Background: Commercial technology-enabled personalised nutrition is undergoing rapid growth, yet its uptake in dietetics practice remains low. This survey sought the opinions of dietetics practitioners on personalised nutrition and related technologies to understand the facilitators and barriers to its application in practice. **Method:** A cross-section of registered dietitians were recruited in the USA, UK, Australia, Canada, Israel, Mexico, Portugal, Spain, and South Africa. The questionnaire sought their views on the risks of genetics technology, the ethics of genetic testing, the usefulness of new personalised nutrition technologies, entrepreneurism, and the perceived importance of new technologies to dietetics. Validated scales were included to assess personality (the Big Five) and self-efficacy (NGSEI). The survey was available in English, Spanish, and Portuguese. Regression analyses were performed to identify factors associated with the integration of nutrigenetic testing into practice, and to identify factors associated with the perceived importance of bio-information, and mobile technology to dietetics practice. **Results:** A total of 323 responses (response rate 19.7%) were analysed. Dietetics 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 ($p < 0.01$). A higher perceived importance of biotechnology to dietetics practice was associated with higher perceived usefulness of omics tests ($p < 0.01$). The perceived importance of information technology was associated with the perceived importance of biotechnology ($p < 0.01$). Mobile technology was 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 the risks perceived to be associated with new technologies, and instill an entrepreneurial mindset.

Introduction

Technology-enabled personalised nutrition has developed rapidly alongside advances in precision health care [1]. The potential benefits of a personalised approach for promoting dietary health include reduced health care spending, improved efficiency, and better engagement by end-users [2]. At the same time, some societal concerns have been raised (e.g., in relation to personal data privacy) which may impede the adoption of personalised nutrition [3, 4]. The industry is expanding rapidly with an annual growth of 17% for genetic testing in response to the falling price of home-testing kits [1] and fuelled by advances in “omics” technologies such as nutrigenetics [2]. Other new technologies associated with personalised nutrition used to generate nutritional and lifestyle recommendations for an individual include microbiome and metabolomics tests that can be offered online direct to the consumer or via a health care professional [2, 5]. Guidelines for interpreting scientific nutrigenetics studies have been recently published with the aim of encouraging international standardisation [6]. Rising consumer interest in health and wellness has encouraged companies to also develop personalised products and offer applications (apps) and platforms enabled by the data generated from wearables (e.g., apps to assess diet, heart-rate, blood pressure and physical activity) and telehealth enabled by technologies such as artificial intelligence and chatbots [2, 7, 8].

Although dietitians from various countries have ventured into this emerging area of technology-enabled personalised nutrition and are integrating technologies into practice [9], the application across the dietetics profession remains low [10–13]. Possible reasons suggested by previous research (which has focused on the adoption of personalised nutrition) by nutrition professionals as part of their practice are low confidence in genetics technology, a lack of knowledge of the role of genetics in chronic diseases, and concerns about direct-to-consumer (DTC) tests [11, 14].

Results from the recent "Future Dietitian 2025" project [15] highlighted a need for skills training and recommended, *inter alia*, that dietitians should be provided with continuous professional development and training so as to keep abreast of technological advances, raise the awareness of novel technologies, and widen the use of personalised nutrition in dietetics [15]. Indeed, there has been a lack of research which has studied factors determining the uptake and non-uptake of personalised nutrition technologies by dietetics practitioners [13]. Whilst the genomics field is considered to be of increasing importance [16–20], many concerns have been raised in relation to the technology-enabled personalised nutrition field, includingthose related to the ethics of genetic testing [21], the reliability of tests [22], and the scientific validity [6], clinical utility [2, 23], and efficacy of this emerging technology [2, 24]. This research, therefore, will consider the factors determining the uptake of personalised nutrition technologies by dietitians.

Qualitative research [9] has provided a voice for dietitian practitioners who have integrated personalised nutrition technologies into practice. Entrepreneurial traits, an appetite for life-long learning, a high tolerance for the risks associated with technology, and an optimistic view of the future are perceived to be important factors determining whether or not they apply personalised nutrition. Previous research into entrepreneurship amongst university students has also pointed to the intricate relationship between risk-taking behaviour, personality, self-efficacy, and entrepreneurial traits [25–28]. The propensity for entrepreneurial traits and risk-taking behaviour, personality, and self-efficacy, therefore, could also be associated with the adoption of personalised nutrition and related technologies [25, 29, 30]. According to Human Capital Theory, the greater the knowledge, skills, and capabilities an individual acquires, the greater their chances of attaining performance outcomes [31, 32]. In line with this, a meta-analysis [33] 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 [34] considers how new technologies are adopted by different stakeholders. According to diffusion theory, the 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) [34]. Early adopters must believe in and trust a new technology in order to influence the next customer segment [34]. As new personalised nutrition technologies become available, they will impact on the way that personalised nutrition is delivered and practised [35]. This implies that it would be appropriate to study and compare early adopters, in this case dietitian practitioners who have integrated personalised nutrition technologies into practice, with late adopters within the occupational group, in order to understand the factors that determine the application of personalised nutrition in practice.

The aim of the research presented has been to identify the barriers to and facilitators of the adoption of personalised nutrition and related technologies by dietetics professionals. Psychological factors have been analysed to determine those that distinguish between dietitian practitioners who have and have not integrated personalised nutrition and associated technologies into their practice. It is hypothesized that higher self-efficacy, perceiving oneself as an entrepreneur, higher perceived importance of new personalised nutrition technologies, and professional skills as well as lower perceived risk of genetic testing will be associated with early adoption of personalized nutrition. These factors, together with differences in personality, could determine whether or not dietitians integrate personalised nutrition testing into their practice. It is also hypothesized that the perceived importance of 3 types of technology (bio-, information, and mobile technology) to dietetics practice will be associated with higher self-efficacy, higher perceived usefulness of omics technology, higher perceived importance of professional skills, lower perceived risk of genetic testing, ethical considerations, personality traits (e.g., extraversion), and higher perception of the self as an entrepreneur/innovator.

Method

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 the time constraints and spread of registered dietitians (RDs) across countries.

Questionnaire

The final questionnaire consisted of 62 questions which took an average of 8–10 min to complete. The first section asked about demographic information. The design of the remainder of the survey tool, including the selection of validated scales, was informed by prior qualitative research [9]. As implied by the qualitative research and in keeping with the diffusion of innovation [34] and entrepreneurial theories [36], the questions focused on technologies associated with personalised nutrition. Items tapped into the perceived risk of genetic technology, views on the ethics of genetic testing, the perceived usefulness of new personalised nutrition technologies, the perceived importance of new technologies/skill area to dietetics practice, and the perception of the self as an entrepreneur/innovator (Table 1).

The remaining sections asked questions about self-efficacy and personality traits. The construct of self-efficacy was originally developed by Bandura [37], and it refers to a 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 Schwarzer and Jerusalem [38] and then amended and revalidated by Chen et al. [39]. The scale comprised 8 questions and the responses were on a 5-point scale. Each item was equally weighted. The items were then summed and a mean score per participant was calculated.

Personality has frequently been assessed using the “Big Five” framework, which assumes that differences in personality between individuals can be identified by looking at 5 broad traits: extraversion; openness; conscientiousness; agreeableness; and, neuroticism [40]. Although personality has yet to be linked to entrepreneurism [36], the justification for assessing personality in the context of our study was to determine whether differences regarding the adoption of personalised nutrition technologies are associated with personality. For the purpose of this study, the 10-item version of the “Big Five Inventory” developed by Gosling et al. [41] was used. This version has demonstrated adequate levels of reliability and convergence with the full 44-item inventory [41] and been found to retain 85% of test-retest reliability [42]. Previous authors have recommended its use in research where data need to be collected from individuals in a short time [41]. The scale has also been validated [41, 42]. The scale consists of 10 questions, 2 for measuring each trait, for which responses are given on a 5-point scale.

Also included were questions, the content of which was derived from the findings of a previous qualitative study by Abrahams et al. [9]. Responses were provided on a 5-point Likert scale. Two questions asked about the perceived risks of nutrigenetic testing. Two questions enquired about views on the ethics of nutrigenetic testing. Four questions asked about the perceived usefulness of technology-enabled personalised nutrition regarding the microbiome, metabolomics, food allergy, and food sensitivity. Questions about the perceived importance of nutrition technologies (bio-, information, and mobile technology), and skill areas related to the field of dietetics (research, business, entrepreneurship, creativity, and training), items on perceptions of the self as an entrepreneur or innovator were also included.

Procedure

Sampling

Based on an α value of 0.05, a power of 0.9, and a potential effect size of 0.8, an estimated total sample size of 122 was required [43]. Dietitians were accessed between May and June 2017 through dietetics associations, and through dietetics-related social media networks (Facebook 1K, LinkedIn 1K, European Federation of Associations of Dietetics 2.6K, and Association of Nutrition and Dietetics 2K) based in English, Spanish, and Portuguese speaking countries. Personal invitations were also sent via LinkedIn to RDs. Only one person declined. One dietetics association in South Africa posted the information about the study in their weekly newsletter (1.5k). CEOs of companies that provide nutrigenetic testing kits to health care professionals for use in practice were requested to distribute the survey to their database of RDs. 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 and 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 e-mail containing an online link to the survey. Participants could withdraw their responses at any time, but no such requests were received.

Survey

The questionnaire was translated from English into Portuguese and Spanish and then 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. The option "non-binary" was added to the question on gender. The term "non-profit" was changed to "not-for-profit". The survey was made available over a 5-week period, during which time a reminder email was sent via the social media platforms.

Data Analysis

Treatment of Missing Data

At the end of the 5 weeks, the total number of completed questionnaires was 383. Participants with >5 demographic entries missing (10% of the survey) and those who identified themselves as students (*n* = 2, 0.5%) were removed from the database. Also excluded were 65 responses in which the participants had provided demographic information but did not complete any of the scales.

Treatment of Included Data

All the variables are summarised in Table 1. Responses to the 2 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 freetext box which included: high cost to clients (*n* = 3); job change (*n* = 2); a 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 [38] and personality (Big Five) [41] were calculated according to how the scales had been validated. Specific items on the self-efficacy and 10-item Big Five scales were reverse-scored [38, 41]. Missing data were replaced with the series means.

Cronbach's α implied very good reliability and high internal consistency for the self-efficacy tool (α = 0.87). For the 10-item personality scale, the results of the reliability tests for the 5 traits were: α = 0.70 (extraversion); α = 0.22 (agreeableness), α = 0.45 (conscientiousness); α = 0.54 (neuroticism); and, α = –0.43 (openness).

Principal component analysis (PCA) was performed on the unvalidated scales (perception of risks of genetic testing, ethics of genetic testing, usefulness of omics, usefulness of food testing, perceived importance of skill area, perceived importance of bio-, information, and mobile technology). A factor-loading threshold of 0.4, and an eigenvalue >1 were used to identify factors. PCA indicated that the 2 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 1 factor (an eigenvalue of 0.94). The Cronbach α for this variable labelled as “perceptions of risk” showed good reliability (α = 0.78).

PCA indicated that the 2 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 1 factor but with low reliability (α = 0.44). This factor was labelled “ethics”. Items on the usefulness of the microbiome, metabolomics, food allergy, and food sensitivity testing loaded onto 2 factors each, with an eigenvalue of 0.90. These were labelled “usefulness of omics” (microbiome and metabolomics: α = 0.84) and “usefulness of food testing” (food allergy and food sensitivity: α = 0.73).

The 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” loaded onto 3 factors, creating new variables labelled: “biotechnology” (α = 0.85), “information technology” (α = 0.84), and “mobile technology” (α = 0.61).

Items assessing the perceived importance of “creativity, innovation, and entrepreneurship,” “business and marketing,” “research,” and “teaching and training” loaded onto 1 factor, with “creativity, innovation, and entrepreneurship” contributing to the highest weighting of 0.80 and with adequate reliability ($\alpha = 0.51$). All 4 items were combined into a single variable labelled “importance of skill area.”

Pearson correlation was used to check for intercorrelations between the following 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.” The 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 [44]). Power analysis was performed using G*3-power software v3.1.9.2 [45].

Model 1 calculated the factors that determined the integration of personalised nutrition technologies into practice: “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-, information, and mobile technology;” “importance of skill area;” “ethics of genetic testing;” and, “perceptions of risk of genetic testing” as independent variables. “Having integrated nutrigenetic testing into practice” was the dependent variable.

Model 2 calculated factors that determined the perceived importance to dietetics of different types of technology. 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 dietetics practice" as independent variables. Perceived "importance of biotechnology;" "information technology;" and, "mobile technology" were entered as dependent variables. SPSS© (IBM) v24 was used to analyse data.

Results

Sample Description

The final sample comprised 323 RDs from the countries involved, as outlined in Table 2. The questionnaire was distributed to approximately 8,000 RDs, 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. [11]). The sample consisted mainly of females (93.8%) with only 5.6% male and non-binary gender 0.2% (Table 2). Age ranged from 21 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 technologies into their practice with regard to age ($t[321] = -0.63$, $p = 0.53$) or the 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 one-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 2 groups in terms of the sector where they worked ($t[321] = -0.14$, $p = 0.76$) or the number of years working ($t[321] = -0.29$, $p = 0.78$; range 1–50 years, median 12 years, and mean 10 years). Of the dietetics practitioners offering personalised nutrition (84%), 7 were based in the UK (14%), 1 in Australia (2%), 6 in Canada (12%), 12 in the USA (24%), 1 in Israel (2%), 9 in Mexico (18%), 4 in Portugal 4 (8%), 7 in South Africa (14%), 1 in the UAE (2%), and 1 in Norway (2%).

Factors Associated with the Integration of Personalised Nutrition into Practice

Traits that were positively correlated with having practiced personalised nutrition were: higher extraversion (r[321] = –0.11, p < 0.05); 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 dietetics practice (r[321] = –0.24, p < 0.01); higher perception of the 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); and, higher perceived usefulness of omics (r[321] = –0.21, p < 0.01) and food testing technologies (r[321] = –0.13, p < 0.01) (Table 3).

The regression model 1 of factors predicting the integration of personalised nutrition technology testing into practice explained 49% of the variance between dietetics 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% CI 0.94–2.36) (Table 4). Factors which predicted whether an individual had integrated personalised nutrition and associated technologies into practice were: a higher "perception of self as an entrepreneur" (B = –0.06; t = –2.73, p < 0.01, 95% CI –0.12 to –0.02 effect size d = 0.64) which was the strongest predictor; lower "perception of risk" associated with genetic testing technologies (B = 0.04; t = 3.14, p < 0.01; 95% CI 0.02–0.07; effect size d = 0.88); higher perceived "importance of biotechnology" (B = –0.03, t = –3.54, p < 0.01, 95% CI –0.05 to –0.02; effect size d = 0.74); lower perceived "importance of skill area" (B = 0.03, t = 2.09, p = 0.04, 95% CI 0.00 to 0.05; effect size d = 0.18); and, lower "perceived importance of information technology" (B = 0.02, t = 2.54, p = 0.01, 95% CI –0.01 to 0.03; effect size d = 0.02).

Factors Associated with the Perceived Importance of New Technologies

Three regression models were created to determine the perceived importance of each of the 3 types of personalised nutrition technology identified in the PCA analysis, labelled "biotechnology," "information technology," and "mobile technology" (Tables 5–7). 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 to –0.17), and lower “mean number of years working” (B = -0.04, $t = –3.02$, $p < 0.01$, 95% CI –0.06 to –0.01). This model explained 75% of the variation between variables and was significant (F[3211, 3212] = 21.43, $p < 0.01$, 95% CI –4.55 to 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 a higher perceived “importance of skill area” (B = 0.49, $t = 4.87$, $p < 0.01$, 95% CI 0.29 – 0.68), and higher perceived “importance of mobile technologies” (B = 0.42, $t = 4.09$, $p < 0.01$, 95% CI 0.22–0.63). This model explained 69% of the variability between variables and was significant (F[3211, 3212] = 15.16, $p < 0.01$, 95% CI –9.82 to 0.53).

Factors associated with 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 (F[3211, 3212] = 4.58, $p < 0.01$), 95% CI –1.26 to 4.34).

Discussion

The purpose of this research has been to identify the barriers to and facilitators of the adoption of personalised nutrition and related technologies by dietetics professionals. We sought to determine what distinguished dietitian practitioners who had integrated personalised nutrition technology into their practice from those who had not. Those who had integrated personalised nutrition technology into their practice considered themselves to be entrepreneurs, perceived a lower risk of genetic testing, and rated the importance of biotechnology as higher and professional skills as lower in dietetics practice. The finding that those who practiced technology-enabled personalised nutrition perceived less risk of 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 [46, 47]. This implies that more could be done to encourage discussion on the risks of genetic testing in dietetics practice.

The finding that the integration of personalised nutrition technology was also associated with a higher perceived importance of biotechnology but lower perceived importance of information technology would align with predictions made by the Diffusion of Innovation Theory [34] . This implies that more could be done to increase awareness of new bio-technologies among those dietetics practitioners who have not yet integrated personalised nutrition into practice.

Perception of self as an entrepreneur also distinguished between those dietitian practitioners who had integrated personalised nutrition technology into practice and those who had not. This may have important implications for policy and practice, as the diffusion of new innovations may be accomplished by enabling a dietitian to think more like an entrepreneur without necessarily having to become one.

The finding that perceived importance of “skill area” was not a predictor of the integration of personalised nutrition into practice is supported by previous research [9] that suggests that those who already practice technology-enabled personalised nutrition do not consider that additional professional skills are required. Hickson et al. [15] recently recommended the need for the development of a career framework which maximises and utilizes the existing skills and knowledge of dietitians.

As suggested by previous research [7], 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 proactive personalities tend to have higher self-efficacy [26, 27], greater risk-taking and opportunity-seeking behaviours [48], are goal-oriented, and have a need for achievement [49]. Self-efficacy has also been closely associated with entrepreneurial intentions and traits [50], entrepreneurial self-efficacy, and entrepreneurial intentions [28, 51–53]. Given that self-efficacy is task- and situation-dependent and can be increased through learning and experience [37], future considerations could include specific training directed towards raising the level of self-efficacy among nutrition and dietetics students. Contrary to previous research [54, 55], neither sector of work nor personality were associated with the integration of personalised nutrition technologies into dietetics practice.

A second objective sought to determine the factors associated with the perceived importance of personalised nutrition technologies to dietetics practice. The finding that the perceived importance of biotechnology was determined by the perceived usefulness of "omics" indicates that a potential strategy to encourage the 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, and addressing any negative perceptions that non-practicing dietitians may hold [34]. These include a fear of one's practice license being revoked and adopting a technology that is not evidence-based or endorsed by professional organizations [9, 13].

The perceived importance of information technology was also associated with perceived importance of biotechnology. Recent research has highlighted the value of sensors and wearable and nutrition informatics technologies for early detection, tracking, monitoring, and intervention to produce quality evidence-based personalised recommendations to individuals in real time [56]. Whilst nutrition informatics competencies among dietitians have already been investigated [57], in view of the rapid advances in personalised nutrition technologies, even more research is now needed [58, 59]. Factors that predicted the perceived importance of mobile technology such as higher perceived importance of information technology, higher conscientiousness, and higher qualifications, may imply the need for further training in telehealth and wearable and information technologies.

Limitations of the Study

Among the study limitations are those inherent to the use of self-report methodology, including the potential bias associated with perceived social desirability in responses [60, 61]. The online survey methodology meant that compliance was low, although the response rate was comparable to other online surveys that used a similar recruitment methodology [11] andadequately 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 (n = 274). Given that this is an emerging field and the research on the potential health benefits of a personalised nutrition approach is limited, one would expect the number of practitioners of personalised nutrition to be small.

Whilst the number of countries included was large, this reflects current practice among nutrigenetic testing companies that are making testing kits available across national borders. Low numbers of participants in certain countries, however, rendered it impossible to analyse for between country differences and this may have impacted upon the findings. The results of the prior qualitative study [9] 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 all items were understood in the same way by the 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 the perception of the self as an entrepreneur) may not have been sensitive as multi-scaled validated measures. The existing validated scales, however, would have taken a long time to complete and could have affected compliance. In addition, given that the aim of the study was to measure the perception of the self as an entrepreneur, rather than actually being an entrepreneur, no existing scale would have been entirely appropriate. Another factor which could have affected the ability of the measure to differentiate was that the 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 RDs to understand their reasons for stopping. Another omission was that respondents were not asked for the reasons why they had not used, or ceased to use,personalised nutrition technologies in practice. Possible contributing factors which could be explored in future research include organisational culture [18], a lack of opportunity, or constraints on resources. Another limitation is that the variable “ethics of genetic testing” had low reliability and the personality trait of “openness” had a negative Cronbach α value, indicating that these results must be interpreted with caution.

Conclusion

To our knowledge, this is the first multi-national study undertaken to determine how psychological and personal factors may influence the adoption of new personalised nutrition technologies in a cross-section of dietetics practitioners. These findings therefore have important implications for practice and policy, and in opening up dialogue on technology-enabled personalised nutrition. 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 the risks associated with personalised nutrition and associated technologies and into understanding how entrepreneurial traits and efficacy can be harnessed for the delivery of tech-enabled personalised nutrition in the near future.

Statement of Ethics

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

Disclosure Statement

The authors have no conflicts of interest to declare.

Author Contributions

M.A. designed the study, conducted the field work, completed the data analysis, and drafted the initial article. B.S.-K. and E.B. contributed to the design of the research co-analysed the data, and produced the final article. L.J.F. contributed to the design of the study and critically reviewed and approved the final article.

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Appendix after References (Editorial Comments)

Legend(s)

Table(s)

Footnote(s)

Table 1. Survey questions and associated variables

Question	Variable Type of scoring (scale) First author [ref.], year
Please indicate the answer that most accurately describes you – I will be able to achieve most of the goals that I have set for myself – When facing difficult tasks, I am certain that I will accomplish them – In general, I think that I can obtain outcomes that are important to me – I believe I can succeed at most endeavours to which I set my mind – I will be able to successfully overcome many challenges – I am confident that I can perform effectively on many different tasks – Compared to other people, I can do most tasks very well – Even when things are tough, I can perform quite well	Mean self-efficacy Likert scale (1–5) Schwarzer [38], 1995
Please indicate the answer that most accurately describes you – Gene- and other omics-based technologies to personalise nutrition represent a risk to me professionally – Gene-based personalised nutrition represents a risk to my patients and clients	Perception of risks (of genetic testing) Likert scale (1–5) Abrahams [9], 2018
Please indicate the answer that most accurately describes you – I consider myself to be an innovator	Perception of the self as an innovator Likert scale (1–5) Abrahams et al. [9], 2018
Please indicate the answer that most accurately describes you – I consider myself to be an entrepreneur	Perception of the self as an entrepreneur Likert scale (1–5) Abrahams [9], 2018
Please indicate the answer that most accurately describes you – Genetic testing poses an ethical dilemma to me – Genetic testing should not be available direct to consumers	Ethics of genetic testing Likert scale (1–5) Abrahams [9], 2018
Please indicate the answer that most accurately describes you – Microbiome testing is useful to personalise diets – Metabolomics is a useful tool to personalise diets	Usefulness of omics Likert scale (1–5) Abrahams [9], 2018
Please indicate the answer that most accurately describes you – Food allergy testing is a useful tool to personalise diets – Food sensitivity testing is a useful tool to personalise diets	Usefulness of food testing Likert scale (1–5) Abrahams [9], 2018
How well do the following statements describe you? I see myself as someone who – 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	Personality traits Likert scale (1–5) Gosling [41], 2003
Please indicate how you rate the importance of each area below to dietetics practice – Research – Creativity, innovation, and entrepreneurship – Business and marketing – Teaching and training	Perceived importance of skills area Likert scale (1–5) Abrahams [9], 2018
Please indicate how you rate the importance of each area below to RDs in dietetics practice – Genomics – Microbiome testing – Metabolomics – Functional and integrative nutrition	Perceived importance of: – Biotechnology
– Food engineering – Bio-informatics – Artificial intelligence and machine learning	– Information technology

– Chatbots – Virtual and augmented reality – Telehealth – Wearable technology	 – Mobile technology Likert scale (1–5) Abrahams [9], 2018

Table 2. Characteristics of the study sample (*n* = 323)

Gender	
Male	18 (5.6)
Female	303 (93.8)
Non-binary	2 (0.2)
Age range, years	21–72
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 sector	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	
UK	133 (41)
Australia	6 (1.86)
Canada	23 (7)
USA	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)
Scandinavia	2 (0.6)
The Netherlands	1 (0.3)
St Helena	1 (0.3)
Egypt	1 (0.3)
Number of years in practice (range)	1–10
Nutrigenetic testing has been integrated into practice	
Yes	49 (15)
No	274 (85)

Values express *n* (%), unless otherwise indicated.

Table 3. Mean and SD scores for dietitians who had (*n* = 49) and had not (*n* = 274) integrated nutrigenetic testing into their practice

	Early adopters (15%)		Non-adopters (85%)	
	mean score	SD	mean score	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 skills 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 as an:				
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

* $p < 0.01$ indicates significance. SD, standard deviation.

Table 4. Factors associated with the integration of personalised nutrition into practice (*n* = 323)

	Unstandardized coefficients		Std. coefficients	*p* value
	B	SE	β	
Constant	1.651	0.362		0.000
Gender	0.094	0.070	0.072	0.179
Age in years	0.005	0.004	0.141	0.195
Highest level of qualification gained	–0.016	0.023	–0.038	0.482
Sector of work	0.009	0.011	0.043	0.405
Mean number of years working	–0.007	0.004	–0.192	0.078
I consider myself to be an innovator	0.023	0.026	0.057	0.383
I consider myself to be an entrepreneur	–0.062	0.023	–0.181	**0.007**
Mean self-efficacy score	–0.048	0.048	–0.062	0.320
Extraversion	–0.014	0.010	–0.077	0.161
Agreeableness	0.002	0.012	0.009	0.874
Neuroticism	0.015	0.011	0.078	0.165
Openness	0.000	0.013	0.001	0.980
Conscientiousness	0.009	0.015	0.036	0.548
Country (UK and other)	–0.105	0.042	–0.144	**0.014**
Importance of skills area	0.028	0.013	0.128	**0.037**
Perception of risks of genetic testing	0.044	0.014	0.184	**0.002**
Ethics of genetic testing	–0.004	0.012	–0.019	0.738
Usefulness of omics	–0.009	0.016	–0.036	0.554
Usefulness of food testing	0.003	0.011	0.016	0.778
Importance of mobile technology	0.003	0.013	0.012	0.841
Importance of information technology	0.018	0.007	0.177	**0.012**
Importance of biotechnology	–0.033	0.009	–0.269	**0.000**

Bold type denotes ■■■. * $p < 0.05$ indicates significance.

Table 5. Factors predicting the perceived importance of biotechnology in a cross-section of dietitians

	Unstandardized coefficients		Standard coefficients	*p* value
	B	SE	β	
Constant	–0.553	2.031		0.785
Highest level of qualification gained	0.259	0.142	0.074	0.068
Sector of work	0.046	0.067	0.027	0.492
Mean number of years working	–0.036	0.012	–0.120	**0.003**
I consider myself to be an innovator	0.020	0.164	0.006	0.902
I consider myself to be an entrepreneur	0.003	0.139	0.001	0.982
Mean self-efficacy score	–0.222	0.298	–0.035	0.457
Extraversion	–0.025	0.063	–0.016	0.696
Agreeableness	0.082	0.073	0.045	0.263
Neuroticism	0.016	0.066	0.010	0.813
Openness	0.037	0.079	0.018	0.644
Conscientiousness	0.023	0.090	0.011	0.801
Importance of professional skills	0.297	0.078	0.169	**0.000**
Perception of risks of genetic testing	–0.334	0.085	–0.170	**0.000**
Ethics of genetic testing	0.115	0.076	0.064	0.131
Usefulness of omics	0.516	0.093	0.245	**0.000**
Usefulness of food testing	0.144	0.066	0.090	0.031
Importance of mobile technology	0.100	0.081	0.053	0.220
Importance of information technology	0.333	0.040	0.397	**0.000**

Bold type denotes ■■■. * $p < 0.05$ indicates significance.

Table 6. Importance of information technology to dietetics practice in a cross-section of dietitians

	Unstandardized coefficients		Standard coefficients	*p* value
	B	SE	β	
Constant	–4.645	2.630		0.078
Highest level of qualification gained	–0.147	0.185	–0.035	0.430
Sector of work	–0.122	0.087	–0.060	0.159
Mean number of years working	0.027	0.016	0.077	0.082
I consider myself to be an innovator	0.302	0.213	0.076	0.158
I consider myself to be an entrepreneur	–0.016	0.181	–0.005	0.928
Mean self-efficacy score	0.142	0.388	0.019	0.714
Extraversion	0.022	0.081	0.012	0.788
Agreeableness	0.118	0.095	0.055	0.217
Neuroticism	–0.026	0.086	–0.014	0.762
Openness	0.021	0.103	0.009	0.842
Conscientiousness	–0.219	0.116	–0.091	0.061
Importance of professional skills	0.486	0.100	0.232	**0.000**
Perception of risks of genetic testing	0.124	0.113	0.053	0.273
Ethics of genetic testing	–0.057	0.099	–0.027	0.561
Usefulness of omics	0.071	0.127	0.028	0.576
Usefulness of food testing	–0.090	0.087	–0.047	0.302
Importance of mobile technology	0.423	0.103	0.187	**0.000**
Importance of biotechnology	0.564	0.067	0.474	**0.000**

Bold type denotes ■■■. * $p < 0.05$ indicates significance.

Table 7. Importance of mobile technology to dietetics practice in a cross-section of dietitians

	Unstandardized coefficients		Standard coefficients	*p* value
	B	SE	β	
Constant	1.539	1.424		0.281
Highest level of qualification gained	0.219	0.099	0.119	**0.028**
Sector of work	0.043	0.047	0.048	0.355
Mean number of years working	0.000	0.008	0.001	0.987
I consider myself to be an innovator	0.016	0.115	0.009	0.888
I consider myself to be an entrepreneur	–0.040	0.097	–0.027	0.679
Mean self-efficacy score	0.251	0.209	0.076	0.231
Extraversion	–0.010	0.044	–0.012	0.826
Agreeableness	–0.054	0.052	–0.057	0.292
Neuroticism	0.025	0.047	0.031	0.590
Openness	0.022	0.056	0.020	0.699
Conscientiousness	0.181	0.062	0.170	**0.004**
Importance of professional skills	0.038	0.056	0.042	0.493
Perception of risk of genetic testing	0.077	0.061	0.075	0.205
Ethics of genetic testing	0.062	0.053	0.066	0.245
Usefulness of omics	–0.081	0.068	–0.073	0.240
Usefulness of food testing	–0.061	0.047	–0.072	0.191
Importance of biotechnology	0.049	0.040	0.094	0.220
Importance of information technology	0.123	0.030	0.279	**0.000**

Bold type denotes ■■■. * $p < 0.05$ indicates significance.