above validity questions are "No," the review should be designated with a minus (-) symbol on the Evidence Quality Worksheet.</i>				
NEUTRAL (∅) <i>If the answer to any of the first four validity questions (1-4) is "No," but other criteria indicate strengths, the review should be designated with a neutral (∅) symbol on the Evidence Worksheet.</i>				
PLUS/POSITIVE (+) <i>If most of the answers to the above validity questions are "Yes" (must include criteria 1, 2, 3, and 4), the report should be designated with a plus symbol (+) on the Evidence Worksheet.</i>				

Appendix B –**Information sheet and consent form****PROJECT TITLE: Registered Dietitians in the genomic era; attitudes, perspectives and experiences of early users****Participant information sheet**

You are being invited to take part in a research study. Before you decide whether to participate or not, it is important for you to understand why the research is being done and what it will involve. Please spare a few minutes to read the following information carefully.

What is the purpose of the study?

The purpose of this study is to gain an understanding of attitudes, perspectives and experiences of early nutritional genomics users (or non-users) in clinical practice.

Why have I been invited to participate?

You have been invited to take part in this study because you are a registered dietitian who has incorporated the emerging science of nutritional genomics into your practice. We would like to provide early users such as yourself, the opportunity of a voice to share your perceptions, motivations and experiences (in an anonymous format) with colleagues and peers in order to ensure that registered dietitians become, and remain, the go-to nutrition experts of the field.

Do I have to take part?

Taking part in the study is entirely voluntary. If you do decide to take part you will be given this information sheet to keep and asked to sign a consent form. You are under no obligation to complete the study and you are free to withdraw at any time before the data is analysed without having to give any reason.

What will happen to me if I take part?

You will be asked to join an online focus group with 3-4 other early users. During the focus group, we will discuss issues and developments around the integration of nutritional genomics into practice as well as what the future may hold. The focus group will take around 30-45 minutes and you will be able to take part from the comfort of your home or office at a time that suits you.

What are the possible benefits of taking part?

As an entrepreneurial early adopter, your valuable insights and input will play an integral part in the shaping of dietitians' perception and attitudes towards this exciting field. Your contribution will help to influence and guide policy regarding education and practice and therefore will benefit the profession as a whole.



Will what I say in this study be kept confidential?

In line with the British Psychological Society guidelines for ethics and conduct of research, all information collected in this study will be kept strictly confidential. Only the researcher will have access to the information collected. No names or other personal information will be used in the reporting of the research or disclosed to any third parties. Data including consent forms will be kept securely in a locked cabinet within a locked room that only the researcher will have access to.

What should I do if I want to take part?

If you wish to take part in this study, then please reply to the email address or click on the link below to complete your details and I will get in touch with you directly to send you the consent form. You are welcome to contact me should you have any questions about the study before you agree to participate. At this stage, you are still able to withdraw from the study without giving a reason.

What will happen to the results of the research study?

The results of this study will be used as part of my PhD research. There is a possibility that the results will be published in a scientific journal, but all data will remain anonymous.

Who is organising the research?

I am conducting the research as a PhD student in the Division of Psychology at the University of Bradford, UK.

Who has reviewed the study?

This study has been reviewed by the Humanities, Social and Health Sciences Research Ethics Panel at the University of Bradford.

Contact for Further Information

For further information or any other questions that would inform your decision to participate in this research, please contact myself, Mariëtte Abrahams at; **miabraha@bradford.ac.uk**
If you have any queries or concerns about the way in which the study has been conducted then please contact Prof Barbara Stewart-Knox at; **b.stewart-knox@bradford.ac.uk**

Thank you for taking the time to read this information sheet.

Kind regards

Mariëtte Abrahams MBA RD

miabraha@bradford.ac.uk

PROJECT TITLE: What needs to be in place in order to ensure that RD's are able to provide gene-based personalised nutrition services?

Focus group interview guide

Abbreviations

Nutritional Genomics

(NGx) Registered

Dietitians (RD's)

Focus Group Topic	Type of questions
Practice	Tell me about how you came about integrating NGx into your practice
Experience	Can you tell me more about your experience of using NGx testing in your practice
Attitude	What are your thoughts on the scientific field (of NGx) in general? What is your opinion about the state of the science?
Perception	How do you think the profession views the science and practice overall?
Drivers & Barriers	Tell me about the drivers and barriers you have dealt with when you decided to integrate
Education & Training	Can you tell me about education and continuous development opportunities in NGx field How do you think the education for future nutrition professionals will evolve?
Skills	What skills apart from nutrition and nutrigenetics do you think a RD needs in order to integrate the science into practice?
Practice	What do you think is the best way for interested individuals to access a nutrigenetics service?

Division of Psychology (SIS), University of Bradford.

Consent form

Researcher/s: Professor Barbara Stewart-Knox and Mrs Mariette Abrahams

What needs to be in place in order to ensure that RD's are able to provide gene-based personalised nutrition services?

Thank you for considering taking part in this research study. Please read through the following questions and indicate your response to each of them. This is to ensure that you are fully aware of the purpose of the research and that you are willing to take part.

I have been informed about the purpose of the study and have had the opportunity to ask questions about it if I wished **YES/NO**

I understand that I can withdraw from the study at any stage, without giving a reason **YES/NO**

I understand that if I withdraw from the study that any data already provided will be removed immediately, unless the results of the research have been submitted for publication. **YES/NO**

I understand that I will be required to participate in an online focus group **YES/NO**

I understand that I am free to choose not to answer a question without giving a reason why **YES/NO**

I understand that the online focus groups will be recorded **YES/NO**

I understand that any information I provide will be kept confidential and only the researchers will have access to the information. **YES/NO**

I give my consent to take part in the research.

Participant

Signed

NAME IN BLOCK LETTERS

Date

Researcher/s **Professor Barbara Stewart-Knox and Ms Mariette Abrahams**

Signed

NAME IN BLOCK LETTERS

Date.....

Approved ethics checklistEC2447

Dear Barbara and
Marianne, Ethics
Checklist: EC2447

Title: An in-depth view into the practice and experiences of registered dietitians who have integrated new technology

Your ethics submission and documents have now been reviewed by the Chair of the Research Ethics Panel.

I am pleased to inform you that the Chair has confirmed approval of this study, with no further ethical scrutiny required.

NOTE that this approval is for this study only.

Should there be any changes to this study, you must inform ethics@bradford.ac.uk.

Once your changes have been reviewed and you have approval to proceed, only then can you recommence the study.

Failure to do so will render your original approval invalid and withdrawn.

Please add a sentence onto any material you share with participants confirming that ethics approval has been granted by the Chair of the Humanities, Social and Health Sciences Research Ethics Panel at the University of Bradford on 10/03/17.

Thank you

Best Wishes

Deborah

Deborah Hodgson

Research Support Administrator
RKTS, F.24

Ext: 3196

Appendix C

Attitudes toward novel nutrition-related technologies among Registered Dietitians

Attitudes toward novel nutrition-related technologies among Registered Dietitians

This survey research is being conducted as part of a PhD studentship held by Mariette Abrahams, based within the School of Psychology at the University of Bradford (UK) and supervised by Professor Barbara Stewart-Knox and Dr. Ellie Bryant.

The purpose is to gain a deeper understanding of current perspectives and attitudes of registered dietitians (not students) in different countries towards innovation and new technologies in relation to nutrition.

Participation is entirely voluntary and the online questionnaire will take around 10-12 minutes of your time to complete.

We are currently living in a digital age where rapid technological change impacts our daily and professional lives. Your contribution will help to provide an overview of the profession regarding education and practice in the application of novel technologies used to deliver personalised nutrition and therefore, will benefit the profession as a whole.

This study has been approved by the Health and Social Sciences Research Ethics Committee at the University of Bradford.

Only the researcher will have access to the information collected and no names or other personal information will be used in the reporting of the research or disclosed to any third parties.

If you have any questions or concerns before completing the survey, please contact the main researcher

If you do agree to participate, please do respond to all the questions until the end.

The survey closes 5th September

Contact Details:

Mariëtte Abrahams – Registered Dietitian and PhD candidate

Email : miabraha@bradford.ac.uk

Tel : 00351 964450622

* 1. I hereby confirm that I am a registered Dietitian and give my full consent to participate in the study

Please tick

Please answer all questions

* 2. Your gender

- Female
- Male
- Non- binary

* 3. Age (*Enter your age in yrs*)

* 4. Have you integrated Nutrigenetic testing into your practice?

- Yes
- No
- Yes, at some point (please explain below)

If you chose the last option, please indicate your reason for discontinuing

* 5. Number of years working (*Please enter number of yrs*)

Please answer all the questions

*** 6. Highest level of qualification gained**

Please indicate the highest level of Qualifications gained to date

Please tick

BSc

Honours

Masters

Doctorate

Post-graduate diploma

PhD/M Phil by thesis

Other (please specify)

*** 7. Sector where majority of work is conducted**

Please indicate the sector that contributes to the majority of your workload

Please tick

Public

Private

Non- profit /charity

Not clinical

Other (please specify)

* 8. Country of work

Please indicate the country where you work

Please tick

United Kingdom	<input type="radio"/>
Australia	<input type="radio"/>
New Zealand	<input type="radio"/>
Canada	<input type="radio"/>
United States	<input type="radio"/>
Israel	<input type="radio"/>
Mexico	<input type="radio"/>
Spain	<input type="radio"/>
Portugal	<input type="radio"/>
South-Africa	<input type="radio"/>
Belgium	<input type="radio"/>
Brazil	<input type="radio"/>
Portugal	<input type="radio"/>

Other (please specify)

Please answer all the questions

* 9. Please indicate the answer that most accurately describes you

	Completely disagree	Disagree	Neither disagree/nor agree	Agree	Completely agree
I will be able to achieve most of the goals that I have set for myself	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
When facing difficult tasks, I am certain that I will accomplish them	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In general, I think that I can obtain outcomes that are important to me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I believe I can succeed at most endeavours to which I set my mind	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I will be able to successfully overcome many challenges	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am confident that I can perform effectively on many different tasks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Compared to other people, I can do most tasks very well	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Even when things are tough, I can perform quite well	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gene-and other omics based technologies to personalise nutrition represent a risk to me professionally	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gene-based Personalised nutrition represents a risk to my patients and clients	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gene-based Personalised nutrition is not evidence-based	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Incorporating the latest technologies into my practice helps me to provide the best service to my patients	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Completely disagree	Disagree	Neither disagree/nor agree	Agree	Completely agree
Genetic testing has the potential to personalise nutritional recommendations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have positive views towards new technologies such as machine-learning and artificial intelligence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I consider myself to be an innovator	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I consider myself to be an entrepreneur	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I work in an organisation that encourages creativity and innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 10. Please indicate your main promoters or sources of innovation

	1 (Highly unlikely)	2	3	4	5 (Highly likely)
Colleagues & peers	<input type="radio"/>				
Professional organization	<input type="radio"/>				
Training & Education	<input type="radio"/>				
Work exposure	<input type="radio"/>				
Conferences, events & workshops	<input type="radio"/>				
Clinical guidelines	<input type="radio"/>				

* 11. Please indicate the answer that most applies to you

	Completely disagree	Disagree	Neither disagree/nor agree	Agree	Completely agree
Genetic testing poses an ethical dilemma to me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Genetic testing should not be available direct to consumers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Microbiome testing is useful to personalise diets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Metabolomics is a useful tool to personalise diets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food allergy testing is a useful tool to personalise diets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food sensitivity testing is a useful tool to personalise diets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 12. How well do the following statements describe you?

I see myself as someone who

	Completely disagree	Disagree a little	Neither disagree/nor agree	Agree a little	Completely agree
Is reserved	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is generally trusting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tends to be lazy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is relaxed, handles stress well	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has a few artistic interests	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is outgoing, sociable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tends to find fault with others	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Does a thorough job	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gets nervous easily	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has an active imagination	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

* 13. Please indicate how you rate the importance of each area below to RD's

	Completely unimportant	Slightly unimportant	Neutral	Slightly important	Very important
Research	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creativity, innovation & entrepreneurship	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Genomics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Functional & Integrative nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business & Marketing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food engineering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Bio-informatics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Teaching & training	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Artificial intelligence and machine learning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Chatbots	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Microbiome testing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Metabolomics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Virtual and Augmented reality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Telehealth	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wearable technology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Thank you very much for taking the time to complete the survey!
Mariette

PROJECT TITLE: Attitudes toward novel nutrition-related technologies in Registered Dietitians**Participant information sheet**

You are being invited to take part in a research study. Before you decide whether to participate or not, it is important for you to understand why the research is being done and what it will involve. Please spare a few minutes to read the following information carefully.

What is the purpose of the study?

The purpose of this study is to gain a deeper understanding of current perspectives and attitudes of registered dietitian towards innovation and new technologies.

Why have I been invited to participate?

You have been invited to take part in this study because you are a registered dietitian who is practising in nutrition and whose practice may be affected by future innovations.

Do I have to take part?

Taking part in the study is entirely voluntary. If you do decide to take part you will be given this information sheet to keep and asked to sign a consent form. You are under no obligation to complete the study and you are free to withdraw at any time before data are analysed without having to give any reason.

What will happen to me if I take part?

You will be asked to complete an online survey which will take 10-12 minutes of your time.

What are the possible benefits of taking part?

We are living in a digital age where technology impacts our daily and professional lives. Your contribution will help to influence and guide policy regarding education and practice and therefore will benefit the profession as a whole.

Will what I say in this study be kept confidential?

In line with the British Psychological Society guidelines for ethics and conduct of research, all information collected in this study will be kept strictly confidential. Only the researcher will have access to the information collected. No names or other personal information will be used in the reporting of the research or disclosed to any third parties. Data including consent forms will be kept securely in accordance with the Data Protection Act (1998), in a locked cabinet within a locked room that only the researcher will have access to.

What should I do if I want to take part?



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If you wish to take part in this study, then you have to click on a secure weblink which will take you directly to the survey. You are welcome to contact me should you have any questions about the study before you agree to participate. At this stage, you are still able to withdraw from the study without giving a reason.

What will happen to the results of the research study?

The results of this study will be used as part of my PhD research. There is a possibility that the anonymised results will be published in a scientific journal in which case no information will be supplied in the publication that could possibly identify you or your workplace or company.

Who is organising the research?

The research is being conducted as part of a PhD studentship held by Mariette Abrahams, based within the Division of Psychology at the University of Bradford (UK) and supervised by Professor Barbara Stewart-Knox and Dr Ellie Bryant.

Who has reviewed the study?

This study has been reviewed by the Humanities, Social and Health Sciences Research Ethics Panel at the University of Bradford.

Contact for Further Information

For further information or any other questions that would inform your decision to participate in this research, please contact myself, Mariëtte Abrahams at; **miabraha@bradford.ac.uk**
If you have any queries or concerns about the way in which the study has been conducted then please contact Prof Barbara Stewart-Knox at; **b.stewart-knox@bradford.ac.uk**

Thank you for taking the time to read this information sheet.

Kind regards

Mariëtte Abrahams MBA RD

miabraha@bradford.ac.uk

15/10/2015 Ethics Application E466 Mariette Abrahams

<https://outlook.office.com/owa/#viewmodel=ReadMessageItem&ItemID=AAMkAGE2YmVjODE5LTVmYjQtNDVjNi1iMWUwLTkwNDRjYTE3MTZiMwB...>

1/3

Approved ethics application E466

Dear Barbara and Mariette Ethics Application: E466 Your ethics application, amendments and additional information has now been reviewed by the independent reviewer. I am pleased to inform you that the Chair of the Research Ethics Panel has confirmed approval of this study, with no further ethical scrutiny required. NOTE that the approval is for this study only, should there be any changes, you must stop your research and contact ethics@bradford.ac.uk with your changes.

Once you have approval for any changes, only then should you commence your research. Failure to do so will class your approval as inapplicable and withdrawn. Please add a sentence onto any material you share with participants confirming that ethics approval has been granted by the Chair of the Humanities, Social and Health Sciences Research Ethics Panel at the University of Bradford on 29th September 2015. Best Wishes

Omar Ali

Research Funding Co-ordinator RKTS, F.24 Richmond Building

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Appendix D

Food4me survey

Dear participant,

Thank you for taking the time to fill in this questionnaire with regard to your views on personalised nutrition.

Your participation is totally voluntary. Please remember we are seeking your opinions and there are no right or wrong answers. All your answers will be kept completely anonymous. The questions take about 20 minutes to answer.

This survey is part of the EU funded project “Food4Me” which is examining the issues and challenges associated with personalised nutrition. One of the objectives of the Food4Me project is to understand consumers’ opinions about personalised nutrition.

Before you start answering the questions we would like to draw your attention to the definition of personalised nutrition which is: **“healthy eating advice that is tailored to suit an individual based on their own personal health status, diet, physical activity and/or genetics”**

Thank you for your participation!

Q1. Please indicate the extent to which you agree or disagree with the following statements:

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/nor agree</i>	<i>Agree</i>	<i>Completely agree</i>
I can be as healthy as I want to be	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am in control of my health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can pretty much stay healthy by taking care of myself	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Efforts to improve your health are a waste of time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am bored by all the attention that is paid to health and disease prevention	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
What's the use of concerning yourself about your health you'll only worry yourself to death	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q2. Please indicate the extent to which you agree or disagree with the following statements:

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/nor agree</i>	<i>Agree</i>	<i>Completely agree</i>
Eating healthily is something I do frequently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I eat healthily without having to consciously think about it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel weird if I don't eat healthily	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Eating healthily is something I do without having to think about it doing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q3. Please indicate how certain you are that you could overcome the following barriers:

	<i>Very uncertain</i>	<i>Uncertain</i>	<i>Neither certain/nor uncertain</i>	<i>Certain</i>	<i>Very certain</i>
I can manage to stick to healthy foods: even if I need a long time to develop the necessary routines	0	0	0	0	0
I can manage to stick to healthy foods: even if I have to try several times until it works	0	0	0	0	0
I can manage to stick to healthy foods: even if I have to rethink my entire way of nutrition	0	0	0	0	0
I can manage to stick to healthy foods: even if I do not receive a great deal of support from others when making my first attempts	0	0	0	0	0
I can manage to stick to healthy foods: even if I have to make a detailed plan	0	0	0	0	0

Q4. Please give your position on the following statements.

It is important to me that the food I eat on a typical day:

	<i>Not at all important</i>	<i>A little important</i>	<i>Moderately Important</i>	<i>Very Important</i>	<i>Extremely important</i>
Contains a lot of vitamins and minerals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Keeps me healthy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is nutritious	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is high in protein	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is good for my skin/teeth/hair/nails etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is high in fibre and roughage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Helps me cope with stress	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Helps me to cope with life	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Helps me relax	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Keeps me awake/alert	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cheers me up	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Makes me feel good	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is easy to prepare	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can be cooked very simply	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Takes no time to prepare	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Can be bought in shops close to where I live or work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is easily available in shops and supermarkets	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Smells nice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	<i>Not at all important</i>	<i>A little important</i>	<i>Moderately important</i>	<i>Very Important</i>	<i>Extremely important</i>
Looks nice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has a pleasant texture	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tastes good	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contains no additives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contains natural ingredients	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contains no artificial ingredients	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is not expensive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is cheap	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is good value for money	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is low in calories	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Helps me control my weight	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is low in fat	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is what I normally eat	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is well-known	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is like the food I ate when I was a child	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Comes from countries I approve of politically	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Has the country of origin clearly marked	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Is packaged in an environmentally friendly way	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q5. Please indicate the extent to which you agree or disagree with the following statements:

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/nor agree</i>	<i>Agree</i>	<i>Completely agree</i>
Personalised nutrition represents a risk to me personally	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personalised nutrition represents a risk to my family	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personalised nutrition represents a risk to an average member of the society in which I live	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q6. Please indicate the extent to which you agree or disagree with the following statements:

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/nor agree</i>	<i>Agree</i>	<i>Completely agree</i>
Personalised nutrition will benefit me personally	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personalised nutrition will benefit my family	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personalised nutrition will benefit an average member of the society in which I live	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q7. Personalised nutrition is:

	<i>Very worthless</i>	<i>Worthless</i>	<i>Neither worthless/nor valuable</i>	<i>Valuable</i>	<i>Very valuable</i>	
Worthless	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Valuable
	<i>Very unpleasant</i>	<i>Unpleasant</i>	<i>Neither unpleasant/nor pleasant</i>	<i>Pleasant</i>	<i>Very pleasant</i>	
Unpleasant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Pleasant
	<i>Very boring</i>	<i>Boring</i>	<i>Neither boring/nor interesting</i>	<i>Interesting</i>	<i>Very interesting</i>	
Boring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Interesting
	<i>Very bad</i>	<i>Bad</i>	<i>Neither bad/nor good</i>	<i>Good</i>	<i>Very good</i>	
Bad	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Good

Q8. Please indicate the extent to which you agree or disagree with the following statements:

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/nor agree</i>	<i>Agree</i>	<i>Completely agree</i>
I intend to adopt personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would consider adopting personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am definitely going to adopt personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q9. How appealing is personalised nutrition based upon:

	<i>Not at all appealing</i>	<i>Slightly appealing</i>	<i>Moderately appealing</i>	<i>Very appealing</i>	<i>Extremely appealing</i>
Information regarding the food you eat and the exercise you take	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your blood chemistry in addition to information regarding the food you eat and the exercise you take	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
An analysis of your DNA in addition to information regarding the food you eat and the exercise you take	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Considering that a diet program provided by a qualified dietician costs about 100 € for the first 6 months.

Q10. Would you be willing to pay 100 € for personalised nutrition based upon information you have provided about the food you eat and the exercise you take?

- Yes (answer question A and go to Q21)
- No (answer questions B and C and go to Q21)

If YES:

A. How much would you be willing to pay at most for this service as a maximum? Please answer on the scale below by drawing a cross*.

100		500
euro		euro

----* For the digital version of the questionnaire please make sure that the sliding cursor is situated at the left end (100 euro) of the bar.----

If NO:

B. How much would you be willing to pay for this service as a maximum? Please answer on the scale below by drawing a cross*.

0		99
euro		euro

----* For the digital version of the questionnaire please make sure that the sliding cursor is situated at the right end (99 euro) of the bar.-----

C. What reason is most important for you in wanting to pay less for personalised nutrition based upon information you have provided about the food you eat and the exercise you take compared to conventional dietary advice, tick any which apply:

- I cannot afford to pay
- I can get this for free
- My GP/health provider should provide this for free
- I am not interested in personalised nutrition

I do not think it will be useful to me

I don't think it is possible to provide personalised nutrition on the basis of information regarding the food I eat and the exercise I take

Other, please specify.....

.....

Q11. Would you be willing to pay 100 € for personalised nutrition based upon an analysis of your blood chemistry in addition to information you have provided about the food you eat and the exercise you take?

Yes (answer question D and go to Q22)

No (answer questions E and F and go to Q22)

If YES:

D. How much would you be willing to pay at most for this service as a maximum? Please answer on the scale below by drawing a cross*.

100		500
euro		euro

----* For the digital version of the questionnaire please make sure that the sliding cursor is situated at the left end (100 euro) of the bar.-----

If NO:

E. How much would you be willing to pay for this service as a maximum? Please answer on the scale below by drawing a cross*.

0		99
euro		euro

----* For the digital version of the questionnaire please make sure that the sliding cursor is situated at the right end (99 euro) of the bar.-----

F. What reason is most important for you in wanting to pay less for personalised nutrition based upon an analysis of your blood chemistry in addition to information you have provided about the food you eat and the exercise you take, tick any which apply:

I cannot afford to pay

I can get this for free

My GP/health provider should provide this for free

I am not interested in personalised nutrition

I do not think it will be useful to me

I don't think it is possible to provide personalised nutrition on the basis an analysis of my blood chemistry in addition to information I have provided about the food I eat and the exercise I take

Other, please specify.....

Q12. Would you be willing to pay 100 € for personalised nutrition based upon an analysis of a sample of your DNA in addition to information you have provided about the food you eat and the exercise you take?

- Yes (answer question G and go to Q23)
- No (answer questions H and I and go to Q23)

If YES:

G. How much would you be willing to pay at most for this service as a maximum? Please answer on the scale below by drawing a cross*.

100		500
euro		euro

----* For the digital version of the questionnaire please make sure that the sliding cursor is situated at the left end (100 euro) of the bar.-----

If NO:

H. How much would you be willing to pay for this service as a maximum? Please answer on the scale below by drawing a cross*.

0		99
euro		euro

----* For the digital version of the questionnaire please make sure that the sliding cursor is situated at the right end (99 euro) of the bar.----

I. What reason is most important for you in wanting to pay less for personalised nutrition based upon an analysis of a sample of your DNA in addition to lifestyle information, tick any which apply:

- I cannot afford to pay
- I can get this for free
- My GP/health provider should provide this for free
- I am not interested in personalised nutrition
- I do not think it will be useful to me

- I don't think it is possible to provide personalised nutrition on the basis an analysis of a sample of my DNA in addition to information I have provided about the food I eat and the exercise I take
- Other, please specify.....
.....

Q13. I am confident that:

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/ nor agree</i>	<i>Agree</i>	<i>Completely agree</i>	<i>I don't know</i>
Current regulations in my country are adequate to protect consumers from the potential risks of personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Current regulations in my country are adequate to protect personal data and privacy associated with personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are adequate procedures in place to ensure that everyone who may benefit from personalised nutrition will have access to services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q14. Please indicate the extent to which you trust each of the following organisations to protect consumers in relation to personalised nutrition services:

	<i>Distrust extremely</i>	<i>Distrust</i>	<i>Neither trust/nor distrust</i>	<i>Trust</i>	<i>Trust extremely</i>
Your national government ministry or department of health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The European Commission	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your health provider (adjust to national requirements)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food manufacturers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food retailers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consumer organisations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Universities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Health insurance companies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other, please specify					

Q15. Please indicate the extent to which you trust each of the following information sources to provide accurate information about personalised nutrition:

	<i>Distrust extremely</i>	<i>Distrust</i>	<i>Neither trust/n or distrust</i>	<i>Trust</i>	<i>Trust extremely</i>
Your family doctor	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your national government ministry or department of health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The European Commission	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your health provider (adjust to national requirements)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food retailers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food manufacturers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Online personalised nutrition companies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Universities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consumer organizations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dieticians/nutritionists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal trainers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Friends and family	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
News media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Social media	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other, please specify					

Q16. Please indicate the extent to which the following potential outcomes would increase the likelihood of you adopting personalised nutrition:

	<i>Not increase it at all</i>	<i>Increase it slightly</i>	<i>Increase it moderately</i>	<i>Increase it strongly</i>	<i>Increase it extremely</i>
Knowing what foods are best for me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Losing weight	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gaining weight	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fitness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving my family's health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving my health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving my quality of life	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving my sports performance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Preventing a future illness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Preventing the expression of a hereditary illness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other, please specify					

Q17. Please indicate the extent to which you agree or disagree with the following statements:

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/nor agree</i>	<i>Agree</i>	<i>Completely agree</i>
I worry that a personalised diet plan is not effective	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry about how my personal data might be used by authorities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry that my personal data may not be treated confidentially	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry about how my personal data and test results might be stored	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry about how my personal data might be used by personalised nutrition providers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry about how my personal data might be used by advertisers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry about how my personal data might be used by insurance companies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I worry that my personal data might be accessed by hackers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other, please specify.....

Q18. Please indicate to what extent you agree or disagree that the following issues represent barriers to personalised nutrition?

	<i>Completely disagree</i>	<i>Disagree</i>	<i>Neither disagree/nor agree</i>	<i>Agree</i>	<i>Completely agree</i>	<i>Not applicable</i>
Providing different foods for family members	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficulties in maintaining healthy eating habits when eating out in restaurants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficulties in maintaining healthy eating habits when eating at other people's houses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficulties in maintaining diet when travelling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficulties maintaining diet when at work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Being told to eat foods you don't like	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Not being recommended to eat foods you like	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My family rejecting the adoption of personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My friends rejecting the adoption of personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Society rejecting the adoption of personalised nutrition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other, please specify.....						

Q19. Please indicate the extent to which the following situations would make you anxious:

	<i>Not at all anxious</i>	<i>Slightly anxious</i>	<i>Moderately anxious</i>	<i>Very anxious</i>	<i>Extremely anxious</i>
Taking a blood test	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Providing blood through a finger prick blood test	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Taking a DNA test	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sending blood samples by mail for analysis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sending DNA samples by mail for analysis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Identifying through a blood test a disease that can't be treated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Identifying through a DNA test a disease that can't be treated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The security of the blood test data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The security of the DNA test data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other, please specify.....					

Q20. Please indicate the extent to which you would prefer personalised nutrition to be provided through the following communication channels:

	<i>Not at all</i>	<i>Slightly</i>	<i>Moderately</i>	<i>Very</i>	<i>Extremely</i>
Email contact from a named person	<input type="radio"/>				
Automated internet service	<input type="radio"/>				
Telephone call	<input type="radio"/>				
Video call (e.g. Skype)	<input type="radio"/>				
Personal meeting	<input type="radio"/>				
Apps	<input type="radio"/>				
Other, please specify.....					

Q21. Please indicate the extent to which you would prefer the following people or organisations to provide a personalised nutrition service:

	<i>Not at all</i>	<i>Slightly</i>	<i>Moderately</i>	<i>Very</i>	<i>Extremely</i>
Family doctor/GP	<input type="radio"/>				
Private health organisations	<input type="radio"/>				
Dietitian/Nutritionist	<input type="radio"/>				
Supermarket	<input type="radio"/>				
Other, please specify.....					

Demographics

Q22. Please state your occupation:.....

Q27. Please state the occupation of your partner (if applicable):.....

.....

Q23. How healthy do you consider yourself?

<i>Very unhealthy</i>	<i>Unhealthy</i>	<i>Moderately unhealthy</i>	<i>Healthy</i>	<i>Very Healthy</i>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q24. Are you on a restricted diet for a personal reason(s)? (If yes, please list the personal reason(s) and the foods and drinks you cannot consume as a consequent of that personal reason(s)).

No

Yes

Personal reason(s):.....

.....

Foods and drinks that I cannot consume:.....

.....

Q25. Are you on a restricted diet because of your religion? (If yes, please list religion and the foods and drinks you cannot consume as a consequent of your religion)

No

Yes

Religion:.....

.....

Foods and drinks that I cannot consume:.....

Q26. Do you have a food intolerance?

No

Yes

If yes please state which:.....

Q34. Do you have a food allergy?

No

Yes

If yes please state which:.....

Q27. In this box you can post any remarks or comments on this survey you want to share with us.

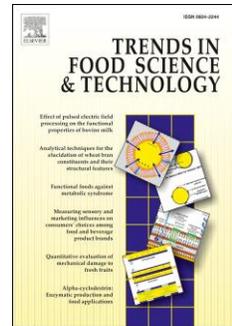
Thank you for your participation!

Appendix E

Accepted manuscripts & publications

Factors determining the integration of nutritional genomics into clinical practice by registered dietitians

Mariëtte Abrahams, Lynn J. Frewer, Ellie Bryant, Barbara Stewart-Knox



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This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please

note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

1 **Factors determining the integration of nutritional genomics into clinical practice**
2 **by Registered Dietitians**

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12

13 **Conflict of Interest**

14 MA has worked with several start-ups as a consultant in the area of nutrigenetic testing.
15 This research has not been supported by a research award or allocation of external
16 financial resources

17

18 Abstract

19 **Background:** Personalised nutrition has the potential to improve health, prevent disease
20 and reduce healthcare expenditure. Whilst research hints at positive consumer attitudes
21 towards personalized nutrition that draws upon lifestyle, phenotypic and genotypic data,
22 little is known about the degree to which registered dietitians (RD) are engaged in the
23 delivery of such services. This review sought to determine possible factors associated
24 with the integration of the emerging science of Nutritional Genomics (NGx) into the
25 clinical practice setting by practicing registered dietitians.

26 **Scope:** Search of online databases (Pubmed; National Library of Medicine; Cochrane
27 Library; Ovid Medline) was conducted on material published from January 2000 to
28 December 2014. Studies that sampled practicing dietitians and investigated integration
29 or application of NGx and genetics knowledge into practice were eligible. Articles were
30 assessed according to the American Dietetic Association Quality Criteria Checklist.

31 **Key Findings:** Application of nutritional genomics in practice has been limited.
32 Reluctance to integrate NGx into practice is associated with low awareness of NGx, a
33 lack of confidence in the science surrounding NGx and skepticism toward Direct to
34 consumer (DTC) products. Successful application to practice was associated with
35 knowledge about NGx, having confidence in the science, a positive attitude toward
36 NGx, access to DTC products, a supportive working environment, working in the
37 clinical setting rather than the public health domain and being in private rather than
38 public practice.

39 **Conclusions:** There is a need to provide RGs with a supportive working environment
40 that provides ongoing training in NGx and which is integrated with clinical practice.

41 **Keywords:** Dietitians; nutritional genomics; involvement; personalised nutrition.

42

43 Background

44 Since the completion of the Human Genome Project in 2003 (Venter, 2011),
45 vast progress has been made in the field of identifying human genetic variations which
46 may play a role in the development of obesity and chronic diseases such as diabetes,
47 cardiovascular disease and dementia (Nielsen & El-Sohehy, 2012). With regards to
48 modernizing healthcare, the United Kingdom (UK) government, in particular, is aiming
49 to lead genomic research and its application within the NHS (NHS, 2015). According to
50 the 5-Year Forward Review Report (DOH, 2014), personalized healthcare will be
51 delivered using digital technologies and will be informed by genomic data, which is
52 poised to revolutionize healthcare toward personalized treatment plans. Although
53 personalized nutrition is not explicitly mentioned within the plans, diet and lifestyle
54 play a key role in the prevention of non-communicable diseases, the European
55 Commission (EC) has pledged make personalised diets a priority by 2050 (EC, 2014).
56 As a consequence, nutrition is expected to become a key focus for prevention. It has
57 been speculated that wide adoption of personalized nutrition could result in health care
58 expenditure reduction of 13% (Marsh & McLennan, 2014).

59 Rapid developments in genomic research have led to the emerging field of
60 nutritional genomics (NGx), which encompasses both nutrigenomics (the study of the
61 impact of diet on gene expression) and nutrigenetics (which looks at how our genetic
62 make-up affects nutrient response) (Müller & Kersten, 2003). Rosen *et al.*, (2006,
63 p1243) defined the application of NGx as “the interpretation of genetic profile
64 information with subsequent therapeutic prescription of an individualized dietary
65 regimen that was tailored to the prevention or management of one or more specific
66 diseases or conditions identified by the genetic profile”. In addition, the position paper

67 of the Academy of Nutrition and Dietetics (AND) on NGx states “The application of
68 NGx in clinical practice requires that healthcare professionals understand, interpret and
69 communicate complex test results in which the actual risk of developing a disease may
70 or may not be known” (Camp & Trujillo 2014, p299). The purpose of nutritional
71 genomics is to enable the delivery of a personalized approach to nutrition intervention
72 which is based on lifestyle, genotype and/or phenotype and in doing so, to prevent or
73 mitigate the development of chronic diseases (Fenech *et al.*, 2011).

74 The clinical utility of genetic tests designed to inform personalised nutrition
75 plans have been widely criticized mainly because of a lack of evidence for strong gene-
76 nutrient interactions as well as lack of effectiveness regarding (short and long term)
77 behavior change (Ries & Castle, 2008; Fraker & Mazza, 2010; Burke, 2014; Pavlidis *et*
78 *al.*, 2015; Hollands *et al.*, 2016). Against this, there is mounting evidence regarding the
79 benefits of a personalized nutrition approach with regards to dietary behavior change
80 (Arkadianos *et al.*, 2007; Chao, 2008; Tierney *et al.*, 2011; Nielsen & Sohemy, 2012;
81 Nielsen & El-Sohemy, 2014; Frankwich *et al.*, 2015; Celis-Morales *et al.*, 2016; Fallaize
82 *et al.*, 2016; Livingstone *et al.*, 2016).

83 The term ‘personalized nutrition’ has, at times, been used synonymously with
84 ‘nutritional genomics’. Personalized nutrition, however, has been defined more broadly.
85 The Food4me project (Food4me.org) was a European-wide research effort that looked
86 extensively into public perceptions of, attitudes towards, and preferences for delivery of
87 different types of personalised nutrition. The potential of different business models for
88 delivering personalized nutrition were also examined (Ronteltap *et al.*, 2012; Stewart-
89 Knox *et al.*, 2013; Berezowska *et al.*, 2014; Poinhos *et al.*, 2014; Stewart-Knox *et al.*,
90 2014; Fallaize *et al.*, 2015; Rankin *et al.*, 2016; Fischer *et al.*, 2016; Berezowska *et al.*,
91 2015). Gene-based personalized nutrition was extensively researched in previous large

92 studies such as LIPGENE and PREDIMED, and has already been commercialized
93 through various avenues (Ronteltap *et al.*, 2012). For the purpose of the Food4me
94 project, personalized nutrition was defined on three levels: dietary analysis; dietary
95 analysis + phenotypic information (eg. blood nutrient profile, anthropometry); or dietary
96 analysis + phenotype + genotype (Celis-Morales *et al.*, 2016; Fallaize *et al.*, 2016;
97 Livingstone *et al.*, 2016). Results from the Food4me project results have indicated a
98 willingness among the European public to pay for a personalized nutrition service
99 which includes some combination of dietary, phenotypic and genotype data, at least for
100 some groups of individuals in the population (Ries *et al.*, 2010; Fischer *et al.*, 2016;
101 Stewart-Knox *et al.*, 2016). Dietitians were identified as being among preferred
102 providers of personalized nutrition (Stewart-Knox *et al.*, 2013; Póinhos *et al.*, 2014;
103 Fallaize *et al.*, 2015; Stewart-Knox *et al.*, 2016). Hence, RD's may have an important
104 role to play in being the bridge between the science and the client (Gilbride, 2007). It is
105 crucial, therefore, to address any gaps that may exist between potential future demand
106 and supply of practitioners adequately trained in the science at all levels. Registered
107 Dietitians (RD's) already provide personalized nutrition plans based on various
108 parameters such as age, medical history as well as blood biochemical data (Nielsen &
109 El-Sohemy, 2012; BDA, 2013). NGx adds an additional layer of personalization by
110 including genotype information.

111 Debate, meanwhile, continues as to whether RD's should be delivering gene-
112 based service when there is only limited evidence for links between diet and genetics
113 (Görman *et al.*, 2013). Professional guidelines, therefore, do not yet explicitly
114 recommend that nutrigenetic testing is applied in routine dietetic practice (Camp &
115 Trujillo, 2014). Meanwhile, there is a growing expectation that RD's should be
116 competent in genetics (HCPC, 2013; BDA, 2013), have a basic knowledge of nutritional

117 genomics (Learning Outcomes for Dietitians on Nutritional Genomics, 2014) and be
118 prepared to integrate NGx into their practice (Collins et al., 2014). There has also been
119 an education drive for front-line healthcare practitioners to become familiar with
120 genomics (Public Health Genomics Education, 2015). Only a few research studies,
121 however, appear to have examined healthcare professionals' (including RD's)
122 engagement in the field of nutritional genomics (Lapham *et al.*, 2000; Rosen *et al.*,
123 2006; McCarthy *et al.*, 2008; Whelan *et al.*, 2008; Collins *et al.*, 2013). With an
124 interested potential consumer market (Stewart-Knox *et al.*, 2016; Fischer *et al.*, 2016), it
125 is essential to identify and address any barriers that may affect the integration of
126 nutrigenomic science into practice. Any lack of engagement and/or understanding of the
127 science by nutrition providers, may impact negatively upon public perception which
128 could have a knock-on effect on public health. The aim of this review, therefore, has
129 been to identify and understand factors that are associated with the integration and
130 application of NGx by registered dietitians in clinical practice. Clinical dietetic practice
131 refers both to advising clients or patients, who may or may not have medical conditions,
132 on nutrition (BDA, 2013). The application or integration of NGx is defined as the use of
133 information (including genetics), to assess an individuals' predisposition or risk of
134 developing a disease and maintain health (Collins *et al.*, 2014; Camp & Trujillo, 2014;
135 NHS, 2014).

136

137 **Method**

138 Databases searched were: Pubmed; Ovid Medline; Nat Lib Med; Cochrane
139 Library). Keyword strategy included a combination of Dietitian or Dietician AND
140 Nutritional Genomics OR Nutrigenomics OR Nutrigenetics OR Diet- Gene Interaction

141 AND Integration OR Application OR Translation OR Involvement OR Attitude OR
142 Clinical Practice.

143 All studies published between January 2000 and December 2014 were
144 considered eligible for inclusion. Additional references were found in the bibliography
145 of articles. Review papers, papers not in English and animal studies were excluded.
146 Studies that looked only at dietetic students were also excluded as the purpose of this
147 review has been to understand the perspective of registered dietitians in clinical practice
148 ie. those already qualified. A total of 917933 records were found. After limits were
149 applied (human studies, English and date range) 11057 articles remained. Following this
150 step, 11048 were screened and excluded on the basis of the title or if the abstract did not
151 meet the criteria for the review.

152

153 **Figure 1 here**

154

155 **Data Extraction and Analysis**

156 A total of 9 eligible studies were identified (table 1). Each study was assessed
157 according to the American Dietetic Association Quality Criteria Checklist (ADA,
158 2003). This entailed answering a number of questions with the response 'yes', 'no' or
159 'neutral' related to each study. If most of the answers were yes, the study received a
160 positive quality rating, if most of the answers were no, the study received a negative
161 rating, and if most answers were not applicable, the study received a neutral rating. The
162 evidence base is very small but mostly of positive quality as indicated in Table 1.

163

164 **Insert table 1 here**

165

166 **Results**

167 Inclusion criteria as outlined in Table 1 were met by 9 studies. The research mostly
168 included level 4 studies (cross-sectional, case-studies) which were conducted in mainly
169 English-speaking countries including UK, US, Canada, Australia and South-Africa. Six
170 out of nine studies were surveys (either mailed or online), two were mixed-method
171 (survey and interviews or focus groups) and one was a focus group only. The study
172 designs were mainly cross-sectional in nature, meaning it included dietitians from
173 various clinical backgrounds and specializations, levels of post-graduate education as
174 well as years of experience. Response rate ranged between 13% (Collins *et al.*, 2013)
175 and 65% (Whelan *et al.*, 2008). The number of participants in each study ranged
176 between 16 (Li *et al.*, 2014) to 1844 (Collins *et al.*, 2013). As there were a limited
177 number of studies and methods across studies were not consistent, a narrative approach
178 will be adopted to analyze the findings.

179

180 **1. Key factors associated with the integration of NGx into practice**

181 **1.1. Involvement with NGx in the Clinical and Education Setting**

182 Involvement in NGx has been identified as one of the key factors associated with
183 integration into practice (Whelan *et al.*, 2008; Oosthuizen, 2011; Collins *et al.*, 2013).
184 Whelan and colleagues (2008) and Collins and colleagues (2014) have broadly defined
185 the term 'involvement' (in NGx), to refer to a various clinical (11) and educational (3)
186 activities concerned with genetics and nutritional genomics. These included clinical
187 activities such as "discussing the genetic and dietary basis of disease" or "providing

188 nutrition advice to patients which is specific to the genetic nature of their condition” as
189 well as educational activities such as “providing training to students or other healthcare
190 professionals on diseases that have both a dietary and genetic component”. Involvement
191 in NGx has been predominantly measured via online surveys using Likert scales
192 (Christianson *et al.*, 2005; Rosen *et al.*, 2006; Whelan *et al.*, 2008; Oosthuizen, 2011;
193 Collins *et al.*, 2013; Cormier *et al.*, 2014). Involvement has been found to be low, such
194 that fewer than 50% of dietitians based in the clinical setting reported engaging in
195 activities associated with NGx (Whelan *et al.*, 2008; Oosthuizen., 2011; Collins *et al.*,
196 2013). Activities included referring individuals for genetic counselling. The proportion
197 was even lower in the educational setting (46.1%) where activities included being active
198 in teaching genetics to students and other healthcare professionals (Whelan *et al.*, 2008;
199 Oosthuizen., 2011; Collins *et al.*, 2013).

200 A multinational online survey study (N=1844) conducted by Collins *et al* (2013)
201 in the United Kingdom (UK), Australia and the United States (US), indicated that
202 genetics and nutritional genomics activities were not not always clearly separated, as
203 implied in the Whelan *et al.* (2008) study. Given the study was cross-sectional in nature
204 and that RD’s from various sub-disciplines were included in the study it was not
205 possible to distinguish between those who were dealing with monogenetic (congenital)
206 disorders and those with polygenetic disorders. For the purpose of statistical analysis the
207 ‘involvement’ variable score was calculated from the sum of clinical and educational
208 activities, rendering it difficult to separate out and establish the level of integration
209 specifically into clinical dietetics practice.

210

211 1.2 Confidence in NGx Science and Technology

212 Confidence in the science of genetics and NGx has been identified as one of the
213 strongest predictors of having integrated it into practice (Grimaldi, 2014). Dietitians
214 with a moderate/high level of confidence (54%) were more likely than those with lower
215 confidence to be involved in activities relating to genetics and NGx (Collins *et al.*,
216 2013). Not only did the dietitians lack confidence, but it also appeared that confidence
217 decreased with increasing years of experience (following qualification) (Collins *et al.*,
218 2013). Rosen and colleagues reported the results of a survey (N= 995) conducted in the
219 US in 2004 (Rosen *et al.*, 2006). The results indicated that 60% of RD's had little
220 confidence in their ability to provide nutrition services based on NGx. According to the
221 multinational (US; UK; and, Australia) survey conducted by Collins and colleagues
222 (2013), confidence in NGx was associated with having engaged in education or clinical
223 activities. Those who were involved in NGx appeared to have greater confidence in the
224 science and in their ability to apply it to practice.

225

226 1.3 Knowledge of NGx

227 Lack of knowledge of the science has been identified as a reason for low
228 integration of NGx into practice (Collins *et al.*, 2013). A survey (N=390) conducted in
229 the UK (Whelan *et al.*, 2008) and another (N=373), more recently conducted in Canada
230 (Cormier *et al.*, 2014) found that 75.9% of RD's in the clinical nutrition (public
231 healthcare setting) and 62.9% of RD's working as freelance RD's in the private sector
232 reported that they did not believe that had sufficient knowledge to incorporate NGx into
233 their clinical practice

234 The notion that lack of knowledge deters the application of NGx is backed up by
235 results of the largest (N= 1844) survey study of its kind (Collins *et al.*, 2013) which

236 indicated that only 18.8% of RD's knew the answer to the question "What condition is
237 not associated with the MTHFR 677C→T defect?" At most, 33.5% could describe what
238 the terms NGx or nutrigenetics meant. A survey (N=297) of South-African dietitians
239 (Oosthuizen, 2011) found that higher qualifications were associated with greater
240 knowledge and involvement in NGx. Those with postgraduate Masters and Doctoral
241 level qualifications were more likely to be engaged in genetics and NGx related
242 activities. This finding, however, was not borne out in the multinational study
243 conducted by Collins et al. (2013) who found no association between knowledge of
244 NGx and involvement. The possibility of any relationship between knowledge and level
245 of qualification, however, was not measured. This nevertheless implies that for NGx to
246 be applied in practice a sustainable means through which to communicate with RG's on
247 developments in NGx science on an ongoing basis may be required. Further research
248 may be required to determine the type of information on NGx required by practicing
249 RD's.

250

251 **1.4 Attitudes toward NGx**

252 Relatively few studies have considered the attitudes of RG's toward NGx. A
253 small mixed-method approach study (N=16) conducted in the UK and Australia by Li
254 and colleagues (2014) found that 50% of dietitians in both countries surveyed did not
255 believe that NGx played any role in informing their current practice. They also found a
256 general reluctance among RD's to integrate the science owing to a perceived lack of
257 evidence for its efficacy. Differences between the two countries were not measured.
258 Another survey study (N=235) undertaken by Christianson and colleagues (2005)
259 amongst Australian RD's, reported that the majority (71%) attributed the lack of

260 integration of NGx to not having encountered patients with genetic disorders. Given
261 genetic disorders constitute only a small part of what NGx encompasses, this suggests
262 that many RD's have only a very limited concept of the scope of NGx comprises (ie.
263 counselling those with monogenetic disorder) and of its potential role in the prevention
264 and treatment of non-communicable disease in the general population. Although there
265 were positive views on the potential role of NGx in preventing the development of
266 chronic diseases, the majority of RD's did not believe that NGx could improve the
267 quality and relevance of nutritional recommendations (Cormier *et al.*, 2014). This
268 suggests a need for initiatives to inform RD's on the scope of NGx and potential for
269 NGx in public health nutrition.

270

271 **1.5 Attitudes toward Direct-to-Consumer (DTC) Nutrigenetic tests**

272 Digital technological advances are expected to revolutionize preventative public
273 healthcare (EC, 2014) and present an opportunity to deliver digital health technologies
274 direct to the consumer (DTC). RD's, however, are purported to hold negative opinions
275 of DTC testing (Weir *et al.*, 2010; Cormier *et al.*, 2014; Li *et al.*, 2014) and appear
276 skeptical of DTC NGx products owing to the perceived lack of scientific evidence for
277 the efficacy of such products (Weir *et al.*, 2010; Li *et al.*, 2014). Negative attitudes
278 toward DTC testing have been put forward as a possible reason for low integration of
279 NGx into practice. RD's have also expressed concern that the results of DTC
280 personalized nutrition assessment if conveyed without adequate support and follow-up
281 could cause unnecessary worry in consumers (Weir *et al.*, 2010; Cormier *et al.*, 2014; Li
282 *et al.*, 2014).

283

284 1.6 Job area and Healthcare Environment

285 Quantitative survey (N=373) conducted in Canada, has suggested that RD's in
286 public health/health promotion and food service management may be less likely than
287 clinically based RD's to apply NGx in practice (Cormier *et al.*, 2014). This finding
288 echoes results of a mixed-method study reported by Li and colleagues (2014) which
289 found that neither clinically based nor public health RD's (UK and Australia), perceived
290 any role for NGx in providing population level dietary advice. Whereas dietitians in
291 public health failed to see NGx within the scope of preventative public health, those in
292 the acute (clinical) setting saw NGx as having a preventative rather than a therapeutic
293 role. The upshot was that neither public health nor clinical dietitians viewed NGx as
294 relevant to their own area of practice. Other studies (Oosthuizen, 2011; Cormier *et al.*,
295 2014), meanwhile, have indicated that those engaged in NGx related activities are most
296 likely to be based in academia, private practice or the food industry. This implies an
297 imperative for research to target RD's practicing in the clinical and public health sectors
298 in an endeavor to better understand the perceived barriers encountered when seeking to
299 engage with NGx, and to apply this understanding to the design of interventions to
300 encourage and support them in providing personalized nutrition services.

301

302 1.7 Endorsement by Professional Organisations

303 A US survey (N=995) of RD's (Rosen *et al.*, 2006) found that 80% had never
304 encountered NGx in practice. A possible reason for the lack of integration of NGx into
305 practice could be the lack of priority assigned to nutrigenomics by dietetic professional
306 associations (Li *et al.*, 2014). Endorsement by professional bodies would serve to
307 encourage RD's to acquire knowledge of the links between genetics and diet and to

308 become involved in activities relating to NGx (Rosen *et al.*, 2006; Oosthuizen, 2011;
309 Collins *et al.*, 2013; Li *et al.*, 2014). Although Cormier and colleagues (2014) found that
310 more than 75% (N=383) of RD's in the Quebec-area (Canada) knew about NGx, it was
311 not clear from the study whether this knowledge led to integration of NGx into practice.
312 The application of NGx in practice will require leadership from professional
313 organisations representing dietetics professionals.

314

315 Discussion

316 The aim of this review has been to identify barriers and enablers to the
317 integration of NGx into dietetics practice and to pinpoint areas for research and
318 intervention and policy to promote the application of NGx by RGs. Existing studies
319 imply that the apparent reluctance to integrate NGx into practice is associated with low
320 awareness of NGx and its range and scope, a lack of confidence in the science
321 surrounding NGx and skepticism toward DTC products. Integration of NGx also
322 appears to vary among the different dietetics domains (eg. clinical; public health) and
323 area of practice (eg. health service; commercial). All of these factors have potential to
324 respond to leadership by professional bodies and the introduction of core education and
325 training initiatives.

326 Genetics has been designated a compulsory component of dietetics training since
327 2008 (ASCEND, 2011; BDA, 2013) yet, nutritional genomics remains only an optional
328 module in undergraduate training in the UK and a module as part of MSc programs
329 throughout the UK (BDA, 2013). RD's involved in managing patients with inborn
330 errors of metabolism appeared more confident in providing genetic services (Gilbride &
331 Camp, 2004), possibly because this is covered in the undergraduate curricula. NGx in

332 the broadest sense, however, is not yet a part of clinical practice training, which could
333 partly explain the apparently poor knowledge, lack of confidence and involvement in
334 NGx activities amongst practicing RD's (Collins *et al.*, 2014).

335 Previous studies have demonstrated that dietitians have a preference for
336 education and training in seminars, workshops or online courses (Busstra *et al.*, 2007;
337 Newton, 2007b; Morin, 2009). Nevertheless, even after such training, the uptake and
338 integration of NGx can remain low (Newton, 2007b). This gap in provision of
339 translational education has partly been solved by private companies offering continuous
340 education to various healthcare professionals on the topic (Ronteltap *et al.*, 2012).
341 Owing to RD's skepticism towards DTC, however, these opportunities may not be fully
342 exploited. Digital technological advances may afford the opportunity to integrate the use
343 of digital health technologies which includes big (omics) data on nutrition, into the
344 dietetic curricula. Meanwhile, there may be wider issues associated with the lack of
345 interest and involvement in updating skills in NGx despite the available educational
346 opportunities, which require further investigation.

347 Confidence in the science of NGx appears to be lowest in those with more years
348 since graduation while knowledge is highest amongst less experienced RD's, possibly
349 because they have had recent training on the topic at undergraduate level (Whelan *et al.*,
350 2008; McCarthy *et al.*, 2008; Oosthuizen, 2011; Collins *et al.*, 2013; Cormier *et al.*,
351 2014). This could suggest that RD's who have been out of practice for longer should be
352 afforded continuous education opportunities to gain experience in NGx. This apparently
353 higher level of knowledge among recent graduates, however, does not appear to
354 translate into clinical practice for reasons that are not entirely clear. A possible
355 explanation could be lack of a supportive working environment (Li *et al.*, 2014).
356 Possible ways to overcome the apparent knowledge-practice gap need to be explored in

357 future research. Given that repetition and exposure to clinical situations can encourage
358 learning (Banet & Nunez, 2007), the amount of genetics (and optional genomics)
359 currently delivered through the curriculum in the UK (Dietetic Standards Health & Care
360 Professions Council, 2013) may need to be re-evaluated. Students learn about the
361 science but then do not receive further exposure during their clinical placement.
362 Reviewing the curriculum to increase knowledge and enhance confidence through
363 clinically based support and training may be necessary to address this in the future
364 (Wright, 2014).

365 In view of the wide range of dietetic roles currently available, a need for change
366 in how we train future dietitians has already been identified. The recently published
367 paper on standards of education (BDA, 2015: p16) concluded that “the profession is
368 ready and in need of a change of approach to student training” and that “the sole use of
369 the one-to-one model is neither sustainable nor appropriate and similarly students who
370 only experience NHS acute or community placements do not gain a true understanding
371 of the breadth of dietetic practice”. The profession, therefore, needs to consider RDs’
372 role and preparation within the ‘omics’ era (Wright, 2014). The core competency in the
373 Learning Outcomes Framework on NGx for Dietitians (The UK National Genetics and
374 Genomics Education Center, 2014: p1) stipulates that it is important to have “a broad
375 understanding of genetics, genomics and genetic testing as it relates to common
376 disorders seen by dietitians, in order that you are able to answer patients’ questions”.
377 Professional guidance and RD genomics education websites, however, caution that it is
378 too early to integrate genetic testing to provide genotype-based PN advice (Camp &
379 Trujillo., 2014). This renders involvement in NGx a difficult task, as RD’s have little
380 exposure to NGx in the dietetic curricula.

381 With rapid expansion of the direct to consumer (DTC) nutrigenetic testing
382 market (Saukko, 2013), the public are likely to seek access to qualified professionals to
383 interpret their results (Critchley, 2015). Whilst nutrigenetic tests have been criticized for
384 lack of clinical utility and validity (Pavlidis *et al.*, 2015), strong market growth
385 (Bloomberg, 2010) indicates market interest is growing. Yet, RD's appear to have a
386 poor perception of direct-to consumer testing products (Bouwman *et al.*, 2008; Weir *et*
387 *al.*, 2010; Cormier *et al.*, 2014; Li *et al.*, 2014). When considering DTC company
388 websites such as Nutrigenomix (Toronto, Canada <http://nutrigenomix.com>) and
389 DNAnalysis (Johannesburg, South-Africa <http://dnanalysis.co.za>), it becomes clear that a
390 number of RD's have started integrating NGx into practice. So why do some RD's
391 integrate NGx and others don't? Although this may be explained by factors operating
392 within the healthcare environment such as employment in public health services
393 (Government contracted/NHS) versus private practice (Industry) within which RD's
394 practice, how this operates in practice is currently not clear. The use of NGx by RD
395 working in the NHS may also be less relevant. RD's are also concerned about cost and
396 that DTC results could unnecessarily worry clients and that specific groups, for
397 example, those on lower incomes, could be excluded from accessing such products
398 (Weir *et al.*, 2010; Cormier *et al.*, 2014; Li *et al.*, 2014). Whilst policy needs to consider
399 the needs of the less advantaged members of society, this should not pose a barrier to
400 RD's increasing their knowledge in preparation for responding to questions from
401 patients and the general public.

402 Previous research into the integration of NGx into practice has only touched
403 upon relevant issues in current NGx practice. A possible reason for this is that the term
404 'involvement' (in NGx) has been used in several papers, without it being either fully
405 operationally defined with regard to the application of NGx or used consistently

406 between studies. A first step toward enabling research on the integration of NGx in
407 dietetics practice, therefore, would be to define what the integration of NGx into
408 practice actually means. When looking at the detail within some of the published
409 research papers (Whelan *et al.*, 2008; Collins *et al.*, 2014), it is also evident that none of
410 the activities referred to as nutritional genomics actually involved the use of a
411 nutrigenetic test or genotypic information. Previous studies have indicated some
412 confusion among RD's about what activities are comprised in nutritional genomics
413 beyond the management of inherited conditions (Whelan *et al.*, 2008; Collins *et al.*,
414 2014). Future research on this topic, therefore, should provide a full definition of NGx
415 which encompasses all of what it entails in practice going beyond medical nutritional
416 therapy for genetic conditions such as Coeliac Disease or lactose intolerance. In
417 defining NGx therefore, a distinction needs to be made between monogenetic disorders
418 (such as inborn errors of metabolic disorders) and NGx which relates more to chronic
419 diseases.

420 Most studies that have looked at the integration of NGx into practice have been
421 quantitative, mainly on-line survey and cross-sectional in nature (Lapham *et al.*, 2000;
422 Christianson *et al.*, 2005; Rosen *et al.*, 2006; Whelan *et al.*, 2008; Weir *et al.*, 2010;
423 Oosthuizen, 2011; Collins *et al.*, 2013; Cormier *et al.*, 2014) and a dearth of in-depth
424 research which could assist in explaining the findings. Some of the surveys suffered
425 from poor response rates (Oosthuizen, 2011; Collins *et al.*, 2013; Cormier *et al.*, 2014)
426 and small sample sizes (Weir *et al.*, 2010; Li *et al.*, 2014), the reasons for which are
427 unclear. Another limitation is that only certain countries have been surveyed (Australia,
428 South-Africa, US, UK and Canada), with a relative lack of research in emerging and
429 developing countries.

430

431 Future Directions

432 The perceived importance of genetics based practice among the dietetics
433 profession appears to be associated with their level of knowledge of NGx (McCarthy *et*
434 *al.*, 2008; Collins *et al.*, 2013). Although it is difficult to determine the direction of
435 causation between high perceived importance and knowledge of NGx, that neither are
436 necessarily associated with integration of NGx into practice, warrants further study.

437 Existing research has also suggested that RD's have ethical concerns, most
438 especially that disadvantaged groups could be excluded from accessing products and
439 services if they are only offered commercially (Weir *et al.*, 2010; Cormier *et al.*, 2014;
440 Li *et al.*, 2014). Recent research into opinions among the European public on
441 personalised nutrition, however, has suggested that there may be two potential markets,
442 one delivered commercially and the other through existing health services (NHS), and
443 that under certain circumstances these types of provision should be synchronized
444 (Stewart-Knox *et al.*, 2013; Stewart-Knox *et al.*, 2014; Fallaize *et al.*, 2015; Fischer *et*
445 *al.*, 2016; Stewart-Knox *et al.*, 2016). This implies a future where dietetics practitioners
446 work alongside commercial providers of NGx and that further research is required to
447 determine how best to encourage collaboration between DTC and clinical NGx
448 providers.

449 The apparent narrow view of NGx as the management of genetic conditions
450 rather than the promotion of dietary health could demonstrate a lack of understanding of
451 the links between genes, diet, health and propensity for chronic disease (Gilbride,
452 2007), which will need to be addressed through education and training initiatives. With a
453 low response rate of only 13% in the largest study (Collins *et al.*, 2013), however, the
454 results may not be applicable to the dietetic profession as a whole.

455 Given the finding that there is divided opinion on which specializations and area
456 of practice are best place to integrate NGx, future policies will need to ensure that NGx
457 is integrated throughout professional practice. To our knowledge no comprehensive
458 work has been conducted to look at current provision on nutritional genomics within the
459 dietetic curriculum. Nor do any studies appear to have looked into the attitude and
460 perceptions of RD's who have integrated NGx into their practice (using the classic
461 definition of NGx) to provide gene-based PN services. The time is right, therefore, to
462 grasp the opportunity to conduct research with 'early adopters' of NGx and enquire into
463 traits, attitudes and perceptions that could help to determine the factors that are
464 associated with successful integration of NGx and which can inform initiative and
465 policies to encourage the rest of the profession to add this exciting new technology to
466 their practitioner resources.

467

468 **Insert table 2 here**

469

470 **Conclusions**

471 Owing to limitations in previous research, very few conclusions can be drawn
472 from studies of NGx integration into practice. At present, there is global variation in
473 how NGx is integrated at the clinical practice level, with the majority of RD's
474 abstaining. Further research should seek to understand the drivers, barriers and
475 challenges the profession faces with regards to integration of NGx into practice. Greater
476 clarity is needed at the strategic and policy level on how RD's could potentially use
477 genotype information and translate it into therapies and in dealing with client's
478 questions. A future concern and one that policy needs to address, is the issue of equality

479 of access to NGx (Stewart-Knox *et al.*, 2016). RD's in both private and public health
480 provision will need enabled to deliver NGx services. Meanwhile, there appears to be a
481 gap between what RD's are expected to know in terms of learning outcomes and what
482 actually happens in practice and further research is required to determine and
483 understand the reasons why.

484 It is clear that action is needed to ensure that more experienced RD's become
485 familiar with the science, its application and the potential professional opportunities this
486 could present. Measures also need to be taken to ensure that less experienced RD's are
487 encouraged to remain interested in the field once they are qualified and are afforded the
488 opportunity to integrate NGx into their practice. How much emphasis is placed on NGx
489 in clinical practice by educators, senior practitioners and professional organisations,
490 therefore, could play a major role in the establishment of a confident and competent
491 workforce that is prepared for changes the genomic revolution may bring and ready for
492 full integration of nutrigenomics into dietetic practice (Li *et al.*, 2014).

493 The future of modernized healthcare is likely to rely heavily on personalised
494 health promotion and disease prevention (EC, 2014). Whilst genetic contribution of
495 individual single nucleotide polymorphism to disease susceptibility is small 0-10%
496 (Minihane, 2013) and between gene-environment interactions are still being unraveled,
497 advanced skills and knowledge in genomics and systems biology may open up new
498 opportunities in the food industry for the development of functional food, as part of
499 digital health programs. In order to achieve this goal, educational and policy initiatives
500 will be required to integrate NGx across all levels and domains of practice. RD's are
501 ideally positioned to bridge the gap between suppliers and consumers. Equally, there is
502 an opportunity to foster links between industry and academia in terms of training in

503 order to satisfy demand for personalized nutrition products that can mitigate disease and
504 promote health.

505

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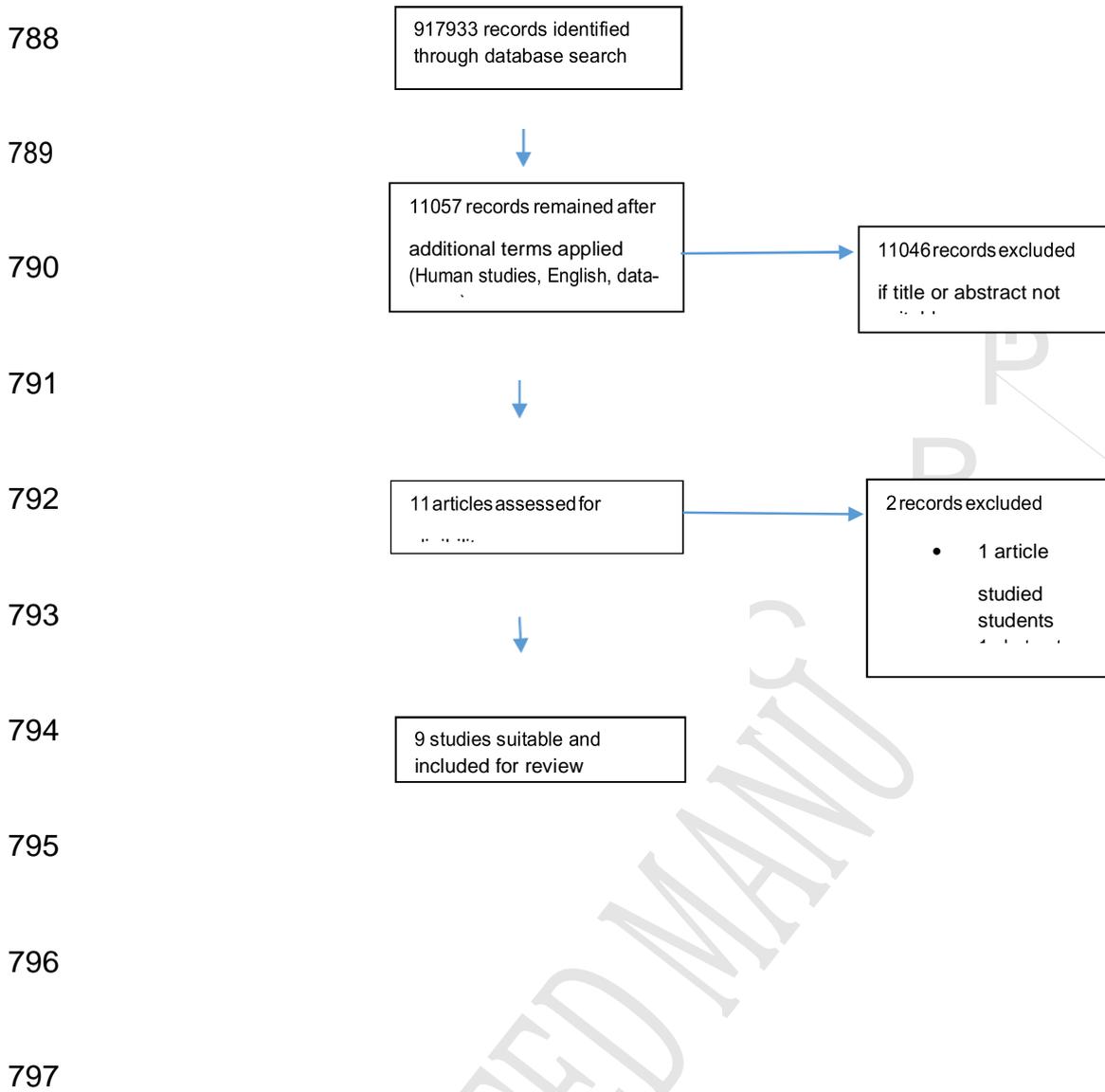
787 **Figure 1**

Table 1: Summary of studies that met the inclusion criteria for the critical analysis

Study, (Country)	Participants	Design	Quality criteria checklist	Factors influencing integration	Outcome of study	Result
Collins et al 2013 (UK, US, Australia)	Dietitians N=1844 (13% response rate)	Cross-sectional study using online survey	Positive	Confidence Knowledge	Knowledge of genetics & NGx Involvement and confidence in undertaking clinical or educational activities related to genetics and NGx	Strongest predictor of high involvement for clinical activities was high confidence p<0.001
Whelan et al 2008 (UK)	Dietitians N=390 (65% response rate)	Postal survey	Positive	Confidence Knowledge	Involvement, confidence and knowledge of dietitians in genetics and diet-gene interactions	Involvement was associated with confidence, but limited to discussing diseases with dietary and genetic component (49%) or advising patients where to access information relating to a disease with a dietary and genetic component (33%)
Cormier et al 2014 (Canada)	Dietitians N=373 (15.3% response rate)	Online survey	Positive	Experience Perception Knowledge Ethical issues Market need Job role	Current knowledge of RD's regarding NGx to identify training needs in NGx of RD's and to highlight the perceived limitations of the use of genetic tests in their scope of practice	Less experienced dietitians were more knowledgeable but not applying it in practice Senior dietitians were less knowledgeable and more skeptical and concerned about ethical and legal aspects associated with D-T-C tests RD's in private practice more

						likely to integrate than RD's in acute and food serve setting
Weir et al 2010 (Canada)	Hcp's including Dietitians n=4, nutritionist n=1	Focus groups	Neutral	Competency Perceived benefit Attitude	Knowledge and attitude of hcp's regarding NGx and nutrigenetic testing	High level of skepticism towards nutritional benefit. Lack of confidence and knowledge hindered integration
Christianson et al 2005 (Australia)	HCP's including dietitians N=235 (response rate 34%)	Cross-sectional survey	Positive	Attitude	Knowledge	71% did not work with patents with genetic conditions. Lack of knowledge and understanding of the link between diet and genes
Lapham et al 2000 (US)	Dietitians N=362 (62% response rate)	Survey and focus groups	Positive	Confidence	To determine the Genetics education needs and priorities of RD's and other hcp's	Involvement was limited to genetic component of disease problems (67%) and counselling patients with a genetic condition (24.1%) RD's had low confidence in applying genetics in practice
Rosen R et al 2006 (US)	Dietitians N=995 (40% response rate)	Mailed survey	Positive	Knowledge Confidence Attitude	To assess continuing education needs for RD's regarding application of NGx	Positive attitudes were associated with greater confidence in ability to apply knowledge. Factors that hindered application included: Lack of knowledge (81%); Uncertainty about reimbursement (84%); Lack of CPD (73%);

						Lack of professional expertise (72%).
Li S et al 2014 (Australia & UK)	Dietitians N=16 (semi-structured interviews) N=7 (Focus groups)	Semi-structured interviews Online surveys Focus groups	Neutral	Confidence Knowledge Environment Perception	Low Involvement	Lack of supportive environment Limited exposure and training Lack of relevance to practice Lack of scientific evidence Too early to integrate the science into practice
Oosthuizen 2011 (South-Africa)	Dietitians N= 297 (response rate 15.2%)	Cross-sectional online and mailed survey	Positive	Knowledge Confidence	To determine involvement, knowledge and confidence in genetics and NGx	Significant positive association between involvement and confidence (p<0.001) Those with higher involvement had higher knowledge and were more confident

Table 2: Current gaps in our knowledge and research questions

- **How can digital technology be best used to increase knowledge, heighten interest and encourage the inclusion of NGx into the dietetic education curriculum?**
- **What training is currently offered on nutritional genomics in the dietetic curriculum across the globe?**
- **How has NGx been successfully integrated into clinical practice and what are the drivers, perceptions and experiences that have influenced early adopters?**
- **What are the perceived barriers faced by RD's in adopting NGx into practice?**
- **Has translation of the science and the barriers encountered in doing so, been consistent across countries?**
- **Most research has been conducted in English speaking countries. What are the views and practices of dietitians in non-English speaking and emerging countries?**

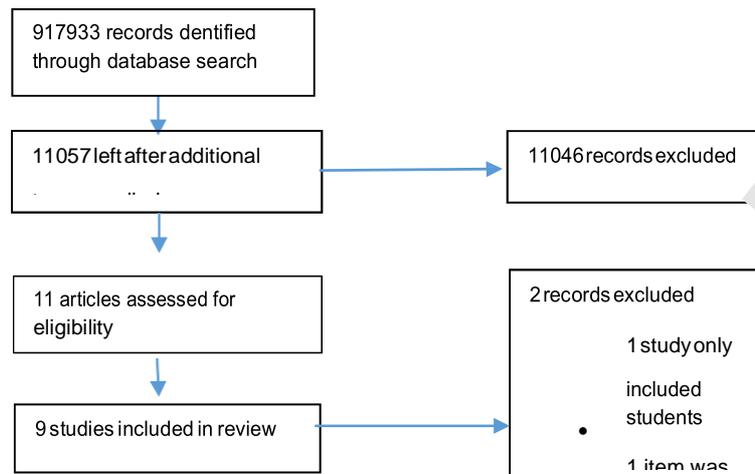


Figure 1: Literature search procedure

Highlights

- Registered Dietitians (RD's) have been identified as key healthcare professionals to translate Nutritional Genomics (NGx) into practice
- There is a lack of research conducted into the views of RD's who have integrated NGx into practice
- Higher education curricula do not integrate genomics data into clinical practice and integration of NGx into practice is low.
- There is an opportunity to integrate DNA testing and digital health platforms into the curriculum as an innovative way to increase interest and engagement with NGx
- Leaders of dietetic organizations and academic institutions need to place nutritional genomics higher on the strategic agenda in order to progress the profession and to create new opportunities.

Perceptions and experiences of early-adopting registered dietitians in integrating nutrigenomics into practice

Early-adopting
registered
dietitians

763

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Abstract

Purpose – The purpose of this paper is to explore the perceptions and experiences of early adopters of the technology.

Design/methodology/approach – Registered dietitians (RDs) ($n = 14$) were recruited from the UK, Canada, South Africa, Australia, Mexico and Israel. Six qualitative interviews and two focus groups were conducted online using a conference calling platform. Data were recorded, transcribed and thematically analyzed.

Findings – Early adopters of nutrigenomics (NGx) were experienced, self-efficacious RDs who actively sought knowledge of NGx through communication with one another and the broader scientific community. They considered NGx an extension of current practice and believed RDs had the skills to deliver it. Perceived barriers to widening the application of NGx were linked to skepticism among the wider dietetics community. Proliferation of unregulated websites offering tests and diets was considered “pseudoscience” and detrimental to dietetics fully embracing NGx. Lack of a sustainable public health model for the delivery of NGx was also perceived to hinder progress. Results are discussed with reference to “diffusion of innovation theory.”

Originality/value – The views of RDs who practice NGx have not been previously studied. These data highlight requirements for future dietetic training provision and more inclusive service delivery models. Regulation of NGx services and formal recognition by professional bodies is needed to address the research/practice translation gap. Further research is required to inquire as to the views of the wider dietetics profession.

Keywords Perceptions, Qualitative, Nutrigenomics, Personalized nutrition, Registered dietitians

Paper type Research paper

1. Introduction

Nutritional genomics (NGx) is an emerging field focused on interactions between food, nutrition and genes (Ferguson *et al.*, 2016). Increased understanding of gene-nutrient interactions may facilitate health and disease prevention (Casas *et al.*, 2016; Corella *et al.*, 2016; Celis-Morales *et al.*, 2016). A growing market offers genetic tests “direct-to-consumer (DTC)” as well as via healthcare professionals. The Food4me project has illustrated how personalized nutrition can be delivered online to the public (Celis-Morales *et al.*, 2016). Tests can deliver information linking diet to health, lifestyle, weight or improved fitness (Covolo *et al.*, 2015; Bloss *et al.*, 2011). Omics technologies (metabolomics, lipidomics and transcriptomics) enable highly personalized and targeted approaches to dietary health promotion (Sun and Hu, 2016) which have already been shown effective for outcomes related

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to cardiovascular disease (Fitó *et al.*, 2016). Consumer interest is high and demand for trained practitioners expected to increase (Berezowska *et al.*, 2015). Registered dietitians (RDs) will be key professionals for translating the science of nutrigenomics into practice (Berezowska *et al.*, 2015; Abrahams *et al.*, 2017; Stewart-Knox *et al.*, 2013, 2016; Fallaize *et al.*, 2015). The Academy of Nutrition and Dietetics, however, do not consider the field ready for routine practice (Camp and Trujillo, 2014), so that application of nutritional genomics has tended to be low amongst the dietetics profession (Collins *et al.*, 2013; Whelan *et al.*, 2008).

Whilst two large multinational European studies (LIPGENE and Food4me) have explored consumer perceptions of personalized nutrition (Stewart-Knox *et al.*, 2016; Stewart-Knox *et al.*, 2013; Poinhos *et al.*, 2014; Stewart-Knox *et al.*, 2009), and some research on stakeholder views has been undertaken (Ronteltap *et al.*, 2008), to our knowledge no research has investigated perceptions and experiences of RDs who are already delivering personalized nutrition services (Abrahams *et al.*, 2017). Rogers' diffusion of innovation theory describes a process by which an innovation disseminates through a societal group taking into account various adopter categories (early adopters, early majority, late majority, laggards), communication (awareness and knowledge of the innovation), innovation decision processes (initial knowledge, attitude, intention to adopt or reject, implementation, decision to adopt or reject) and characteristics of the technology (relative advantage, compatibility/fit, complexity/ease of use, trialability, observability of results). According to innovation theory, a novel technology such as nutritional genomics will diffuse through society via early adopters such as freelance RDs (Peterson *et al.*, 2007). This study, therefore, has sought to understand the perceptions, experiences and characteristics of RDs who have integrated genetic testing into practice. The objectives have been to determine the profile of an early-adopter RD, to explore perspectives among early adopters, to understand challenges encountered in integrating NGx in practice, capture views on the future role for RDs in the delivery of personalized nutrition and, to construct theory through which to understand and explain the above.

2. Method

2.1 Sampling

Volunteers were approached through the managing directors (CEOs) of three international DTC genetic testing companies working with RDs. The aim was to sample from a range of countries (Australia, Canada, Israel, Mexico, South Africa, UK) and in so doing to obtain the various perspectives of RDs working alongside different health systems. An information sheet was sent via e-mail to practicing RDs in their database. Inclusion criteria were English speaking RDs who had been applying nutrigenomic (NGx) testing in practice for at least six months. Of 20 invitations, 11 RDs (55 percent) responded and agreed to participate (Table I). No remuneration was offered.

2.2 Materials

Interviews and focus groups were conducted using the Citrix Platform (Citrix Systems Inc.). Topics discussed included: experience of using tests in practice; perceptions of NGx; perceived barriers, challenges and drivers; skills required; perceived implications for education and training; and future directions. Open-ended questions included: "tell me about how you got started in the field," "what has your experience been with using tests with your clients been so far?"; and "how do you think you are perceived by your dietetic colleagues?".

2.3 Procedure

Ethical approval was obtained from the University of Bradford Research Ethics Committee. Pilot interviews were conducted with two UK-based RDs. Given technical problems during

		Early-adopting registered dietitians
Total RDs	12	
Gender (female)	12	
<i>Years since graduation</i>		
0-9 years	1	
10-19 years	6	
20-29 years	3	
> 30 years	2	
<i>Level of education</i>		
BSc	5	
Masters	6	
PhD	1	
<i>Other qualifications</i>		
Food science	1	
Sport science	1	
Medical herbalism	1	
Business and management	2	
Clinical research	1	
CPD nutritional genomics	12	
<i>Job roles</i>		
Lecturing/private practice	4	
Business/private practice	4	
Private practice only	4	
<i>Country of residence</i>		
UK	2 (Pilot)	
Australia	3	
South Africa	2	
Canada	3	
Israel	1	
Mexico	3	
		765

Table I.
Profile of the
participating
registered
dietitians (RDs)

the first interview, and because the second pilot interviewee appeared more relaxed and verbal without the camera, it was decided not to use video in the main study. Mixed methods were employed in order to achieve an international perspective. Where use of a focus group was not pragmatic because of time zone differences, individual interviews were conducted. This approach also enhanced the possibility of obtaining rich, novel data. Whereas group discussions by virtue of the social interaction, facilitate expression of new ideas (Kitzinger, 1994), interviews allow for the expression of diverse, more privately held views (Silverman, 2013). Once a date and time was agreed, dial-in details to access the conference calling facility were sent via e-mail. One final e-mail reminder was sent a day before the call. On the day of the interview, participants accessed the online conference room. Discussion was moderated by the first author (MA). A total of six interviews and two focus groups were held between February and April 2016 ranging between 30 and 60 minutes in length, at which point data were deemed saturated.

2.4 Data analysis

Anonymised transcripts were transcribed from the recordings verbatim by MA. Thematic analysis was deemed appropriate as the people in the sample represented was an under-researched topic and group (Vaismoradi *et al.*, 2013). All transcripts were read and re-read recursively by the first author (MA). Data were encoded using an inductive approach and then explored and organized into themes that were inclusive of the data set and common to

all transcripts. Initial themes were checked, refined and categorized further into sub-themes. To assure rigor, consistency and reliability of the coding and analysis, a second author (BS-K) checked the transcripts against the coding framework and themes. Any discrepancies were discussed and themes and sub-themes agreed, interpreted and pertinent extracts selected.

3. Results and discussion

Data were best described by four main themes (profile of the NGx practitioner, experiences of RDs in practice, perceived barriers to NGx and perspectives on the future and sub-themes (Figure 1). These provide insights into NG practice from the perspective of practicing RDs, and convey their opinions and views on how clinical practice and training could and should evolve, and how best to deliver such services in the future.

3.1 Profile of the NGx practitioner

Nutrigenomics RDs were highly trained and experienced (Table I), and were self-employed within private practice, or working in a clinic employed by a general practitioner for clients who were self-insured or had their own companies.

Agency/self-efficacy: acquiring the skill base. The RDs had actively sought and engaged in activities associated with continuous professional development, which enabled them to learn more about NGx. Becoming part of the wider scientific culture was considered key to keeping up with the rapid scientific advance associated with NGx, and crucial to best practice. Consistent with diffusion theory, adoption of nutrigenomics was perceived to be driven by the RDs themselves through collaboration and communication with one another and between the technology and users. Participants spoke of attendance at scientific conferences that were not exclusively dietetic which provided opportunities to network, actively seek out new knowledge and share it with interested professionals both within and beyond dietetics:

Okay, so what happened is that I went to an Expo in the United States [...] that was the first time I really knew about nutrigenomics [...] this was five years ago. Then I started to study a bit more [...] reading by ourselves (FG1, Mexico).

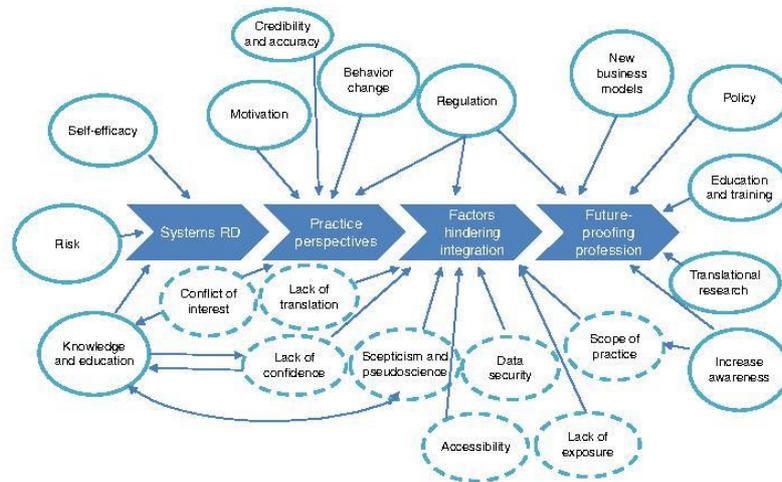


Figure 1. Profiles, perspectives, attitudes and experiences of early users, thematic analysis

This sense of agency appeared to be underpinned by interests beyond dietetics (e.g. sports science, complementary medicine) which widened their knowledge, skill set and worldview:

I was busy with the herbal medicine degree and I started getting a lot of publishing or papers on nutrigenomics and [...] it did spark my interest (IV1, South-Africa).

Agency/self-efficacy: applying existing skills. The RDs claimed to possess a wide skill set which reached into various ancillary fields rendering them competitive in the nutrigenomics marketplace. They reported being able to apply existing skills and acquire new ones. Diffusion theory holds that innovation decision processes such as initial knowledge are important for adoption. The consensus was that RDs already possessed the skills required to deliver personalized nutrition, such as counseling clients “one to one” and translating information into practical solutions (e.g. menus). NGx was considered merely an add-on to the range of tools already at the disposal of the RD:

[...] at the end of the day we are giving menus and we are all doing the same kind of approach with the patients of giving one on one visits and everything. I think what makes us different it is that we use a DNA test (FG1, Mexico).

Whilst nutrigenomic practice was new, there was agreement that RDs were in effect already providing such advice, and required no new skills apart from a basic understanding of genetics:

I'm not sure that you need any different skills because the skill has always been to translate the person's medical or social or other issues into something practical that they can use to improve their nutrition (IV5, Australia).

Perceived skills already held also included “passion” for the science and having the “self-confidence” to apply and deliver it:

Passion for the subject, I think, is the main skill (IV6, South-Africa).

It's just the only skill they need is self-confidence – that they are qualified to do it (IV4, Australia).

These findings are consistent with those of previous quantitative research that found skills and experience were associated with pre-adoption of novel technologies among health professionals (Aarons *et al.*, 2011). Whilst previous research on RDs has suggested that integration of NGx into practice may be commercially driven through the sale of tests (Cormier *et al.*, 2014; Li *et al.*, 2014), drivers included their keen interest in technology, “love” for the subject and desire to add value to what they offered their clients.

3.2 Experiences of NGx in practice: becoming empowered and engaged

Our participants conveyed positive experiences of applying NGx in practice and noted how it excites and motivates clients and brings about compliance with personalized advice:

[...] when it is personalized, you know that it is based on your genes, and you really get this sense from people like they're interested in it, they're excited, they understand what changes they need to make [...] it's very motivational (FG2, Canada).

This aligns with previous research which found that personalized information improved healthy eating indices (Celis-Morales *et al.*, 2016) and adherence to a Mediterranean-type dietary pattern (Livingstone *et al.*, 2016). Diffusion theory holds that aspects of the technology such as observability of results are important for its adoption (Ronteltap *et al.*, 2007). Using nutrigenomic testing with clients was perceived by the RDs to enhance their confidence, render them more engaged as therapists and enable “different” practice:

Because I have more confidence in the exact recommendations I'm giving them. I might actually be counseling differently – for whether they had a nutrigenomics test or not (FG2, Canada).

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Confidence in using the new technology mirrors existing survey studies which indicated that lack of confidence was associated with low involvement in NGx (Collins *et al.*, 2013; Oosthuizen, 2011; Whelan *et al.*, 2008). Whether this was a response to personalized recommendations, or the style of delivery, is unclear. That the RDs felt more engaged when a client had undergone NGx testing could explain dietary change in their clients. It is generally accepted that healthcare professionals play an integral role in bringing about behavior change in consumers (Rankin *et al.*, 2017; Solas *et al.*, 2016). As “diffusion of innovation” theory would suggest (Peterson *et al.*, 2007), the RDs appear to be “champions” of the technology and acting as “agents” in its application. Further research is required to unravel the effect of the messenger (practitioner) from the message (genotype) and the technology applied.

3.3 Perceived barriers to integration of NGx into dietetics practice

Challenges faced by RDs in integrating NGx technology into practice related to social norms associated with the professional context of practice, the perceived research-translation-practice gap and the need for regulation and practice guidelines.

Perspectives on the wider dietetics and medical professions. Diffusion theory postulates that attitude toward and acceptance of new technologies is the result of a trade-off between the perceived cost/risk and benefit of doing so (Ronteltap *et al.*, 2008). Where risk is perceived, especially where knowledge is considered limited, as is the case with nutrigenomics, there can be uncertainty about the potential benefit of the technology. Participants in the current study reported differences between RDs in private and public practice in their tolerance of risk and uncertainty which were perceived to limit application of nutrigenomics. It was felt that there was little recognition of NGx by the wider scientific and medical community who were perceived as risk averse and lacking a sense of adventure rendering them unresponsive to emerging science affecting nutrition. This apparent “us and them” view of dietetics practice may reflect a perceived differing culture between RDs who worked in independent private practice as opposed to those employed in public health services. This implies some dissociation between early adopters of NGx and the wider dietetics profession. Terms such as “conservative,” “fear,” “scary,” “lack of awareness,” “confused,” “less flexible” and “reluctance” were used when referring to the wider profession:

Overall I think the dietetic professionals tend to be a little bit [...] less adventurous in terms of finding out what works for a patient. They're less flexible (IV1, South-Africa).

There was awareness of misperceptions widely held among peers of what NGx comprises, as well as a narrow view of what falls within the scope of dietetic practice. Nutrigenomic testing (focused around personalizing diets for health), tended to be confused with disease risk prediction and reduction (associated with disease outcomes and therefore not considered within dietitians' scope of practice):

And then some people just really not knowing what it's about at all, [...] or thinking that it's too much about predicting disease, which it's not. And I think there's a lot of confusion. Education is huge here (FG2, Canada).

Perceived negativity toward NGx was also attributed to skepticism among the wider profession about the efficacy of novel technologies. This perspective fits with diffusion theory which holds that characteristics of the technology pertinent to adoption are likely to be related to its perceived efficacy (Ronteltap *et al.*, 2007):

The response has always been, “well, that's not something that we necessarily learned” and “how scientifically proven is it?” (IV6, South-Africa).

There was consensus that despite enough evidence for the efficacy of NGx at this time, disinterest prevailed among the wider profession:

Early-adopting
registered
dietitians

[...] you're meant to be evidence-based but you're not being evidence-based" Because if the evidence is there, why not adopt it? I find they're not quite interested (IV4, Australia).

As diffusion theory (Peterson *et al.*, 2007) would imply, there was a consensus that communication was needed to address misperceptions of the science among the wider profession. Meanwhile, there was awareness that acceptance of nutrigenomics among peers was growing and that attitudes were gradually becoming more positive:

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So, when I first started out, the perception was incredibly poor [...] "that's a bit of a dodgy space, isn't it?" [...] As times moved on, acceptance or the realization that actually, this is an area, an actual area of science, and it's important for nutrition as a whole [...] that perception has definitely grown (IV3, Australia).

Science vs pseudoscience. Whilst it was accepted that the science of NGx was (at the time of data collection) developing, it was agreed that there was sufficient current evidence to make actionable recommendations. Perceptions of risk and uncertainty are important for the acceptance or rejection of new food technologies (Ronteltap *et al.*, 2007). The perception of an innovation as low risk has previously been shown to increase pre-adoption of novel technology in allied health professions (Mitchell *et al.*, 2010; Greenhalgh *et al.*, 2004). NGx was considered low risk because it is entirely evidence based and targeted towards the promotion of health rather than disease risk reduction:

We're just trying to make a diet more precise according to your DNA. We're not taking on the whole, you know preventing major illnesses (FG2, Canada).

There was a consensus that the wider dietetics profession considered NGx as "pseudoscience," thus was restricting application in practice. This echoes previous research indicating that NGx is not considered relevant to the practice of clinical dietetics (Li *et al.*, 2014; Christianson *et al.*, 2005). Participants felt that they were competing in a marketplace awash with unregulated and diverse offerings, some based on weak or non-existent science and prescribed "fad diets" delivered by less-qualified nutrition practitioners often promoted by celebrities:

I think we're facing a huge challenge in the social media space where anyone who's a celebrity can say "Look at me this is the diet I follow. Isn't this fantastic?" You know the most ridiculous people promoting the most ridiculous diets and people believe them over traditional dietitians or science, true science (IV5, Australia).

Proliferation of unregulated niche commercial offerings was perceived to have fueled skepticism toward nutrigenomics among the dietetics profession and was blamed for lack of recognition among the wider scientific community:

I think there's a lot of skepticism, is this yet another fad? And there are companies that are doing really obscure stuffs in all sorts of areas (IV5, Australia).

There was a perceived need for clearer practice guidelines to enable consistent use of genomics terminology, especially across countries:

What I find challenging is the lack of guidelines of best practice out there because the results they're not "one-size-fit-all". They still depend on the context of it – the health context of the patient themselves. I mean, the environment plays such a large role (IV3, Australia).

The International Society of Nutrigenomics and Nutrigenetics recently published guideline papers to ensure that the field is communicated scientifically and accurately (Ferguson *et al.*, 2016; Kohlmeier *et al.*, 2016).

Research-knowledge-translation gap. A perceived gap between the body of research knowledge and how to apply it was considered a contributing factor to the lack of translation of NGx into practice:

But what I find lacking is the translation into practice or the interventions – what to actually do about it (IV3, Australia).

There was the view that the only way to learn about NGx and for personalized nutritional science to advance, research and practice should be integrated as far as possible. This notion of “research in practice” could be a function of the autonomy that working in private practice affords practitioners:

Someone’s gotta jump first, right? Cause you won’t have evidence until people are jumping. It’s like you can’t expect there to be enough evidence if people aren’t using it (IV4, Australia).

Consistent with the notion of innovation diffusing through a community by means of “champions” (Peterson *et al.*, 2007), a future was envisioned in which they, as leaders in the field, would play a crucial role in ensuring that translational research is conducted by RDs, helping to build the evidence base.

3.4 Preparing for the future

Diffusion theory (Peterson *et al.*, 2007) emphasizes communication between stakeholders in the adoption of innovation. Accordingly, sub-themes on the future of NGx related to training and education, application in practice and the need for new models of service provision.

Education. Teaching of nutritional genomics at undergraduate level, with courses delivered by those with practical experience in the field, was considered crucial to ensure that the translational aspect was included during clinical placements (Wright, 2014). This view is consistent with recent calls for a more integrative and functional approach to the dietetic curriculum (Augustine *et al.*, 2016). Incorporation of novel technology into curricula has been positively associated with adoption of new innovations among various professions (Aarons *et al.*, 2011; Mitchell *et al.*, 2010; Greenhalgh *et al.*, 2004). Participants believed that nutritional genomics should be part of the undergraduate core curriculum, delivered by experts with experience in the field. A concern was that dietetics’ could be “left behind” as the science advances:

If they keep being behind, one day it will be a lot of studying to do [...] in 5 years or even a year later, if you want to get into nutrigenomics there’s been more and more information. And the barrier would be that yes you have to study (FG1, Mexico).

There were also concerns that not enough emphasis was placed on the relevance of nutritional genomics to dietetics practice, which could be more extensively covered in the curriculum:

You know, if you think of the – four years that we study, it’s kind of like mentioned in passing in one of the lectures. And, because it’s not part of the standard teaching [...] the fresh ones just out of varsity, think that it is irrelevant (IV1, South-Africa).

Lack of exposure to NGx in undergraduate education was considered a threat to translating the science or practice in a safe environment before graduation. The current curriculum was viewed as requiring integration of newer scientific advancements which overlap with nutrigenomics (e.g. metabolomics and metagenomics). Internships were suggested as potential solutions to bridging the research/practice gap:

Yeah, I would agree that this is the future of dietetics. I feel like it’s going to be the younger generation that really picks up on it. And I do see it becoming a more common component of the curriculum at the undergraduate level and having it more into internships and things like that (FG2, Canada).

Models for delivering personalized NGx services. Another important insight was that, following initial contact with clients to explain the genetic results and provide nutritional recommendations, discussants preferred to hand over long-term counseling to another RD who specialized in dietary behavior change. An ideal model was one that embraced a team approach whereby clients/patients would first be seen by a “systems” RD who would go through their genetic, metabolic and other profiles using a precision nutrition approach. This would be followed by a counseling RD who would help them to make the recommended dietary changes:

Or nearly, when the nutrigenomics dieticians work with other more traditional dieticians, when they come in and they do that consult and then the other dietician takes over. That would be a better model (IV4, Australia).

This approach would fit with the proposed business models outlined in the Food4me White Paper (Food4me, 2015) and with diffusion theory (Peterson *et al.*, 2007), whereby RDs act as “connectors” for other health professionals. Hubs of practitioners would then interpret results, translate the science and provide support to other healthcare professionals who would communicate personalized dietary advice (online or otherwise). Although the viability of this model would need assessment, it could fit well within public healthcare systems and commercial services (Stewart-Knox *et al.*, 2016).

Limitations of the commercial model. There was some discomfort about dietetics becoming integral to commercial offerings in that it may cater mainly for the wealthy, worried, well (Fischer *et al.*, 2016) and could exclude economically disadvantaged clients and that this could deter adoption among practitioners working in the public health sector. Consistent with previous research on potential consumers of NGx (Stewart-Knox *et al.*, 2016), discussants referred to growing concern around health inequalities and the imperative for the benefits of precision nutrition approaches to reach those who need it the most:

And then, if anyone affiliated with the company, perhaps? There’s that – it’s seen as a bit of a conflict of interest, mistrust because we know a lot of, you know, industry partnerships have turned out badly. And I think the public and professionals, including dieticians, are very hesitant about things that are seen to be, you know commercialized (FG2, Canada).

It was anticipated that national healthcare systems would play an important role in the provision of personalized nutrition services (Stewart-Knox *et al.*, 2016; Fallaize *et al.*, 2015). In the UK, for example, health services are free at the point of contact, clients will expect NGx to be provided free of charge.

Optimism. Nutrigenomics was seen as a positive force in dietetics and one that (by definition) is tightly evidenced based. Adding nutrigenomics services to an offering had potential to keep dietetics “relevant,” while slow uptake of NGx was considered detrimental to the profession’s credibility in the field:

We have to be so evidence-based and anything in the periphery, you’re gonna lose as far as your credibility and your reputation [...] (FG2, Canada).

Despite the perceived lack of support from dietetics peers and wider health professionals, the RDs remained determined and optimistic, another key trait of early adopters (Wisdom *et al.*, 2014):

It’s definitely not one of those fads or trends. Um it’s just booming [...] and think it’s going to be huge, a huge thing in the future (FG2, Canada).

All participants were either self-employed or working in the private sector, where practitioners had autonomy to use NGx. Early adoption of the technology, therefore, was unsurprising in view of the “diffusion of innovation theory” whereby those with greater

control to create change, are more likely to adopt innovation (Peterson *et al.*, 2007; Backer *et al.*, 1986). This could potentially explain the low application of NGx in public health organizations (Collins *et al.*, 2013; Whelan *et al.*, 2008) where strategic decisions regarding practice would be centrally managed. Whereas innovation can diffuse “bottom-up” from champions at the practice end (Peterson *et al.*, 2007), top-down leadership can be negatively associated with adoption of new technologies (Backer *et al.*, 1986). This suggests that for NGx to become mainstream new models for innovation management may need to be considered.

4. Conclusions

This research has sought insight into the experiences and perspectives of RDs who have taken the leap and ventured into NGx practice. Early adopters of NGx were experienced, self-efficacious RDs who actively sought knowledge of NGx through communication at conferences and other media. By virtue of being in the private sector they had autonomy and were able to apply their new knowledge in practice. NGx was considered an extension of current practice for which RDs already had the skills. Perceived skepticism among peers about the efficacy of NGx was perceived to deter adoption of NGx and was blamed on the unregulated proliferation of websites offering tests and “fad” diets. Reluctance to adopt nutrigenomics among the wider dietetics community was also attributed to concern about the potential to widen health inequality by catering to the worried well to the neglect of sustainable public health models for delivery of services to the wider population (Fischer *et al.*, 2016). None of the RDs practiced across national borders so worked along-side national healthcare provision which apparently varied in the level of service offered. Interviewees in the UK and Israel referred to how NGx testing seemed far removed from national healthcare provision, which focused on treatment of acute chronic diseases to the neglect of health promotion and prevention. In Australia and South Africa, in contrast, private medical insurance in some cases allows earned reward points to be used to purchase NGx tests so that no “out of pocket” spend is required. In the Canadian focus group, one participant mentioned how their healthcare system allowed individuals could buy a test privately and be later reimbursed for the dietetic consultation.

Themes fitted well with diffusion of innovation theory. Ronteltap and colleagues (2007) extended diffusion theory and proposed that acceptance of nutrigenomics will depend upon not only risk and uncertainty, communication and characteristics of the technology, but also the degree of perceived control the user may have over the test results and the subjective norm. By virtue of being independent practitioners, the RDs in our study would have sufficient autonomy (perceived control) to translate nutrigenomic results into prescribed behavior and thereby diffuse the technology “bottom up.” The subjective norm (what others are perceived to be doing) in this case among the wider dietetics profession was one of “lacking adventure” and of being managed “top-down,” effectively constraining the ability of RDs to introduce novel technologies into practice. Adoption of nutrigenomics, therefore, may depend upon whether the user is in private or public practice.

Previous qualitative research involving stakeholders implied that adoption of nutrigenomics could rely upon effective commercial exploitation (Ronteltap *et al.*, 2008). This study, therefore, is appropriate, timely and novel in providing a window into the perceptions and experiences of NGx derived from the accounts of practicing RDs. Although this study has taken an international perspective, as with all qualitative research, the results are not generalizable to the general dietetic population and may require testing by quantitative means. Another limitation was that, because data were gathered online without video, there was no way to gauge non-verbal communication. Owing to time zone differences, some participants were interviewed individually whilst others were part of a focus group. Whereas focus group discussion could have been influenced by groupthink

causing discussion to reach consensus and limiting the diversity of opinion expressed (Silverman, 2013), Interview may have enabled individuals to express their personal experiences, opinions and feelings (Fielding, 1994). Combining focus group with individual interviews will have reduced any such biases on data quality (Lambert and Loiselle, 2008). No cross-national differences were observed in approach to the topic. It was clear that adoption of NGx was strongly linked to interest in the field irrespective of country. Those who were more experienced in the field, however, tended to be more vocal in the focus groups. In the Mexican focus group, the leading practice and training RD was more vocal and appeared more comfortable in expressing her thoughts in English. This was managed by the interviewer who ensured that all participants had an opportunity to speak and that a range of opinions were voiced. There was the possibility that sending the invitation to participate through the company CEO could have inhibited discussion of matters specific to the commercial sector. That RDs in our sample all worked in private practice, may have biased responses. Reflecting the controversial nature of the topic, some of the quotes could be perceived as provocative. The perceived views of those working in public services, for example, were referred to at length, implying a need for future research to better understand the views of those RDs working in various public healthcare systems. Another bias was that all participants were female. Whilst males make up a smaller percentage of the dietetics profession, they may have a different perspective and are worthy of study. That the researcher is a practicing NGx RD and known to some interviewees could have affected the dynamic and influenced responses. Any bias in data analysis, however, was minimized through the inclusion of a second analyst who was not an RD. As data saturation was reached with 12 participants from six different countries, it is unlikely that further novel insight could have been found by including more participants.

Our findings have implications for dietetic practice and health policy. Regulation was a concern for the practitioners and one that has previously identified among consumers (Fischer *et al.*, 2016). Whilst it may be easy for RDs to identify reputable companies, guidance may be required for new professionals entering the field (Backer *et al.*, 1986). Perceived negativity among the dietetics profession could also be addressed through tighter regulation of the industry and formal recognition by professional bodies. Actions are required to link teaching, research and practice to address the translation gap. As part of their professional development, for example, established dietitians could attend scientific conferences enabling networking and exchange of ideas with the wider scientific community. RDs should also be encouraged to apply existing skills to new approaches to therapy. Meanwhile, to address health inequalities, more inclusive models for the delivery of NGx will be required. As the prospect of a precision healthcare era becomes increasingly likely in the short term, RDs will be key to the successful application of emerging novel nutritional technologies. Further research is required in order to better understand the modifiable traits and skills of early adopters within group which can be instilled among the next generation of practitioners to future-proof the profession.

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Review

Personalized Nutrition Approach in Food Allergy: Is It Prime Time Yet?

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Abstract: The prevalence of food allergy appears to be steadily increasing in infants and young children. One of the major challenges of modern clinical nutrition is the implementation of individualized nutritional recommendations. The management of food allergy (FA) has seen major changes in recent years. While strict allergen avoidance is still the key treatment principle, it is increasingly clear that the avoidance diet should be tailored according to the patient FA phenotype. Furthermore, new insights into the gut microbiome and immune system explain the rising interest in tolerance induction and immunomodulation by microbiota-targeted dietary intervention. This review article focuses on the nutritional management of IgE mediated food allergy, mainly focusing on different aspects of the avoidance diet. A personalized approach to managing the food allergic individual is becoming more feasible as we are learning more about diagnostic modalities and allergic phenotypes. However, some unmet needs should be addressed to fully attain this goal.

Keywords: food allergy; avoidance diet; nutrition; personalized nutrition; phenotype; microbiome

1. Introduction

The true prevalence of food allergy is still unclear: a systematic review of challenge proven food allergy (FA) prevalence in Europe estimates a very low prevalence of FA of 1% [1] compared to single center studies reporting challenge proven prevalence figures of up to 10%. The latest paper on the prevalence of food allergies in children in the USA reports the number of reported FA of 7.6% in children [2] and 10.8% in adults [3].

A small number of foods, such as milk, egg, peanut, tree nuts, wheat, soy, fish, and shellfish, are responsible of most of IgE mediated allergic reactions [4,5]. These reactions are induced by allergenic proteins in the foods and are characterized by rapid onset (usually <2 h). These foods can provoke severe reactions, especially tree nut and peanuts [5,6]. Clinical reactivity to carbohydrates in mammalian meat is an exception—symptoms can be delayed for as long as 6 h [7].

The cornerstone of the management of FA still relies on avoiding the culprit food, since accidental ingestion of the offending food may lead to symptoms including serious and potentially life-threatening reactions, like anaphylaxis [8].

The management of food allergies has seen major transformations in the last decade. It is increasingly clear that the avoidance diet should be tailored according to the patient FA phenotype [9]. Better characterization of FA phenotypes could help to personalize the dietary management of FA by the degree of avoidance required.

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Furthermore, there is a greater focus seen on tolerance induction and immunomodulation by microbiota-targeted dietary intervention to allow for greater control of allergies. In the era of precision medicine, the field of precision nutrition involves tailored nutritional recommendations to the individual. To plan personalized nutrition advice for patients with a food allergy, many factors including clinical history, type of allergen, sensitization profiles, threshold level, dietary habits, food preferences, physical activity, microbiome and genotype should all be considered.

In the field of food allergy, some of these factors are better-defined thanks to new diagnostic molecular technologies [10]. Allergen-component resolved diagnostics (CRD) allows differentiating between a true food allergy from pollen-food syndrome or clinically irrelevant sensitization. CRD may predict the risk or severity of allergic reactions to specific food by identifying IgE to epitopes within an allergen source. However, many other components necessary for dietary guidance are poorly understood and need further investigation to be incorporated into clinical practice.

In this review, we will focus on the nutritional management of IgE mediated food allergy, the avoidance diet, state of the art tools/therapies, and the remaining knowledge gap.

2. Making an Accurate Diagnosis: The First Step Required to Develop an Avoidance Diet

The first step in the diagnosis of a FA is to distinguish IgE-mediated from non-IgE-mediated reactions. Most IgE caused reactions occur rapidly (minutes up to 2 h after ingestion) with the rare exception [11]. Anaphylaxis is the most serious allergic reaction; it is rapid in onset, life-threatening, and potentially fatal [12]. Different geographical locations show some differences in food allergen triggers for anaphylaxis. A recent one from Spain suggested milk and eggs allergies are more severe than nuts in their population [13].

Unlike IgE mediated, non IgE-mediated reactions are typically delayed from hours to weeks after ingestion of the culprit food(s) [11].

A thorough clinical history is central in diagnosing FA. Components of this history should ideally include food recalls, as well as timing, characteristics, and severity of symptoms. If the history suggests an IgE mediated food allergy, skin prick tests (SPT) or food-specific IgE blood tests can be used to confirm allergy diagnosis [5,14]. A positive test result does not confirm an IgE-mediated allergic reaction, whereas a negative test, with rare exception, eliminates it [15].

In addition to the SPT and specific IgE tests, oral food challenges (OFC) and CRD are important tools for allergy diagnosis. OFC remains the gold standard to confirm clinical reactivity, in most cases [16,17]. Component-resolved diagnostics helps further define specific allergens and reduces misdiagnosis due to cross-reactivity [18,19]. The usefulness of these tools can be explained through the classic example—wheat allergy. Wheat allergy is often over diagnosed, due to the low specificity of wheat IgE testing [20,21]. A patient with a grass pollen allergy may have elevated “wheat IgE levels” while being wheat tolerant [22]. Therefore, both CRD and OFCs should be implemented in children with an SPT or IgE positive wheat allergy. CRD increases the accuracy of wheat allergy diagnosis by identifying the presence of specific IgE to omega-5 gliadin, the antibody highly specific to wheat allergy [23]. Currently, oral provocation with wheat is the reference test for the diagnosis of wheat/cereal allergy as it definitely shows if a child will tolerate wheat.

Additionally, profiling the specific IgE repertoire by CRD may help identify falsely diagnosed allergies in highly polysensitized patients. This can be explained with the case of patients with allergen extract positive but negative genuine components. In children with multiple sensitization to tree nuts, including hazelnut, positive IgE extract but negative IgE genuine component are markers of a probable cross-sensitization with grass pollen. These patients are very likely to be tolerant to hazelnut *in vivo* [24]. CRD has become a useful tool for diagnosing FA, though the use of these tests varies from country to country.; This technique has some limitations that should be considered. For instance, the allergens are in a recombinant form and not always show the same IgE reactivity that natural allergens. This is even more relevant in food allergy testing as the allergens used in the reagents

are processed. Indeed, the oral food challenge (OFC) is the only effective method to confirm the FA diagnosis, although the other preliminary diagnostic techniques could support the diagnosis.

3. Risk Assessment and Individual Threshold Level

In general, for IgE mediated-food allergy it is very important to identify patients who are likely to have severe reactions from patients with mild to moderate ones. Unfortunately, as allergy severity is multifactorial, this is difficult. Possible contributors to severe reactions are allergen bioavailability, patient habits (e.g., Exercise [25]), and history of anaphylaxis—although many people who have a history of only mild symptoms can develop anaphylaxis. Allergen-specific IgE levels and CRD may assist in risk assessment as sensitization to some allergenic molecules is more likely to be related to systemic rather than local reactions.

For instance, high levels of casein IgE has been shown to correlate with severe reactions, due to accidental exposure, in cow's milk allergic children [26]. Similarly, an association between specific IgE to omega-5 gliadin component and severity of reactions during wheat challenge has been reported [21, 27]. In peanut allergic children, Eller and Bindslev-Jensen documented that symptom severity elicited during challenge correlated significantly with the levels of Ara h 2 ($r(s) = 0.60, P < 0.0001$) [28]. However, patients with very low or undetectable sIgE may still experience severe allergic reactions [25,29].

The OFC allows us to ascertain information about individual threshold level can guide the necessary level of food avoidance.

For instance, the challenge food for baked milk contains 1.3 g CM protein (equivalent to 40 mL CM), and children who react during their CM OFC should avoid it completely due to their severe phenotype [30].

Lieberman et al. showed that 66% of the patients with egg allergy undergoing baked egg OFC tolerated baked egg and that most of the reactions were mild and treated with antihistamine alone, regardless of sIgE and/or SPT. [31].

In our opinion, performing OFC with baked milk or egg in a controlled-setting has the potential to greatly improve children's quality of life [32].

4. Avoidance Diet: Towards Personalized Nutrition Advice

Managing food allergies and avoiding food allergic reactions involves an individualized approach to food allergen avoidance while providing sufficient nutrition [33].

An avoidance diet is a complex undertaking that requires education about label reading, cooking, preventing cross-contamination, and communicating information to family, caregivers, friends, and restaurant personnel [34,35]. See Table 1

Table 1. Nutritional management according to risk assessment: What are the challenges?

Challenges of the Nutritional Management According to Risk Assessment
- local availability of food
- lack of understanding about foods to be avoided
- unexpected allergens in foods
- prepacked foods with inadequate allergen labeling
- defining “baked” milk and egg
- identify the “eliciting dose”
- risks of over restrictive diet
- potential long-term effects on health and quality of life

The standard information that should be provided to all patients includes advice on food labels and relevant labeling laws, hidden allergens, and suitable replacement foods [36]. However, avoidance

advice should be individualized considering individual tolerances, cross-reactivity, and specific allergens that drive the reaction. Allergies to novel allergens such as alpha-gal will also require individualized avoidance advice.

Individualized Allergen Avoidance

4.0.1. Milk and Egg

It is known that a large proportion of children with cow's milk and egg allergies will be tolerant to baked milk and egg irrespective of the age or population studied [37]. Baked milk or egg-containing foods typically refer to muffins, but other forms such as cookies, waffles, and pancakes have also been suggested. Baked cheese (pizza) has also been suggested for baked milk challenges [38–43]. No established guidelines to determine when to challenge have been established, so testing depends on combination of history, sIgE, and skin test results. There is limited consensus about the exact time and temperature of baking/cooking that is required, the need for a wheat/starch matrix, and where the challenge/food reintroduction should be conducted, e.g., hospital/in-office vs. at home [44–46]. It is, however, important to realize that some children who react to baked milk or baked egg may experience severe symptoms, requiring epinephrine. [31,32,46]. Risk factors for severe reactions to baked foods need further clarification but may include asthma requiring preventative treatment, multiple IgE mediated food allergies, and a history of anaphylaxis. [45,47]. Baked milk and egg-containing foods are successfully introduced at home in most children's diets post a negative challenge with good compliance; positively affecting the child's food and texture repertoire [48]. However, as it is unclear if continued and regular consumption of baked milk and egg-containing foods will speed up tolerance to uncooked milk or egg [49,50], families should not be pressured about frequent intake unnecessarily.

4.0.2. Peanut, Tree Nuts, Seeds

Previously, patients with peanut or tree nut allergies were advised to avoid all nuts, due to the risk of cross-reactivity or possible cross-contact/contamination. However, recent studies indicate that clinical cross-reactivity may be as low as 30% [51]. For instance, walnuts and pecans are highly cross-reactive with each other, but not with peanuts, hazelnuts or almonds Sensitization or clinical allergy may develop after a period of unnecessarily exclusion [52]. The British Society for Allergy and Clinical Immunology (BSACI) guidelines were the first food allergy management guidelines to recommend active inclusion of tolerated nuts in diets of individuals with peanut or tree nut allergy [53,54]. Peanuts are legumes, but allergy to other legumes is generally uncommon among those with peanut allergy, though this does depend on geography and local diet [55,56]. Lupine, pea, and soybean show some apparent cross-reactivity for patients who are highly allergic to peanut, although it is very difficult to separate cross-reactivity from de novo sensitization. The risk of cross-reaction may be higher for lupin than for other beans, particularly in Europe [57–59]. In the case of lupine allergy, patients need to be informed about foods containing lupin which may include pies, certain breads, and pastries.

Seeds are being used more often in commercial and gourmet foods—most commonly flaxseed, sesame, sunflower, poppy, pumpkin, and mustard seeds [60]. Sesame and mustard seeds are among the 14 most prevalent allergens in the EU, but not in the US [61]. In Europe, prevalence data indicates sesame and mustard seed allergies are geographically disproportionate: high in some areas (France and Spain), much lower in others (Germany and the Nordic countries) and unknown in Eastern Europe [62]. Mustard and sesame seeds are often hidden in commercial foods, making scrutiny of labels required at all times. Sesame seed allergy is not commonly seen outside of Israel and Europe [63]. In addition to scrutiny of labels, children with sesame allergy should always avoid sesame oil as it is cold/expeller pressed [64].

4.0.3. Fruit and Vegetable Allergies

Allergies to fruit and vegetables, in particular, require individualized advice as symptoms range from milder symptoms triggered by pollen-food syndrome (PFS, secondary IgE mediated food allergy) to more severe symptoms triggered by lipid transfer protein syndrome (LTP, primary IgE mediated food allergy) [65]. It is important to differentiate between these two presentations of fruit and vegetable

allergies as that will direct the dietary advice given. With PFS, cooked, canned, baked, microwaved fruit and vegetables are allowed, whereas fruit/vegetable should be completely avoided in the case of LTP allergies. The degree to which cross-reactive fruit and vegetables (including soy and nuts) should be avoided requires careful diagnostic evaluation as blanket avoidance advice is not advocated [66–68].

4.0.4. Fish and Shellfish Allergy

It is important to distinguish between fish and shellfish (crustacean and mollusks) allergies. Fish and shellfish allergies may co-exist [69] but the main allergens differ, and cross-reactivity between fish and shellfish is unlikely. The main allergen in fish is β parvalbumin; in the case of shellfish, the major allergen is tropomyosin [70]. Additionally, allergy to a certain fish or shellfish does not imply allergies to all species in that particular group [71,72]. Subjects who suffer from fish allergy have only about a 50% probability of being cross-reactive to another fish species. This is significantly lower than those with shellfish allergies, who have up to a 75% chance of cross-reactivity [15]. In addition to the allergens derived from fish themselves, fish contaminants, such as the parasite *Anisakis*, can also cause allergic reactions, meaning *Anisakis* allergy can be falsely diagnosed as a fish allergy. In particular, *Anisakis* allergy correlated to prevalence of parasitic infection in fish—for example, in Spain and Southern Italy, there is a higher prevalence of *Anisakis* allergy due to moderately frequent *Anisakis* infection. These allergic patients develop IgE against tropomyosin from *Anisakis*. As always, sensitization depends in part on the consumption pattern of fish (cooked, undercooked or raw) and the infection pattern of fish in the local region [73].

4.0.5. Alpha-Galactosidase

Alpha galactosidase (Alpha-gal) allergy is characterized by delayed (4 to 6 h after the ingestion) hypersensitivity reactions to mammalian meats and is mediated by IgE antibodies to the oligosaccharide galactose-alpha 1,3-galactose. It requires avoidance of mammalian meats and their organ meat. Some individuals also need to avoid ice-cream, milk, and milk products but the degree of avoidance and foods being avoided should be discussed with the allergist. This decision can be made based on past history of reactions or tolerance [74,75]. Where the history is unclear, or the food has not been eaten in the past, an oral food challenge can be conducted [76].

5. Nutritional Impact of Food Allergies: Growth and Nutrient Intake

There is rising concern that children with FA have an insufficient nutrient intake or nutrient imbalance leading to adverse health implications. Data published over the past few years indicates that children with food allergies (IgE, non-IgE, and mixed presentations of IgE and non-IgE) show growth impairment, both in weight and length. They are often underweight [77], and in the case of chronic malnutrition, they become stunted, e.g., a child who is too short for his/her age [78,79]. However, excessive weight gain has also been reported in children with food allergies, but poorly researched [77,80,81]. A recent international survey conducted by Meyer et al. [82] included 430 patients from twelve allergy centers world-wide. The pooled data indicated that 6% were underweight, 9% stunted, 5% undernourished, and 3–5% were overweight. In this study, growth impairments varied by allergy profile. Children with cow's milk allergy (CMA) had a lower weight for age z-score, as a result of acute malnutrition or “wasting”; children with mixed IgE and non-IgE mediated FA were stunted, and children with only non-IgE FA were underweight with lower body mass index (BMI). Very different growth patterns were observed between children from different countries. Atopic comorbidities did not affect growth.

Avoidance diets required for FA management place children at risk for potential inadequate nutrition. In this regard, a number of studies have investigated the nutritional adequacy of elimination diets. However, most of them have been conducted in young children aged six months to four years. Children with food allergies (IgE, non-IgE, and mixed presentations of IgE and non-IgE) are also at higher risk of insufficient intake of protein, calories, vitamins, and minerals [83–87]. The micronutrients

implicated are iodine, calcium, and vitamin D, especially in children with CMA [83,88,89]. However, it has been shown that children with cow's milk allergies or multiple food allergies are able to achieve similar mean intakes of nutrients as healthy children when receiving nutrition counselling and substitution of nutritionally equivalent foods [78,83,90–92].

Limited data exist on dietary intake in teenagers and adults with food allergies, with contrasting results [93,94]. One study reports, higher intakes of calcium, iron, folate, and vitamin E have been demonstrated in participants >20 years with food allergy [44]. Conversely, lower intakes of calcium and phosphorous have been reported in young adults with CMA, with one study reporting that 27% were at risk of osteoporosis [48]. Maslin et al. showed no significant difference between these two groups and control groups with the intake of calcium. Iron, copper, zinc, selenium, and iodine were below the Recommended National Intakes (RNI) for both groups and their controls [94]. There are currently no data on BMI status on adults with IgE mediated food allergy. These factors need to be considered when providing nutrition advice to children and adults with food allergies. Although information on healthy eating is important, consideration to vitamin and mineral supplementation in hypoallergenic formulas in the case of children should be given [84,95]. Nutritional counselling and monitoring growth and development are crucial in the management of FA, as the avoidance diet may affect the well-being of FA patients (see Table 2).

Table 2. Effect of avoidance diet on patients.

Effect of Avoidance Diet
- poor growth
- micronutrient deficiencies
- altered taste perception
- long term effects on food preferences and choices
- reduced quality of life

6. Food Behaviour and Preferences

In children with FA, the development of their food habits and preferences takes place in the context of their chronic condition. Since parents have the main responsibility for the dietary management of their child's food allergies [96], their parenting style and the way they interact with the child during feedings both have an effect on a child's food habits [97]. A child's food allergies add a burden to parents [98]. Food refusal has also been shown to occur in toddlers with food allergies [99] and more specifically eosinophilic gastrointestinal disease [100]. Additionally, a study on children aged 5 to 14 years in France showed that children who have outgrown their food allergies are more reluctant to try new foods than their siblings [101]. Food neophobia and refusal could result from unnecessarily high dietary restrictions that parents place on their children due to increased anxiety and fear of an allergic reaction [102]. The long-term effects of avoidance diet on food behavior and preferences needs further investigation.

Food choice behavioral problems have been documented in older children or adults with food allergies. Teenagers with food allergies, strive to eat the same foods as their peers, often leading to risk taking behavior. However, they reported reluctance to try new foods when away from home. In contrast to the non-food allergic teens, those with food allergies felt that parental control over food intake was to protect them [103].

Adults with FA felt that their allergies limited them from the pleasure of eating and they often found it difficult to find safe foods. They also felt that the need to be constantly organized to have safe foods available was a burden [104].

7. Microbiota-Diet and Genetic Factors: A Complex and Still Unknown Interplay

FA is thought to be the result of a disruption of mucosal immunological tolerance, due to dietary factors, gut microbiota, and interactions between them [105]. Different bacterial taxa may be associated

with different food allergy subphenotypes. Differences in gut microbiome have been observed in subjects with tree-nut allergy in respect to those with cow's milk allergy [106,107]. The observed differences may however be influenced by age, population, sex and diet. Furthermore, recent data indicate that for cow's milk allergy, the microbiome differs between those children who are sensitized vs. not sensitized [108], those with clinical allergy vs. those with no allergy [109], and those who develop tolerance vs. those who do not [110]. Overall, these findings suggest the possibility to manipulate the gut microbiota with preventive or therapeutic purposes.

Data in pediatric studies indicate that certain pre and probiotics tested may address dysbiosis [111] and may even induce tolerance development [112]. More clinical trials regarding the use of pre and probiotics in the management of food allergies are needed before clinical recommendations can be made. These studies should also consider genetic background and age in their design. Another important issue to be considered is that the gut microbiome composition and diversity can be modulated by host genetic profiling [113]. A host's genetic composition is able to modulate their gut microbiota, which is another paramount area of study [114].

Whether diet diversity may improve dysbiosis and microbial diversity in those with food allergies remains to be seen [115].

Further studies need to investigate the complex interplay between the host genetic components and environmental factors, including the microbiota and diet, in the pathogenesis and expression of food allergy that is still largely unknown.

8. The Technology Revolution in FA Management

Increasingly, personalized devices to aid in allergen detection have been invented, and the industry has grown rapidly over the last decade [116]. These technologies have resulted both from increased demand for transparency of product information and scientific advancements. [117]. The rapid drop in the price of personalised nutrition devices has resulted in mass accessibility [118]. Deciphering food labels is a difficult task and for those with allergies, a daily chore that if done incorrectly, can lead to negative and possibly fatal outcomes [119,120].

New digital technologies have started to appear on the market that attempts to address the daily challenges families face when choosing products for a child with allergies. For a full review of technologies involved in portable allergy products, we refer readers to the comprehensive article by Ross, G.M.S [121]. There have been a number of technology services advising about potential risks related to food composition. For concerned consumers, having instant access to information can remove the guesswork and can potentially save time. However, there are no validated, personalized systems for testing individual meals for specific food source products. It is also noteworthy that sometimes component recipes change and accuracy as well of lack of clinical validation of these products are issues frequently raised.

With such rapid advances in the scientific and technology industry, it is, however, important to have comprehensive communication between consumer advocates, the food industry, and the clinicians to help improve avoidance of allergens by technical fixes, while being fully aware of the limitations and current lack of validation of these products in a variety of matrices or in foods with multiple ingredients (see Figure 1). What is clear, is that management of allergies will require the intervention of a specialist multidisciplinary team with registered dietitians playing a key role in supporting families while staying abreast of new technologies [122].

Some examples of products currently available on the market, outlining their pros, cons and future considerations, are listed below (Table 3).

Table 3. Personalized nutrition offering for Food allergies.

Currently Available Resources or Tools	Description	Pros	Cons	Future directions
Apps	Smartwithfood™, Spooonguru™, Foodmaestro™, Whisk™. These apps are available free to consumers. Through barcode scanning, image recognition, natural language processing and machine learning technology, consumers can obtain instant information whether a product contains allergens.	<ul style="list-style-type: none"> • These app scanners provide quick results that are easy to understand and can always be on hand. • They can provide peace of mind as a second line. • The platforms rely on food manufacturers to provide accurate product information in terms of their recipes. 	<ul style="list-style-type: none"> • The app only reports on a limited number of allergens. • The app is not a medical device and, therefore, cannot replace a medical professional's advice; consumers should always ask questions and always check the food label. 	<ul style="list-style-type: none"> • Apps should increase the number of allergens they have information about. • New products could ideally be developed based on the popularity of scanned products.
Food scanners	Scanners such as Tellspec™, Scioscan™ and Nima™ are handheld, mobile devices that use hyperspectral or imaging technology to analyse nutritional information and detect allergens.	<ul style="list-style-type: none"> • These scanners are small, provide quick results that are easy to understand. • They can provide peace of mind as a second line. • These products may provide some reassurance once standard allergen avoidance advice has been followed but should NOT be used instead of advice provided by the allergist or dietitian. 	<ul style="list-style-type: none"> • Costs can be prohibitive. • It is not a medical device and, therefore, consultation with a healthcare professional is still required. • Concerns have been raised about the accuracy in detecting allergens (Popping et al., 2017). • Scanners work best with homogenous solid products. For example, testing may be highly inaccurate in foods with multiple ingredients or high-fat matrices. • It is not clear who holds the data on these products. 	<ul style="list-style-type: none"> • These tools need to be clinically validated • These tools need to comply with medical devices regulation
Wearable devices	Such as Allergy Amulet™ is a device that is worn as a necklace and works by inserting strips into food, available in 2019.	<ul style="list-style-type: none"> • A mobile and attractive device that provides instant results. • These products may provide some reassurance once standard allergen avoidance advice has been followed. 	<ul style="list-style-type: none"> • It is not a medical device • It is important the consumers read labels and ask about ingredients to the dietitian. • Have not been validated for accuracy 	<ul style="list-style-type: none"> • Needs to be clinically validated. • In the future, potentially sensors or implants could detect from a nanoparticle of food.
CRISPR	Is the new technology which enables DNA of food (and humans) to be edited. This means that new foods and products can be developed where the culprit	<ul style="list-style-type: none"> • allergen's DNA has been edited without the devastating effects. 	<ul style="list-style-type: none"> • Consumers with allergies will have a wider variety of foods to eat 	<ul style="list-style-type: none"> • Technology is still expensive. • Some allergens can be removed. It is not clear how differentiating appropriately altered foods from native food sources. For some allergenic sources, such as wheat, the genetic complexity of the crop is unlikely to allow simple genetic knockout of allergenic genes.

Current lack of understanding of the long-term

impact of eating

gene-edited foods.

- Extensive public education will be required.
-

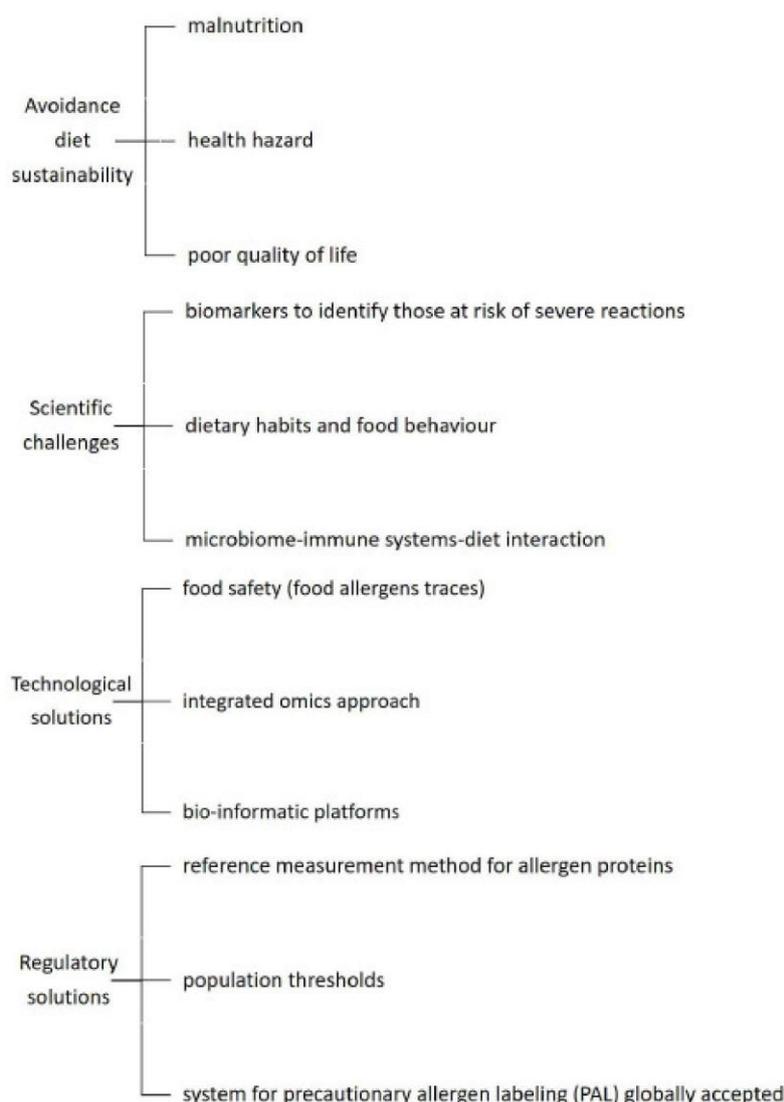


Figure 1. Nutrition approach: unmet needs.

9. Conclusions

A personalized approach to managing the food allergic individual is becoming more feasible as we are learning more about diagnostic modalities and allergic phenotypes. The availability of specialized foods and technology are increasing which also enables the clinicians to provide personalized advice. A multidisciplinary team approach, including a dietitian, is crucial to provide individualized recommendations to patients.

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**Personalised nutrition technologies and innovations: a cross-national
survey of registered dietitians**

3

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**10 Personalised nutrition technologies and innovations: a cross-national
11 survey of registered dietitians**

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16 Keywords: Personalized nutrition, dietitians, nutrigenetics, technology, practice

17

18 **Abstract**

19 **Background:** Commercial technology-enabled personalised nutrition is undergoing
20 rapid growth, yet uptake in dietetics practice remains low. This survey sought the opinions
21 of dietetics practitioners on personalised nutrition and related technologies to understand
22 facilitators and barriers to its application in practice.

23 **Method:** A cross-section of Registered Dietitians were recruited in the US, UK,
24 Australia, Canada, Israel, Mexico, Portugal, Spain and South Africa. The questionnaire
25 sought views on risk of genetic technology, ethics of genetic testing, usefulness of new
26 personalised nutrition technologies, entrepreneurship and the perceived importance of
27 new technologies to dietetics. Validated scales were included to assess personality (Big
28 5) and self-efficacy (NGSEI). The survey was available in English, Spanish and
29 Portuguese. Regression analyses were performed to identify factors associated with
30 integration of nutrigenetic testing into practice, and to identify factors associated with the
31 perceived importance of bio, information and mobile technologies to dietetic practice.

32 **Results:** A total of 323 responses (response rate 19.7%) were analysed. Dietetic
33 practitioners who had integrated personalised nutrition technology into practice perceived
34 technologies to be less risky ($P=0.02$), biotechnology to be more important ($P<0.01$), and
35 professional skills to be less important ($P=0.04$) than those who had not. They were also
36 more likely to see themselves as entrepreneurs ($P<0.01$) and to perceive lower risks to be
37 associated with technology ($P<0.01$). Practitioners of nutrigenetics were lower on
38 neuroticism ($P<0.01$) and higher on self-efficacy ($P<0.01$), extraversion ($P<0.01$) and
39 agreeableness ($P<0.01$). Higher perceived importance of biotechnology to dietetic
40 practice was associated with higher perceived usefulness of omics tests ($P<0.01$).
41 Perceived importance of information technology was associated with perceived
42 importance of biotechnology ($P<0.01$). Mobile technologies were perceived as important
43 by dietitians with the highest level of education ($P=0.02$).

44 **Conclusions:** For dietitians to practice technology-enabled personalised nutrition,
45 training will be required to enhance self-efficacy, address risk perceived to be associated
46 with new technologies and to instil an entrepreneurial mindset.

47

48 1. Introduction

49 Technology enabled personalised nutrition has developed rapidly alongside advances in
50 precision healthcare¹. Potential benefits of a personalised approach to dietary health
51 promotion include reduced healthcare spend, improved efficiencies and better
52 engagement by end-users². At the same, some societal concerns have been raised (for
53 example in relation to personal data privacy) which may impede its adoption^{3 4}. The
54 personalised nutrition industry is expanding rapidly with an annual growth of 17% for
55 genetic testing in response to the falling price of home testing kits¹ and fuelled by
56 advances in 'omics' technologies such as nutrigenetics². Other new technologies
57 associated with personalised nutrition to generate nutritional and lifestyle
58 recommendations for an individual include microbiome and metabolomics tests that can
59 be offered online direct-to-consumer or via a healthcare professional^{2 5}. Guidelines for
60 interpreting scientific nutrigenetic studies have been recently published with the aim of
61 encouraging international standardization⁶. Rising consumer interest in health and
62 wellness has encouraged companies to also develop personalised products and offerings
63 including applications (apps) and platforms enabled by data generated from wearables
64 (eg. with apps to assess diet, heart-rate, blood pressure and physical activity) and
65 telehealth enabling technologies such as artificial intelligence and chatbots^{2 7 8}.

66 Although dietitians from various countries have ventured into this emerging area of
67 technology-enabled personalised nutrition, and have integrated personalised nutrition
68 technologies into practice⁹, application across the dietetic profession remains low¹⁰⁻¹³.
69 Possible reasons suggested by previous research which has focused on adoption of
70 personalised nutrition, by nutrition professionals as part of their practice, are low
71 confidence in genetics technology, lack of knowledge of the role of genetics in chronic
72 diseases, and concerns about Direct-to Consumer (DTC) tests^{11 14}.

73 Results from the recent “Future Dietitian 2025” project¹⁵, highlighted a need for skills
74 training and recommended, *inter alia*, that dietitians should be provided with continuous
75 professional development and training to keep abreast of technological advances, raise
76 awareness of novel technologies and to widen the use of personalised nutrition in
77 dietetics¹⁵. Indeed, there has been a lack of research which has studied factors determining
78 uptake and non-uptake of personalised nutrition technologies in relation to dietetics
79 practitioners¹³. Whilst the genomics field is considered to be of increasing importance¹⁶
80 ^{17 18 19 20}, many concerns have been raised in relation to the technology-enabled
81 personalised nutrition field which relate to ethics of genetic testing²¹, reliability of tests²²,
82 scientific validity⁶, clinical utility^{2 23} and efficacy of this emerging technology^{2 24}. This
83 research, therefore, will consider factors determining uptake of personalised nutrition
84 amongst dietitians.

85 Qualitative research⁹ has provided a voice for dietitian practitioners who *have* integrated
86 personalised nutrition technologies into practice. Entrepreneurial traits, an appetite for
87 lifelong learning, high tolerance to risk associated with technology and an optimistic view
88 of the future were perceived to be important factors determining if they applied
89 personalised nutrition. Previous research on university students of entrepreneurship has
90 also pointed to the intricate relationship between risk-taking behaviour, personality, self-
91 efficacy and entrepreneurial traits²⁵⁻²⁸. Propensity for entrepreneurial and risk-taking
92 behaviour, personality and self-efficacy, therefore, could also be associated with adoption
93 of personalised nutrition and related technologies^{25 29 30}. According to human capital
94 theory, the greater knowledge, skills and capabilities an individual acquires, the higher
95 the chances of attaining performance outcomes^{31 32}. In line with this, meta-analysis³³ has
96 established a relationship between human capital assets (the acquisition of skills and

197 knowledge) and entrepreneurial outcomes, which could be an important consideration in
198 the adoption and perceived importance of personalised nutrition technologies in practice.

199 The Diffusion of Innovation Framework devised by Rogers (1962)³⁴, considers how new
200 technologies are adopted by different stakeholders. According to diffusion theory,
201 adoption of new innovations or technologies is initiated by “innovators”, who are
202 followed by “early adopters” (individuals who represent opinion leaders), the “early
203 majority” (individuals who adopt new innovations before the majority), the “late
204 majority”, (individuals sceptical of innovations, “laggards” (individuals sceptical of
205 change) and “non-adopters” (individuals who will not adopt new innovations)³⁴. Early
206 adopters must believe and trust a new technology in order to influence the next customer
207 segment³⁴. As new personalised nutrition technologies become available, they will impact
208 on the way that personalised nutrition is delivered and practiced³⁵. This implies that early
209 adopters, in this case dietitian practitioners who have integrated personalised nutrition
210 technologies into practice, are appropriate to study and compare with late adopters within
211 the occupational group in order to understand factors determining application of
212 personalised nutrition in practice.

213 The aim of the research presented here has been to identify barriers to, and facilitators of,
214 adoption of personalised nutrition and related technologies by dietetics professionals.
215 Psychological factors that distinguish between dietitian practitioners who have, and have
216 not, integrated personalised nutrition and associated technologies into their practice, have
217 been analysed. The first hypothesis is that higher self-efficacy, perceived importance of
218 new personalised nutrition technologies, and professional skills, as well as levels of self-
219 perception as an entrepreneur, and lower , perceived risks of genetic testing are associated
220 with early adopters together with differences in personality that could determine whether
221 dietitians integrate personalised nutrition testing into their practice.

122 Second, it is hypothesized that the perceived importance of three types of technologies
123 (biotechnology, information technology and mobile technology) to dietetic practice will
124 be associated with higher self-efficacy, perceived usefulness of omics technology,
125 perceived importance of professional skills and lower perceived risk of genetic testing,
126 ethical considerations, personality traits (such as extraversion), and high perception of
127 self as an entrepreneur/innovator.

128

129 **2. Method**

130 The study was of a cross-sectional design by which data were gathered online by self-
131 reported questionnaire. Participation was on a voluntary basis. A cross-sectional survey
132 methodology was chosen as the most suitable design given time constraints and the spread
133 of RD's across countries.

134 **2.1 Questionnaire**

135 The final questionnaire consisted of 62 questions which took an average of 8-10 minutes
136 to complete. The first section asked about demographic information. The design of the
137 remainder of the survey tool, including selection of validated scales was informed by
138 prior qualitative research⁹. As implied by the qualitative research, and in keeping with
139 diffusion of innovation³⁴ and entrepreneurial theories³⁶, questions focussed upon
140 technologies associated with personalised nutrition. Items tapped into perceived risk of
141 genetic technology, views on the ethics of genetic testing, perceived usefulness of new
142 personalised nutrition technologies, perceived importance of new technologies/skill area
143 to dietetic practice, and the perception of self as an entrepreneur/innovator (Table 2).

144 Remaining sections asked questions about self-efficacy and personality traits. The
145 construct of self-efficacy was originally developed by Bandura (1986)³⁷, which refers to

146 the belief in one's own capability to attain a particular goal in a specific domain. Self-
147 efficacy was assessed using the New General Self-Efficacy Instrument (NGSEI)
148 originally developed by Schwartz and Jerusalem (1995)³⁸ and then amended and re-
149 validated by Chen, Gully and Eden (2001)³⁹. The scale comprised eight questions, for
150 which responses were on a 5-point scale. Each of the items were equally weighted, so
151 were summed, and a mean score was calculated per participant.

152 Personality has frequently been assessed using the "Big-5" framework, which assumes
153 that differences in personality between individuals can be identified by looking at 5 broad
154 traits: extraversion; openness; conscientiousness; agreeableness; and neuroticism⁴⁰.
155 Although personality is yet to be linked to entrepreneurship³⁶, the justification for
156 assessing personality in the current context was to determine whether differences in
157 adoption of personalised nutrition technology among dietitians were associated with
158 personality. For the purpose of this study, the 10-item version of the "Big 5 Inventory"
159 developed by Gosling *et al* (2003)⁴¹ was used. The 10-item version has demonstrated
160 adequate levels of reliability and convergence with the full 44-item inventory⁴¹ and has
161 been found to retain 85% of the test-re-test reliability⁴². Previous authors have
162 recommended its use in research where data need to be collected from individuals in a
163 short time⁴¹. The scale has also been validated^{41 42}. The scale consists of ten questions,
164 two to measure each trait, and for which responses were on a 5-point scale.

165 Also included were questions, the content of which were derived from findings of the
166 prior qualitative study (Abrahams *et al.*, 2018)⁹, and for which responses were provided
167 on a 5-point Likert scale. Two questions asked about perceived risks of nutrigenetic
168 testing. Two questions asked for views on the ethics of nutrigenetic testing. Four
169 questions asked about perceived usefulness of tech-enabled personalised nutrition
170 technologies (microbiome, metabolomics, food allergy and food sensitivity). Questions

171 on the perceived importance of nutrition technologies (biotechnology, information and
172 mobile technology), and skill areas related to the field of dietetics (research, business,
173 entrepreneurship, creativity, training) were also included, as were perceptions of self as
174 an entrepreneur or innovator.

175 **2.2 Procedure**

176 Ethical approval for the study was granted by the University of Bradford Ethics
177 Committee (E598)

178 **2.2.1 Sampling**

179 Based on an alpha of 0.05, power of 0.9, and a potential effect size of 0.8, an estimated
180 total sample size of $n=122$ was required³⁸. Dietitians were accessed between May and
181 June 2017 through dietetic associations, and through dietetics-related social media
182 networks (Facebook 1K, LinkedIn 1K, European Federation of Associations of Dietetics
183 2.6K, Association of Nutrition and Dietetics 2K) based in English, Spanish and
184 Portuguese speaking countries. Personal invitations were also sent via LinkedIn to
185 Registered Dietitians (RD's), to which only one person declined. One dietetic association
186 (South-Africa) posted the information about the study in their weekly newsletter (1.5k).
187 CEO's of companies that provide nutrigenetic testing kits to healthcare professionals for
188 use in practice were contacted and requested to distribute the survey to their database of
189 RD's. No reward or gift was offered for participation. Information about the aims of the
190 research, and the study itself was provided on the first page of the survey questionnaire.
191 A separate information sheet was made available as an attachment upon request *via* email.
192 The only exclusion criterion was that unqualified individuals, or students of nutrition
193 and/or dietetics programmes, should not participate. Consent was obtained at the start of
194 the survey and the researcher's contact details were provided. Potential volunteers were

195 then invited to participate by being sent an email containing an on-line link to the survey.
196 Participants could withdraw their responses at any time, although no such requests were
197 received.

198 **2.2.2 Survey**

199 The questionnaire was translated from English into Portuguese and Spanish and back-
200 translated to ensure consistency, accuracy and clarity. The survey was administered using
201 the SurveyMonkey™ platform (SurveyMonkey.com, LLC, Palo Alto, CA, USA, 2014).
202 The questionnaire was initially piloted on UK based dietitians (N=3) using the test
203 function on SurveyMonkey™ to which participants could add comments and questions.
204 Minor changes were made to the questionnaire based on the feedback received. To the
205 question about gender, “non-binary” was added as an option. The term “non-profit” was
206 changed to “not-for-profit”. The survey was made available over a five-week period,
207 during which time one reminder mail was sent *via* the social media platforms.

208 **2.2.3 Data Analysis**

209 **Treatment of missing data**

210 At the end of five weeks, the total number of completed questionnaires was 383.
211 Participants with more than five demographic entries missing (10% of the survey), as well
212 as those who identified themselves as students (N=2, 0.5%), were removed from the
213 database. Also excluded were 65 responses where participants provided demographic
214 information but did not complete any of the scales.

215 **Treatment of included data**

216 All the variables are summarised in Table 2. Responses to the two free-text questions
217 “number of years in practice” and “age” were rounded up to the nearest whole number.

218 Initial responses to the question “have you integrated nutrigenetic testing into your
219 practice?” were coded as ‘yes’, ‘no’ or ‘at some point’. Owing to the small number of
220 responses in the cell “at some point”, the categories “yes” and “at some point” were
221 combined to create a dichotomous yes / no variable. Reasons for stopping were completed
222 by 10 participants in the freetext box which included: high cost to clients (n=3); job
223 change (n=2); lack of knowledge; testing discussed but not used (n=2); and, concern that
224 the underpinning science was not yet ready for practice (n=2).

225 Scores for self-efficacy³⁸ and personality (Big 5)⁴¹ were calculated according to how
226 scales had been validated. Specific items on the self-efficacy and 10-item Big 5 scales
227 were reverse-scored^{38 41}. Missing data were replaced with the series means.

228 Cronbach’s Alpha implied very good reliability and high internal consistency for the self-
229 efficacy tool ($\alpha=0.87$). For the 10-item personality scale, the 5 traits Cronbach-alpha
230 reliability tests were found to be: $\alpha=0.70$ (extraversion); $\alpha=0.22$ (agreeableness); $\alpha=0.45$
231 (conscientiousness); $\alpha=0.54$ (neuroticism); $\alpha=-0.43$ (openness).

232 Principal component analysis (PCA) was performed on the un-validated scales
233 (perception of risks of genetic testing, ethics of genetics testing, usefulness of omics,
234 usefulness of food testing, perceived importance of skill area, perceived importance of
235 biotechnology/information technology/mobile technology). A factor loading threshold of
236 0.4, and eigenvalue >1 was used to identify factors. PCA indicated that the two items on
237 genetic testing: “Gene-and other omics-based technologies represent a risk to me
238 professionally”; and “Gene-based Personalised nutrition represents a risk to my patients
239 and clients”; loaded onto one factor (eigenvalue of 0.94). The Cronbach alpha for this
240 variable labelled as “perceptions of risk”, showed good reliability ($\alpha=0.78$).

241 PCA indicated that the two items: “Genetic testing poses an ethical dilemma to me”; and,
242 “Genetic testing should not be available direct to consumers” (which were reverse
243 scored); loaded onto one factor but with low reliability ($\alpha=0.44$). This factor was labelled
244 “ethics”. Items on the usefulness of: the microbiome; metabolomics; food allergy; and,
245 food sensitivity testing; (supplementary table) loaded onto two factors each with an
246 eigenvalue of 0.90. These were labelled “usefulness of omics”
247 (microbiome/metabolomics)’ ($\alpha=0.84$) and “usefulness of food testing” (food
248 allergy/food sensitivity) ($\alpha=0.73$).

249 Items “I see myself as an entrepreneur” and “I see myself as an innovator” were entered
250 as separate variables into the analysis.

251 Items that followed on from the question “Please rate the importance to dietetics of each
252 area below”: genomics; functional and integrative nutrition; food engineering;
253 bioinformatics; artificial intelligence and machine learning; chatbots; microbiome testing;
254 metabolomics; virtual and augmented reality; telehealth and wearable technology
255 (supplementary tables); loaded onto three factors creating new variables labelled:
256 ‘biotechnology’ ($\alpha=0.85$); ‘information technology’ ($\alpha=0.84$); and, ‘mobile technology’
257 ($\alpha=0.61$).

258 Items assessing the perceived importance of: “creativity; innovation and
259 entrepreneurship”; “business and marketing”; “research”; and, “teaching and training”;
260 loaded onto one factor with “creativity, innovation and entrepreneurship” contributing to
261 the highest weighting of 0.80 and with adequate reliability ($\alpha=0.51$). All four items were
262 combined into a single variable labelled “Importance of skill area”.

263 Pearson correlation (supplementary tables) was used to check for intercorrelations
264 between the independent variables: “age”; “years in practice”; “sector of work”; “highest

265 level of education gained”, “mean self-efficacy”; “perception of risks of genetic tests”;
266 views on “ethics of genetic testing”; “usefulness of omics”; “usefulness of food testing”;
267 perceived importance of “bio, information and “mobile technology”; “importance of skill
268 area”; “extraversion”; “openness”, “conscientiousness”; “agreeableness”; “neuroticism”;
269 “perception of self as an innovator”; “perception of self as an entrepreneur”; and “have
270 you integrated nutrigenetic testing into practice”. Significance level was set at $p < 0.05$.
271 Effect size was measured using Cohen’s d where $d = 0.2$, $d = 0.5$ and $d = 0.8$ equated to a
272 small, medium and large effect respectively⁴⁴(Cohen, 1988). Power analysis was
273 performed using G*3-power software version 3.1.9.2 ⁴⁵

274 Model 1 calculated the factors that determine integration of personalised nutrition
275 technology into practice: “age”; “gender”; “sector of work”; “country”; “number of years
276 working”; “mean self-efficacy”; “extraversion”; “openness”; “agreeableness”;
277 “neuroticism”; “conscientiousness”; “I see myself as an entrepreneur”; “I see myself as
278 an innovator”; “usefulness of omics”; “usefulness of food testing”; importance of
279 “bio/IT/mobile technology”; “importance of skill area”; “ethics of genetic testing”; and,
280 “perceptions of risk” of genetic testing; as independent variables and “having integrated
281 nutrigenetic testing into practice” as the dependent variable.

282 Model 2 calculated factors that determined perceived importance to dietetics of different
283 types of technology. Explanatory (independent) variables were: “have you integrated
284 nutrigenetic testing into your practice”; “age”; “number of years in practice”; “sector of
285 work”; “highest level of qualification gained”; “UK or other”; “I see myself as an
286 entrepreneur”; “I see myself as an innovator”; “ethics of genetic testing”; “perception of
287 risk” of genetic testing; and, “importance of skill area to dietetic practice”; as independent
288 variables. With perceived “importance of biotechnology”, “information technology” and

289 “mobile technology” entered as dependent variables respectively. SPSS© (IBM) version
290 24 was used to analyse data.

291

292 **3. Results**

293 3.1 Sample Description

294 The final sample comprised 323 registered dietitians from the countries as outlined in
295 Table 1. The questionnaire was distributed to approximately 8000 registered dietitians,
296 implying a response rate of 19.7%, which correlates well with the 16% response rate of a
297 previous online survey conducted amongst dietitians (Collins *et al.*, 2013). The sample
298 consisted mainly of females (93.8%) with only 5.6% male and non-binary gender 0.2%
299 (Table 1). Age ranged from 21yrs to 72yrs with a median age of 37.5 years. There was
300 no significant difference between dietetics practitioners who had and had not integrated
301 personalised nutrition technology into practice in terms of age ($t(321)=-0.63$, $P=0.53$), or
302 highest level of education attained ($t(321) = 1.63$, $P=0.11$). More than half (57%) held a
303 BSc (with or without postgraduate diploma), 36% an MSc and 6.5% a Doctorate. More
304 than a third (37%) worked in the public sector (37%) and more than half (52%) in the
305 private sector. One participant was retired. There was no significant difference between
306 the two groups in terms of the sector where they worked ($t(321) = -0.14$, $P=0.76$) or
307 number of years worked ($t(321) = -0.29$, $P=0.78$). The number of years working ranged
308 from 1 up to 50, with a median of 12 years and a mean of 10 years. Of dietetic practitioners
309 of personalised nutrition (84%) were based in: the UK =7 (14%); Australia =1 (2%);
310 Canada = 6 (12%); USA = 12 (24%); Israel = 1 (2%); Mexico = 9 (18%); Portugal = 4
311 (8%); South-Africa = 7 (14%); UAE = 1 (2%); Norway = 1 (2%).

312

313 **Insert Table 1 and 2**

314

315 **Factors associated with integration of personalised nutrition into practice**

316 Traits that were positively correlated with having practiced personalised nutrition were
317 (Table 3): higher extraversion ($r(321)=-0.11$, $P<.05$); lower neuroticism ($r(321)=0.14$,
318 $P=0.01$); higher self-efficacy ($r(321)= -0.14$, $P= 0.01$); lower perception of risk of genetic
319 testing ($r(321)=0.31$, $P<0.01$); higher perceived importance of biotechnology to dietetic
320 practice ($r(321)=-0.24$, $P<0.01$); higher perception of self as an entrepreneur ($r(321)=-$
321 0.22 , $P<0.01$); higher perception of self as an innovator ($r(321)= -0.13$, $P=0.02$); lower
322 perceived impact of ethics of genetic testing ($r(321)= -0.18$, $P=0.001$); higher perceived
323 usefulness of omics ($r(321)= -0.21$, $P<0.01$) and food testing technologies ($r(321)=-0.13$,
324 $P<0.01$).

325

326 **Insert Table 3 and 4**

327

328 The regression model 1 (see Table 4) of factors predicting the integration of personalised
329 nutrition technology testing into practice explained 49% of the variance between dietetic
330 practitioners who had and had not integrated personalised nutrition testing into practice,
331 and was statistically significant ($F(3211, 3212) = 4.41$, $P< 0.01$, 95% CI 0.94 – 2.36).

332 Factors which predicted whether an individual had integrated personalised nutrition and
333 associated technology into practice were: higher “perception of self as an entrepreneur”
334 ($B=-0.06$; $t=-2.73$, $P<0.01$, 95% CI -0.12- -0.02) (which was the strongest predictor with

335 an effect size of $d=0.64$); lower “perception of risk” associated with genetic testing
336 technologies ($B=0.04$; $t= 3.14$, $P<0.01$; 95% CI 0.02- 0.07) (effect size $d=0.88$); higher
337 perceived “importance of biotechnology” ($B= -0.03$, $t= -3.54$, $P<0.01$, 95% CI $-0.05 - -$
338 0.02) (effect size $d=0.74$); lower perceived “importance of skill area” ($B=0.03$, $t=2.09$,
339 $P=0.04$, 95% CI $0.00 - 0.05$) (effect size $d= 0.18$); and, lower “perceived importance of
340 information technology” ($B=0.02$, $t=2.54$, $P=0.01$, 95% CI $-0.01 - 0.03$) (effect size
341 $d=0.02$).

342

343 **Insert table 5, 6, 7**

344

345 **Factors associated with the perceived importance of new technologies**

346 Three regression models were created to determine the perceived importance of each of
347 three types of personalised nutrition technologies identified in the PCA analysis, and
348 which were labelled ‘biotechnology’, ‘information technology’ and ‘mobile technology’
349 (Tables 5-7). The strongest predictor of perceived importance of biotechnology was
350 higher perceived “usefulness of omics tests” ($B=0.52$, $t=5.55$, $P<0.01$, 95% CI $0.33-0.70$)
351 , followed by higher perceived “importance of information technology” ($B=0.33$, $t=8.39$,
352 $P<0.01$, 95% CI $0.26-0.41$), higher “importance of skill area” ($B=0.33$, $t=3.82$, $P<0.01$,
353 95% CI $0.14-0.45$), lower “perception of risk” of genetic testing ($B=-0.33$, $t=-3.952$,
354 $P<0.01$, 95% CI $-0.50- -0.17$) and lower “mean number of years working” ($B=-0.04$, $t=-$
355 3.02 , $P<0.01$, 95%CI $-0.06- -0.01$) . This model explained 75% in variation between
356 variables and was significant ($F(3211, 3212) =21.43$, $P<0.01$, 95% CI $-4.55 - 3.443$).

357 The strongest predictor of perceived “importance of information technologies” was

358 higher perceived “importance of biotechnology” (B=0.56, t=8.39, P<0.01, CI 0.43 –
359 0.70), followed by higher perceived “importance of skill area” (B=0.49, t=4.87, P<0.01, 95%
CI 0.29 – 0.68) and, whether “mobile technologies” were also perceived as important
360 (B=0.42, t=4.09, P<0.01, 95% CI 0.22 -0.63). This model explained 69% of variability
361 between variables and was significant (F(3211, 3212) = 15.16, P<0.01, 95% CI -9.82 –
363 0.53).

364 Factors that determined perceived “importance of mobile technologies” were “highest
365 level of education gained” (B=0.22, t=2.20, P=0.03, 95% CI 0.02-0.41), higher
366 “conscientiousness” (B=0.18, t=2.90, P =0.01, 95% CI 0.58 – 0.30) and, higher perceived
367 “importance of information technology” (B=0.12, t=4.09, P<0.01, 95%CI 0.06-0.18).
368 This model explained 46% of the variability between variables (F3211, F3212=4.58,
369 P<0.01), 95%CI -1.26 – 4.34).

370

371 **Discussion**

372 The purpose in this research has been to identify barriers to, and facilitators of,
373 adoption of personalised nutrition and related technologies by dietetics professionals. In
374 this research we sought to determine what distinguished dietitian practitioners who had,
375 and had not, integrated personalised nutrition technology into their practice. The first
376 finding demonstrated that dietitian practitioners who had integrated personalised nutrition
377 technology into their practice considered themselves to be entrepreneurs, perceived lower
378 risk in genetic testing, rated biotechnology higher and professional skills lower to dietetic
379 practice.

380 That those who practiced technology-enabled personalised nutrition perceived
381 less risk in genetic testing was as expected. In comparison to the general population,

382 dietitians have been found to have average levels of novelty seeking behaviour and high
levels of harm avoidance^{46 47}. This implies that more could be done to open up discussion
383 on risk of genetic testing in dietetics practice.

384 The finding that integration of personalised nutrition technology was also
385 associated with higher perceived importance of biotechnology but lower perceived
386 importance of information technologies would align with predictions made by the
387 diffusion of innovation theory³⁴. This implies that more could be done to not only increase
388 awareness of new technologies among those dietetic practitioners who have not integrated
389 personalised nutrition technology, but also increase understanding of how new
390 technologies impact dietetic practice. Perceived importance of “skill area” was not a
391 predictor for integration of personalised nutrition into practice. This is supported by
392 previous research⁹ and suggests that those who already practice technology-enabled
393 personalised nutrition, do not consider that additional professional skills are required.
394 Hickson *et al* (2017)¹⁵ have recently recommended the need for the development of a
395 career framework which maximises and utilizes the existing skills and knowledge of
396 dietitians.

397 High perception of self as an entrepreneur also distinguished those dietitian
398 practitioners who had integrated personalised nutrition technology into practice. This may
399 have important implications for policy and practice, as diffusion of new innovations may
400 be accomplished by enabling dietitians to think more like entrepreneurs, without
401 necessarily having to become one.

402 Also in keeping with findings of previous research⁷, those who practiced
403 technology-enabled personalised nutrition had higher levels of self-efficacy. Self-
404 efficacy has also been associated with personality, such that those who exhibit more pro-
405 active personalities tend to have higher self-efficacy^{26 27}, greater risk-taking and
406 opportunity seeking behaviour⁴⁸, goal orientation and need for achievement⁴⁹. Self-

407 efficacy has also been closely associated with entrepreneurial intentions and traits⁵⁰,
408 entrepreneurial self-efficacy and entrepreneurial intentions^{28 51-53}. Given that self-efficacy
409 is task and situation dependent and can be increased through learning and experience³⁷,
410 future considerations could include specific training directed towards raising levels of
411 self-efficacy among nutrition and dietetics students. Contrary to previous research⁵⁴⁻⁵⁵,
412 neither sector of work nor personality were associated with integration of personalised
413 nutrition technology into dietetic practice.

414 A second objective sought to determine factors associated with perceived
415 importance of personalised nutrition technologies to dietetic practice. The finding that the
416 perceived importance of biotechnology was determined by perceived usefulness of
417 'omics' technologies indicates that a potential strategy to encourage adoption of
418 personalised nutrition could be to raise awareness of microbiome and metabolomics
419 technology. This could be achieved through case examples, success stories from early
420 adopters, encouraging research as well as addressing the negative perceptions that non-
421 practising dietitians may hold³⁴ which include fear of practice- license being revoked,
422 adopting technology that is not evidence-based or endorsed by
423 professional organizations^{9 13}.

424 The perceived importance of information technology was determined by perceived
425 importance of biotechnology. Recent research has highlighted the importance of sensors,
426 wearable and nutrition informatics technologies in early detection, tracking, monitoring
427 and intervention to produce quality evidence-based personalised recommendations to
428 individuals in real-time⁵⁶. Whilst nutrition informatics competencies for dietitians have
429 already been investigated⁵⁷, more research is needed in view of the rapid advances in
430 personalised nutrition technologies^{58 59}. Factors that predicted the perceived importance
431 of mobile technologies included higher perceived importance of information technology,

432 higher conscientiousness, and higher level of qualifications. This may imply the need for
433 further training in telehealth, wearable and information technologies.

434 Among the study limitations are those inherent to the use of self-report methodologies
435 and include the potential bias associated with perceived social desirability in responses⁶⁰
436 ⁶¹. The online survey methodology meant that compliance was low, although we have
437 estimated that the response rate was comparable to other on-line surveys which used
438 similar recruitment methodologies¹¹, yet the study was adequately powered (0.99).
439 Another potential limitation inherent in the sampling was that the number of dietitians
440 practicing personalised nutrition was small (n=49) relative to those who were not
441 practicing (n=274). Given that this is an emerging area and the research on the potential
442 health benefits of a personalised nutrition approach is limited, we would expect numbers
443 of practitioners of personalised nutrition to be small.

444 Whilst the number of countries included was large, this reflects current practice and
445 online discussion around the world, as nutrigenetic testing companies make testing kits
446 available across country borders. There may have been between-country differences in
447 responses, which given insufficient numbers in certain countries, were impossible to
448 analyse and which may have impacted upon the findings. Results of the qualitative study⁹
449 implied that attitudes, perceptions and practice amongst early adopters of personalised
450 nutrition were similar irrespective of nationality or country of origin. We cannot therefore
451 be certain that items were understood in the same way by dietitians in the different
452 countries. Future research will be required to determine the degree to which views on
453 personalised nutrition and related technologies vary between professions based in various
454 countries.

455 Single items included in the questionnaire (such as that on perception of self as an
456 entrepreneur) may not have been sensitive as multi-scaled validated measures. Existing

457 validated scales, however, would have taken a long time to complete which could have
458 affected compliance. In addition, given that the aim of the study was to measure *self-*
459 *perception* of self as an entrepreneur, rather than actually being an entrepreneur, no
460 existing scale would have been entirely appropriate. Another factor which could have
461 affected discriminate ability of the measure was that responses of those who had at one
462 time used nutrigenetic testing, but who had not continued to do so, were combined with
463 those who continued to apply it in practice. Further research is needed with frontline RD's
464 to understand reasons for stopping. Another omission was that respondents were not
465 asked for the reasons why they had not used personalised nutrition technologies in
466 practice or had ceased. Possible reasons which could be explored in future research
467 include organisational culture¹⁸, lack of opportunity or constraints on resources. The
468 variable "ethics of genetic testing" had low reliability and the personality trait of
469 "openness" had a negative Cronbach indicating that these results should be interpreted
470 with caution.

471

472 **Conclusion**

473 To our knowledge, this is the first multi-national study undertaken to determine how
474 psychological and personal factors may influence adoption of new personalised nutrition
475 technologies amongst a cross section of dietetics practitioners. These findings therefore
476 have important implications for practice and policy to open-up dialogue on tech-enabled
477 personalised nutrition at a more local, country level. Whilst this study adds to the existing
478 small body of literature on personalised nutrition in practice, future research should seek
479 to obtain a comprehensive insight into how health professionals construe risk around
480 personalised nutrition and associated technologies and understanding how

481 entrepreneurial traits and efficacy can be harnessed in the delivery of personalised
482 nutrition.

483

484 **Supplementary Materials**

485 Additional tables are available on request

486

487 **Statement of ethics**

488 The study protocol has been approved by the research institute's committee on human
489 research.

490

491 **Disclosure statements:**

492 The authors have no conflicts of interest to

declare 494

495 **Author contribution detail:**

496 MA designed the study, conducted the field work, completed the data-analysis and drafted
497 the initial article. BSK and EB contributed to the design of the research, co-analysed the
498 data, produced the final article. LF contributed to the design of the study, critically
499 reviewed the article and approved the final article. EB commented on the draft article and
500 approved the final article.

501

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Published articles & blogs

PERSONALISED Personalised Nutrition

Evaluation of an intensive module to develop an entrepreneurial mindset and creativity skills in nutrition & dietetics students



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Registered dietitians and nutritionists currently enjoy a variety of roles from clinical practice to public health, media and industry.¹ With heightened public interest in health and wellness, along with rapidly evolving technologies and falling prices, we have found ourselves in the midst of a digital revolution.²

The rapidly evolving tech-enabled personalised nutrition industry encompasses everything from apps, to diagnostics and wearables all in a bid to enable healthier nutrition and lifestyle choices.³ The technologies used to build these products and platforms extend from blockchain, to artificial intelligence, big data, machine learning and much more. Nutrition and dietetics graduates have a unique opportunity to bring their scientific knowledge and skills to create innovative new products, validate algorithms and add value to existing commercial teams, yet research has demonstrated that knowledge and awareness of nutrition technologies is low amongst the profession.^{4,5,6}

After graduation, many follow a traditional path of working for the NHS, or starting a private practice, or working within the food industry, all very competitive. Yet the digital revolution has brought with it a wealth of opportunities that nutrition graduates and professionals can capitalise on. However, this requires a different skillset, one that can spot opportunities, demonstrate leadership, and create new solutions that are based on a scientific evidence base.

Entrepreneurship and digital proficiency have been placed high on the agenda of governments to ensure societal value creation in social, cultural and economic areas; yet, there are a lack of entrepreneurship programmes specifically aimed at women from a science, technology, engineering, and mathematics (STEM) background.^{7,8}

"Closing the gender gap through digital and entrepreneurship education is vital if Europe is to fully embrace the benefits of the digital revolution... Increasing female participation in these careers will help unleash Europe's digital potential and ensure that women take an equal place in shaping the digital world." **European Commission, 2018**

In addition, to my knowledge, no modules focused on the rapidly evolving area of tech-enabled personalised nutrition. As an entrepreneur and freelancer myself, I can clearly see opportunities to prepare nutrition and dietetics students for a rapidly evolving working environment where remote and short-term contractual service provision will become increasingly common. The World Economic Forum recently reported that businesses will increase the use of contractors and that by 2022 approximately 54% of the workforce will need re or up-skilling.⁹ My aim, therefore, was to design an intensive module to raise awareness and understanding of new personalised nutrition technologies, develop an entrepreneurial mindset, increase self-awareness and confidence to start a business, as well as to create new nutrition technology solutions that can benefit society.

The course was heavily influenced by the top-selling book *The Lean Startup: How today's entrepreneurs use continuous innovation to create radically successful businesses* by Eric Ries.¹⁰ His approach is that in order to innovate and create new products that are consumer-centric, companies need to be able to create a minimally viable product fast, and obtain feedback from their target audience.

Research has indicated that entrepreneurship, ideation, creative problem solving, as well as leadership, are all teachable skills.⁸ Therefore, designing a short module with these specific outcomes in mind were used as a starting point.

The Business Innovation, Creativity & Entrepreneurship Module

The four-day Module was delivered as part of the UK's first and newly launched MSc in Nutrition & Genetics Course at St Mary's University, London, UK. The MSc includes a detailed programme on genetics and genomics, whilst also providing an immersive laboratory experience.

The four-day Module combined lectures, group and individual work, pre-reading, action-learning and concluded with a pitch competition and a business plan assignment. An outline of the Module can be found in **Table One**.

The Module incorporated current examples of female role models who are chief executive officers of companies in the personalised nutrition industry, market statistics, trends and products. There was a strong focus on application with reference to real-life examples, platforms and tips on how to structure a business plan, conduct market research and delivering a pitch. For developing an entrepreneurial mindset, topics included: entrepreneurial theory, creative problem solving, creative thinking, resilience, self-efficacy, risk orientation, leadership skills, entrepreneurial habits and time management. Other topics pertinent to growing a business included: diversity, creating strong teams, finance, contracts and how to handle non-disclosure agreements (NDAs). Each topic was introduced through a lecture which included the background and relevance to running a business, as well as tactics to address the above topics. Thereafter, students were required in their groups to apply these new concepts to their product development process.

Students were asked to build and develop a minimal viable product (MVP) in small teams, based on the information that they had learnt at the beginning of every session over the four days. The final day consisted of a business pitch to the guest lecturer, programme director, nutrition department lecturers and other students.

Four minimally viable products (MVP) created during the group sessions were highly novel, and drew on their nutritional expertise. Students were asked to complete a pre and post evaluation survey after the full Module.

Results

There was a difference between the pre and post evaluation scores in terms of confidence to start their own business (**Figure 1**), level of knowledge in creativity and innovation (**Figure 2**), creative problem solving (**Figure 3**) and level of comfort to contribute to a commercial team. With respect to tech-enabled personalised nutrition technologies, five (62.5%) said that their knowledge had vastly increased, two (25%) said that it slightly increased and one (12.5%) said it had stayed the same.

Table One: Outline of the Personalised Nutrition Business Innovation & Creativity Module

Day 1	Day 2	Day 3	Day 4
<ul style="list-style-type: none"> • Creativity and innovation • Personalized nutrition market overview and technologies • Creative problem – solving framework and techniques • Creating value 	<ul style="list-style-type: none"> • Creating a minimal viable product • Market analysis and validation • Business modelling • Defining a unique selling proposition (USP) 	<ul style="list-style-type: none"> • SWOT analysis • Marketing • Finance • Company set-up • Pitch basics • Business plan development 	<ul style="list-style-type: none"> • Entrepreneurship theory and practice • Leadership, negotiation skills • Building a team • Final group pitch and business plan assignment

Figure 1: Confidence in Starting Own Business

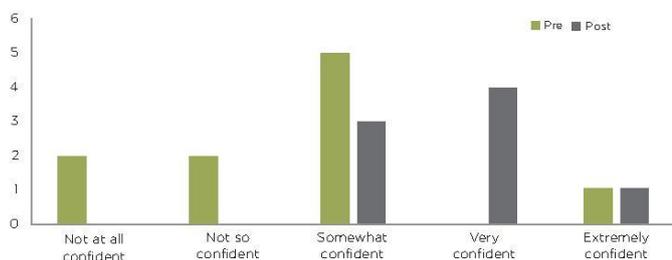


Figure 2: Level of Knowledge on Business Innovation & Creativity

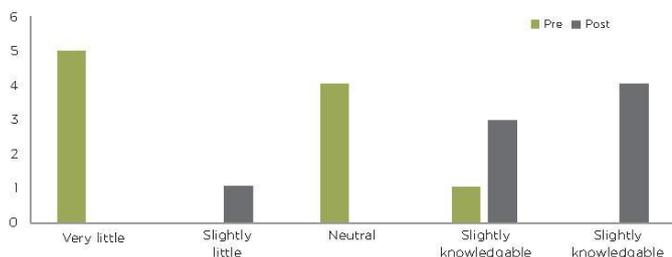
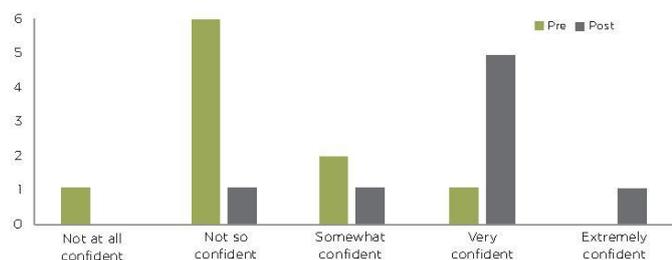


Figure 3: Confidence in Creative Problem Solving



The evaluation showed that participants were more confident to start their own businesses following training. There was a difference between pre and post scores, with students feeling that they were more comfortable to contribute to commercial team by the end of the course.

After completing the module, overall students felt comfortable in developing a business plan, marketing and pitching their ideas to potential investors (Figure 4). When asked what the favourite part of the course was, two students responded:

- "Very hard to choose. I think the session on entrepreneur traits was my favourite as it not only showed me what I would need as an entrepreneur, but also taught me how to change to increase my likelihood of success!"
- "Relating the information to a new idea we came up with and developing it further in each session."

On asking "How did you feel about using role model examples throughout the course?", five (62.5%) responded that it was a great idea and three (37.5%) agreed it was a good idea.

When asked to complete the phrase: "This course helped me to..." students replied:

- "Increase my willingness and determination to create my own company!"
- "Expand my thinking abilities and develop new products/idea."
- "Be creative."
- "Develop a part of me that I never knew I had."
- "Feel the fear and do it anyway."
- "Build my confidence and understanding in the business world and has inspired me to begin brainstorming and implementing my own brand/product ideas."
- "Realise self-potential and how to effectively convey confidence to increase potential job opportunities or business ventures."
- "Understand what goes into creating a start-up and how to negotiate salary/price."

Finally, seven (87.5%) indicated that they would recommend the course to other nutrition students.

Discussion

During this short Personalised Nutrition Business Innovation & Creativity Module, MSc students were guided through the development of a minimally viable product (MVP) and learnt how to validate and market their idea. The innovative ideas students

came up with included a robot, a wearable, an app as well as an ingestible, all of which focused on their core nutrition skills.

Our evaluation suggests that a short-intensive course can benefit students and help them to open their minds to other possibilities in their career by increasing their knowledge, confidence and understanding of what is required in order to venture into the business world if they chose this option.

The Module also demonstrated that using female role models inspired students to see their own potential. Considering that 94% of nutrition graduates are women,¹ there is definitely a need for entrepreneurial courses to be targeted specifically at women.

In summary

A short business innovation, creativity and entrepreneurship course that has a focus on the tech-enabled personalised nutrition industry and is aimed at the needs

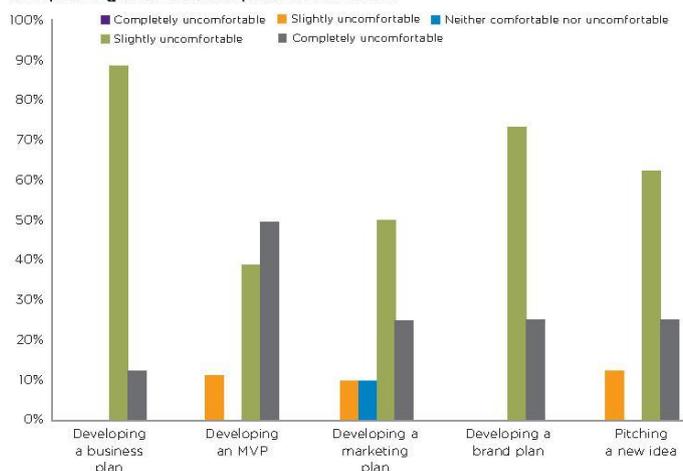
of women, can increase knowledge, increase confidence and inspire new ideas through hands-on involvement. In order to encourage the uptake and creation of new nutrition technology solutions amongst the nutrition profession as the experts, such a business module should be taught by experienced nutrition entrepreneurs through guest lectures, who understand the needs and background of nutrition and dietetics students rather than outsourcing it to their business departments at universities. Teaching entrepreneurial skills to nutrition and dietetics students could open up new career opportunities, develop opportunity seeking behaviour and broaden perspectives in a global environment that is becoming increasingly digital and data-driven. Teaching entrepreneurial skills to medical students through a programme as part of their clinical practical training is already underway in the states and in Europe, but dietetics is yet to follow.

For university lecturers, educators and programme directors who are looking to review their own curriculum, want to have the module delivered at their own university, or who are considering outsourcing an entrepreneurship course to their business departments, a bespoke retreat will be available in April & October 2019 in the Algarve (Portugal), to go through the immersive Nutratech – Business Innovation, Creativity & Entrepreneurship Module.

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Figure 4: Feelings Post Module - Developing a business plan, marketing and pitching their ideas to potential investors



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How important is technology in your dietetic practice?

Why dietitians should get more tech savvy and tips on how to get started



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If you have been online checking your smartphone at least once in the last hour, this article is for you! It comes as no surprise to many that we are in the midst of a digital technology revolution. From apps, to fitness devices and smart scales, there is no lack of solutions to help the tech-savvy public to stay connected and informed. But how well do you use new technology in your practice?

Q. Why does technology matters to dietetics?

The recent Dietitian2020 horizon environmental scanning project conducted by Hickson et al (2017)¹ has highlighted and recommended the need to maximize use of innovative technologies amongst dietitians. Yet another recent study on the use of Health apps has demonstrated that in a cross-section of dietitians in three countries, app usage was limited to Myfitnesspal and the LowFODMAP app by Monash university.²

The uptake of technology amongst the profession is very important. The rapid advances of cloud computing and sensor development has allowed the collection of millions of data points, in real-time, through our online activity, wearable trackers, geolocation and much more. This means that data is being continuously generated, and in healthcare, the interest in using big data to provide personalised healthcare is edging closer and closer.

A recent study has found that personalised care can result in a cost-saving of \$300billion in one year alone. For nutrition, this means that through technology, the opportunity to give personalised nutrition advice at scale becomes possible. The potential for dietitians to play a role in this shift is therefore huge, and it requires us as a profession to value the importance of technology in daily practice.

Q. What does the research say about dietetics and new technologies?

As a freelance dietitian and business consultant, I've become increasingly interested in the use of innovative technologies in dietetics over the last few years. To add to my workload and quench my thirst for continuous learning, I decided to self-fund my PhD, find a topic that interested me, and choose a supervisor that supported what I wanted to achieve. That topic ended up changing the course of my career!

My PhD focused on how early adopters of nutrigenetic tests differed from non-adopter dietitians on different psychological factors with **Professor Barbara Stewart-Knox** as my supervisor at Bradford university, an expert on consumer behaviour and work package lead for the Food4me (Personalised nutrition) project.

What drove me was the fact that whilst dietetic training is relatively similar across countries, some dietitians (including myself) went on to integrate nutrigenetic tests into practice

despite a general agreement in the scientific community that the science is too early to provide nutritional recommendations.³

So what is that intangible something that makes some dietitians jump while others don't? What makes some dietitians better at being able to see future opportunities? What does it take to make that switch from insight and learning to action? These are the questions that were swirling around in my mind.

What quickly transpired during my PhD and consulting journey, was that the tech-enabled personalised nutrition field was and continues to grow at a tremendous rapid rate; and of course my PhD changed along with it. From what was first a focus on nutrigenetics became an interest into new technologies that provide nutritional recommendations overall.

“The uptake of technology is incredibly important for the profession to stay ahead and to stay relevant.”

One of my PhD chapters focused on the perception of risk of genetic testing and the perception of the importance of technologies to dietetics. Complete survey responses were received by a cross-section of 323 dietitians from mostly European countries. In total, there were 49 early adopters and 274 non-adopters. The survey was also translated into Spanish and Portuguese and shared with dietitians in Portugal, Spain and Mexico.

Overall, there were no differences between early adopters and non-adopters in terms of age, gender, level of education, number of years working or sector of work.

In terms of attitude towards the importance of technologies to dietetics and the perception of risk of genetic testing, the results proved to be rather interesting! (See the table). The abstract of this study was accepted for a poster presentation at FNCE in Washington in October which I attended with the support of a GET grant.

The results showed that early adopters of genetic testing perceived significant lower risk ($p < 0.01$). In addition, early adopters perceived the importance of genomics, metabolomics, microbiome and functional and integrative nutrition to dietetics as significantly more important in comparison to non-adopters ($p < 0.01$).

To me, another interesting insight was that there were no differences between the two groups in terms of the importance of other technologies such as wearables, telehealth and chatbots. The reason for this is not entirely clear, but my guess is that, potentially, dietitians are either

not aware, or understand how these technologies impact dietetic practice or how they can be used to enhance our practice.

Q. So what does this mean and what do we need to do?

The results of the survey and my PhD in general, indicate that to increase awareness and uptake of technologies, the development of other professional skills beyond nutrition are crucial; these include business, innovation, creativity and entrepreneurship.

It means that we need dietitians to think more like entrepreneurs without necessarily having to become one. In my own business, I see an increased demand for dietitians with research and statistics skills, and have found that our soft skills, insight into behaviour change, understanding of the scientific literature and how clients/patients think, is invaluable when working with different teams.

Q. How can dietitians develop business, innovation, creativity and entrepreneurial skills?

It is predicted that jobs of the future will require us to work alongside technology and not compete with it. Hence, the skills that will be needed include creative problem solving, synthesizing information and leadership for which dietitians are perfectly positioned.

As part of my PhD, I created and delivered a Business Innovation, Creativity and Entrepreneurship module to students of the first MSc in Nutrition & Genetics at St Mary's University with Dr Yiannis Mavrommatis earlier this year.

Whilst the MSc is focused on providing technical and laboratory skills in nutritional genomics, the objective of the business module was to expose students to new technologies in the personalised nutrition industry, open their minds to new career opportunities by maximising their skills, and be 'hands-on' involved in creating a new tech-enabled nutrition solution that can be pitched to investors.

We received immensely positive feedback about the module and the content has now been amended for lecturers and educators who are interested in delivering the content or outsourcing a similar intensive course. The aim of such courses is to increase knowledge, understand the impact of the tech-enabled personalised nutrition industry and develop new skills.

Q. How should dietitians get started in learning more about technologies to help their practice?

■ If you have already embraced technology in your practice, make a point on a daily basis to investigate new technologies that are released to keep up-to-date. If you have not embraced it yet, start experimenting with personalised recipe sites, barcode scanning apps for shopping, or trialling a virtual practice platform.

■ Read widely. Topics such as new ways of working, the use of big data in personalised healthcare and even cryptocurrency are issues that may have relevance in the future.

■ Map out your own practice by writing down how you provide your nutrition service step-by-step. At every step or contact point with a patient or client, consider which step is repetitive or which could be replaced by

technology to free up your time, make you more efficient and improve your client's experience with your service.

In summary

The uptake of technology is incredibly important for the profession to stay ahead and to stay relevant. Strategies to raise awareness and knowledge of what is currently available, and how these technologies can enhance or impact dietetic practice are needed right now, at both undergraduate and post-graduate levels.

However, successful uptake of technologies requires the acquisition of additional skills, some of which include business innovation, creativity and entrepreneurship which are all teachable skills that can be acquired through an intensive course, delivered by early adopters or by educators with a special interest on the topic.

The integration of technology does not require a huge leap, start small today and build your confidence gradually. For more information on the module or my research, do get in touch.

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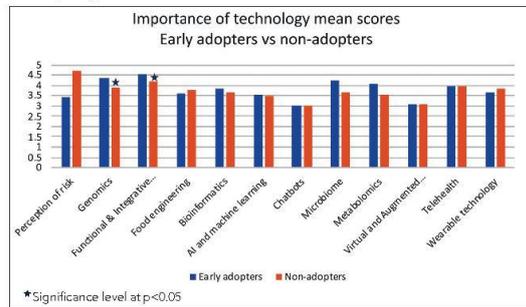
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Glossary/ technical terms explained

Chat bots =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Cloud computing =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Cryptocurrency =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Data points =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Geolocation =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Real-time =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Sensor development =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Smart scales =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Telehealth =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Wearables =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>
Wearable trackers =	<LEAVE TWO LINES DUMMY COPY> <LEAVE TWO LINES DUMMY COPY>

Appendix G

Posters and abstracts



Title: Perception of risk and importance of new personalized nutrition technologies between early adopters and non-adopter RD's

Background and Aim

The tech-enabled personalized nutrition industry is growing at a rapid pace, however awareness and uptake remains low in the dietetic profession. We aimed to establish the difference in perceptions in terms of risk and importance of new technologies in a cross-section of RD's to early adopters and non-adopters of nutrigenetic tests across countries.

Method

- We conducted an online survey using SurveyMonkey which was translated into Portuguese and Spanish
- RD's were recruited via associations and private RD's groups
- The survey was sent out to RD's in the UK, US, Canada, South-Africa, Mexico, Spain & Portugal N=323
- Results were analysed by separating early adopters of nutrigenetic tests (N=49) from non-adopters (N=273)

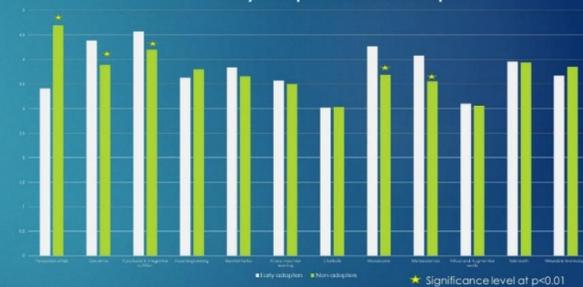
Results

- Using independent T-tests, we found no difference in terms of demographics between EA and NA
- We found a significant difference in the perception of risk of personalized nutrition technologies $p < 0.01$ with EA perceiving lower risk with genetic tests
- EA scored the importance of technologies genomics, metabolomics, function nutrition and microbiome higher $p < 0.001$
- We found no difference between EA and NA in terms of other technologies

Demographics

	N (%)
Gender	18 (5.4%)
Male	303 (93.8%)
Non-binary	2 (0.5%)
Age	N= 323 (100%)
Range	21-72 yrs
Education	
Acc	59 (18%)
Degree/Diploma	126 (39%)
Master's	112 (34%)
Doctorate/PhD	21 (6.5%)
Place of work	
Public sector	119 (37%)
Private sector	148 (45%)
Non-profit/Third sector	4 (1%)
Non-employed	23 (7%)
Public - Other	2 (0.6%)
Public - Non-clinical	1 (0.3%)
Health services/Non-clinical	1 (0.3%)
Other	2 (0.6%)
Public/Non-clinical	2 (0.6%)
Other/Non-clinical	1 (0.3%)
All	
Geographical	
Country of work	
United Kingdom (UK)	133 (41%)
Outside	190 (59%)
Years in practice	323 (100%)
Range	1-10 yrs
Integrated into your practice?	
Yes	49 (15%)
No	274 (85%)

Importance of technology mean scores between Early adopters vs non-adopters



Conclusions

Despite rapid advances in technologies that impact dietetic practice directly, the uptake and perceived importance of technology appears to be low amongst the dietetic profession. Education and practice should consider raising awareness and knowledge of new technologies, potentially through using early adopters as role models.

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APRIL & October 2019 - Portugal



17th International Congress of Dietetics
GRANADA SPAIN 2016

7, 8, 9 and 10
 September

www.icdgranada2016.com

Reference:

3/299

Title: Registered Dietitians in the genomic era – a qualitative study

Authors: Mariette Abrahams, Lynne Frewer, Barbara Stewart-Knox, Ellie Bryant

Workcenter: University of Bradford, University of Newcastle (UK)

Background & research objective

Nutritional genomics is an emerging and exciting new field for nutrition professionals. Involvement, integration and confidence in this new technology has been low amongst the dietetic profession globally. The research objective was to determine the attitudes, perceptions and experience of early users of the technology in different countries.

Method

First a pilot study was conducted (n=1) via Citrix (conference call) to ensure the platform was suitable. Registered Dietitians (RD's) were recruited through personal network and via nutrigenetic testing companies from UK, Canada, South-Africa, Australia, Mexico and Israel. In total, 7 Interviews were held online, using a conference calling platform that were recorded and transcribed. Thematic content analysis was used to analyze the data.

Results

Thematic analysis revealed, 3 main themes and 9 subthemes that were agreed upon by an independent expert as outlined below.

Main Theme	Subthemes	Key participant quotes
Rise of the technology RD	Self-taught & driven	„I've done all the updates, I've done all the trainings, seminars, Passion for the subject, I think, is the main skill
	Strong affinity for technology & accuracy	And with Nutrigenomix, I don't need to do the follow-ups like I do seeing someone for weight loss or anything else. It was kind of, it fit my kind of, uh, work schedule really well cause I could just do it and they could see someone else so they could follow it up. It's quite an easy thing to just do when off-consults. I have more confidence in the exact recommendations I'm giving them
	Strong belief in the science	I think the science is definitely there and it's great that we're able to incorporate nutrigenomics into practice
Professional practice	Challenges in translation	What I found challenging is the lack of guidelines of best practice out there
	Lack of endorsement	there are a lot of opponents out there that, you know, in a credible position and their opinion matters
	Importance for credibility	I think we're facing a huge challenge in the social media space where anyone who's a celebrity can say (erm) "Look at me this is the diet! Follow. Isn't this fantastic?" you know the most ridiculous and people promoting the most ridiculous diets and people believe them over traditional dietitians or (erm) science, true science
Preparing for the future	Dietetics education curriculum	"You know, if you think of the – four years that we study, it's kind of like mentioned in passing in one of the lectures." the curriculum, they say, is saturated so, you know, they're offering so many courses, they can't fit anymore in and that's an excuse, I guess, that they used as to why they're not offering specific course in nutrigenomics
	Requirement for research using nutrigenetic tests to build evidence base	It's like you can't expect there to be enough evidence if people aren't using it.
	Need for public education	So I find the motivators are slightly different, but there's also the one thing that hasn't changed is that people have a very – or the public have a very poor understanding of what Nutrigenetics – or what current evidence-based Nutrigenetics test can actually tell them

Conclusions

Early adopters of nutrigenetic tests into clinical practice are highly educated, self-motivated and driven RD's, who have had positive experiences of using the tests in practice to personalize diets that have resulted in behavior change. Whilst there are many challenges and barriers to overcome such as education, public & professional perceptions, they are optimistic about future opportunities for RD's and research developments in the field.

Appendix H

Supplementary tables

Correlation

		Gender	Age	Integrated NGx?	Highest level of qualification gained	Sector	Nr of working years	Innovation	I consider myself to be an entrepreneur	Mean self-efficacy	Extraversion	Agreeableness	Neuroticism	Openness	Conscientiousness	UKandOTHER	ProfSkills	Risk-gest	Ethics	Usefulness	Food testing	Mobile tech	Biotech	
Gender	r	1																						
	p-value																							
Age	r	-.027	1																					
	p-value	.628																						
Integrated NGx?	r	.073	.035	1																				
	p-value	.189	.532																					
Highest level of	r	.109*	.219**	-.090	1																			

Usefulness of	r	.020	-	-.131 [*]	-.092	-.019	-.096	.051	.123 [*]	.062	-.011	.079	-.090	.018	-.026	.238 ^{**}	.045	-.173 ^{**}	.178 ^{**}	.320 ^{**}	1			
	p-value	.068																						
Food testing	r	.715	.225	.019	.100	.730	.084	.362	.027	.268	.849	.157	.106	.747	.636	.000	.424	.002	.001	.000				
	p-value																							
Mobile tech	r	-.036	.121	.037	.176 ^{**}	.032	.072	.126 [*]	.102	.183 ^{**}	.050	-.004	-.010	.062	.233 ^{**}	-.146 ^{**}	.235 ^{**}	.011	.090	.001	-.074	1		
	p-value	.525	.029	.508	.001	.562	.194	.023	.067	.001	.369	.947	.852	.268	.000	.009	.000	.850	.104	.984	.187			
ITech	r	-.018	.064	.009	.063	-.045	.058	.196 ^{**}	.126 [*]	.095	.029	.145 ^{**}	-.065	.040	.055	.039	.468 ^{**}	-.138 [*]	.146 ^{**}	.251 ^{**}	.071	.341 [*]	1	
	p-value	.741	.249	.871	.262	.423	.302	.000	.024	.087	.601	.009	.246	.471	.323	.489	.000	.013	.009	.000	.203	.000		
Biotech	r	-.043	-	-.238 ^{**}	.075	-.013	-.096	.177 ^{**}	.149 ^{**}	.087	.008	.174 ^{**}	-.060	.032	.058	.166 ^{**}	.404 ^{**}	-.366 ^{**}	.293 ^{**}	.475 ^{**}	.246 ^{**}	.228 [*]	.596 ^{**}	1
	p-value	.439	.448	.000	.179	.822	.084	.001	.007	.120	.881	.002	.282	.567	.296	.003	.000	.000	.000	.000	.000	.000	.000	.000