Title

Does personalized nutrition advice improve dietary intake in healthy adults? A systematic review of randomized controlled trials

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Abbreviations BP, blood pressure; CHD, coronary heart disease; CVD, cardiovascular disease; DHA, Docosahexaenoic acid; EPA, Eicosapentaenoic acid; FA, fatty acid; FFQ, Food Frequency Questionnaire; LDL-C, low-density lipoprotein cholesterol; NS, non-significant; PN personalized nutrition; RA, rheumatoid arthritis; RCT, randomized control trial; SNP, Single nucleotide polymorphism; T2DM, Type 2 diabetes mellitus

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ABSTRACT

Personalized nutrition (PN) behaviour change interventions are being used increasingly in attempts to improve dietary intake; however the impact of PN advice on improvements in dietary intake has not been reviewed systematically. The aim of this systematic review was to evaluate the effect of PN advice on changes in dietary intake compared with generalised advice in healthy adults. Three databases (EMBASE, PubMed and CINAHL) were searched between 2009 and 2020 for RCTs that tested the effect of PN and tailored advice based on diet, phenotype or genetic information. The Evidence Analysis Library Quality Criteria checklist was used to conduct a risk of bias assessment. Information on intervention design and changes in nutrients, foods and dietary patterns were extracted from the 8 studies meeting the inclusion criteria. Studies were conducted in the United States, Canada or Europe, reported outcomes on 57 to 1488 participants, and varied in follow-up duration from 1 to 12 months. Two studies incorporated behaviour change techniques. The risk of bias for included studies was low. Overall, the available evidence suggests that dietary intake is improved to a greater extent in participants randomised to receive PN advice compared with generalised dietary advice. Additional well-designed PN RCTs are needed that incorporate behaviour change techniques, a broader range of dietary outcomes and comparisons between personalization based on dietary, biological and/or lifestyle information.

Keywords personalized nutrition; behaviour change; systematic review; diet; dietary patterns; nutrition; adults; genotype; phenotype

21 INTRODUCTION

22 With poor diet now considered a top risk factor for non-communicable diseases, [1]
23 improving dietary intake is a global priority. [2, 3] Current public health campaigns using
24 “one-size-fits-all” dietary recommendations are not achieving the changes in dietary
25 behaviour needed to shift dietary intake towards healthier dietary patterns. [4, 5] Given the
26 complex and varied nature of individual characteristics influencing dietary behaviour,
27 targeted, or personalized, dietary interventions based on these characteristics may be more
28 effective than generalised advice. [6, 7] With increasing agreement regarding the definition of
29 personalized nutrition (PN), [6, 8] this review considers PN as an approach in which
30 individual dietary intake, phenotypic information (e.g. anthropometric measurements and
31 biomarkers of disease risk) and genetic information (e.g. single nucleotide polymorphisms)
32 are used to design tailored nutrition advice. [9, 10]

33 Few interventions have evaluated the effect of PN advice based on dietary, phenotypic and/or
34 genetic characteristics on improvements in dietary intakes and eating behaviours. [9] Much
35 research to date has focused on the effect of genetic-based PN advice on improvements in
36 diet, with mixed results. [11] While two 12-month RCTs in Canadian adults have shown
37 improvements in intakes of some nutrients (sodium and total fat) following the provision of
38 advice based on carriage of specific risk variants [12, 13], trials in Europe that have studied
39 changes in nutrients, foods and/or overall dietary patterns have observed mixed results for
40 sustained and clinically relevant improvements in diet following provision of genotype-based
41 advice. [9, 14, 15] Nevertheless, a recent systematic review of genetic testing and lifestyle
42 behaviour changes concluded that, of all lifestyle behaviours, changes in dietary intake were
43 the most promising given that genetic testing led to practical recommendations that often
44 focused on changes in diet. [16] Few studies have examined the effect of personalized advice
45 based on phenotypic characteristics and results have been mixed [9, 17] To date, the pan-

European Food4Me study has been the only RCT to evaluate whether PN advice based on diet, phenotype and genotype was more effective for improving nutrient, food group intakes and overall dietary patterns compared with generalised dietary advice. [9]

Despite a rapid increase in commercial, direct-to-consumer PN testing and a systematic review on genetic testing interventions, [18] there has been no systematic review of the evidence from studies that have tested the utility of PN based on current diet, individual biological characteristics, lifestyle information and/ or other personal attributes for improving dietary intake. Such a review is needed to provide a comprehensive and objective analysis of the outcomes of all PN interventions conducted to date. Moreover, there is a need to determine whether PN interventions improve dietary intake to a greater extent than conventional, generic, dietary advice when considering intakes of nutrients, food groups and overall dietary patterns. This systematic review aimed to examine whether PN interventions produce bigger improvements in dietary intake than conventional dietary advice by qualitatively reviewing evidence from PN interventions in healthy adult populations. The results of this review will inform the design of future PN interventions and their potential for implementation into healthy eating strategies and direct-to-consumer PN offerings.

METHODS

This systematic review was conducted according to the Cochrane Handbook for Systematic Reviews of Interventions [19] and reported using the PRISMA guidelines (Supplemental Table 1). [20] The protocol was registered with PROSPERO, the International Prospective Register of Systematic Reviews (registration number CRD42019132050).

Search Strategy

Electronic searches were conducted to identify studies reporting changes in dietary intakes (nutrients, foods and dietary patterns) following a PN intervention. The following databases were searched systematically from July 2009 to June 2020: EMBASE, OVID MEDLINE, and CINAHL. The search strategy combined four search themes using the Boolean operator “AND”. The first theme was (“personalized nutrition” OR “personalised nutrition” OR precision OR genomics OR gene OR genes OR genetic OR genetics OR phenotype OR genotype OR DNA), the second theme was (nutrition OR diet OR diets OR dietary), the third theme was (change* OR effect* OR impact* OR modif*) and the fourth theme was (information OR recommendation OR advice OR intervention* or program* OR counsel*). The specific search strategies for PubMed, EMBASE and CINAHL are presented in Supplemental Table 2. Reference lists of related publications and systematic reviews were hand searched to identify other studies potentially eligible for inclusion.

Study selection and screening

Articles were included if they i) were randomised interventions, ii) assessed the impact of personalized advice on change in nutrients, food groups and/or dietary patterns and ii) were in healthy adults. Multi-component interventions were included if dietary intake was included as an outcome. For the purpose of screening, personalized advice was defined as dietary advice based on either current dietary intake, genotype and/or phenotype. Healthy adults were defined as individuals aged 18 years and over and without a chronic condition (e.g. self-reported or doctor diagnosed type 2 diabetes, cardiovascular disease or cancer). Therefore, studies were excluded if they specifically recruited individuals with a chronic condition. Studies that specifically recruited individuals with overweight or obesity were included in the present review due to the high proportion of individuals with overweight or obesity among the apparently healthy populations in the countries where the PN RCTs were carried out.

However, individuals who are overweight or obese could have undiagnosed health problems and may enter a weight loss intervention with very different motivators for behaviour change. Thus, we reviewed these studies separately. Articles were excluded if they i) did not report dietary intake at both baseline and follow-up, ii) were not in English, iii) were observational or animal studies or iv) did not include a comparator group (i.e. non-personalized advice that was either generalised dietary or behavioural advice depending on the nature of the trial). Included studies were restricted to those published since 2009. This search period was selected on the basis that research on PN was very limited prior to 2009. A 2010 Cochrane review on the effects of communicating DNA-based disease risk estimates on risk reducing behaviours was hand searched to confirm that no studies were missed. [21] Multiple publications from the Food4Me study were identified in the search, [9, 14, 22] and publications reporting changes in dietary intake in response to PN advice were included in this review. [9, 14] Screening of titles and abstracts was performed using the selection criteria by independent reviewers (B.M, A.N and R.J). Full texts of eligible articles were then assessed in duplicate (R.J and A.N) and any discrepancies were resolved by consensus.

Data extraction and quality assessment

A data extraction template was developed and piloted for use in this review. Two reviewers (B.M and R.J) extracted the data independently, which were checked by a third reviewer (A.N). Data were extracted on participants (age, sex, country), study design (intervention and control groups, follow-up duration and dietary assessment methodology), intervention strategy (i.e. basis of PN advice) and outcomes (i.e. dietary intake or other outcomes assessed if a multi-component intervention was used), results and conclusions. The Academy of Nutrition and Dietetics Evidence Analysis Library Quality Criteria Checklist was used to conduct a risk-of-bias assessment on the studies that met the inclusion criteria. [23] Two

reviewers (B.M and R.J) assessed studies independently and any discrepancies were resolved by consensus. An overall score (positive, neutral, negative) was assigned to each article based on four relevance questions and ten validity questions (Supplemental Table 3). [23]

RESULTS

As detailed in Figure 1, our initial search identified 5,465 articles. After removal of duplicates, 3,972 were excluded based on their title and abstract and 122 full text articles were reviewed. Eleven studies met the pre-determined inclusion criteria for the systematic review. Studies were excluded for the following reasons: change in dietary intake was not an intervention outcome (n=36); no PN advice was provided (n=24); no non-personalized comparator group (n=30); participants were not free from chronic conditions as they had irritable bowel syndrome (n=2), type 2 diabetes (n=3), coronary heart disease (n=1) or cancer (n=2); multiple publications from the same intervention study (n=9); full-text not available (n=4). No studies from the 2010 Cochrane review on the effects of communicating DNA-based disease risk estimates on risk reducing behaviours met the eligibility criteria due to none providing PN advice (n=7).

Of the eleven studies included, the sample size of participants varied from 57 [11] to 1488 [9], with an age range from 18 to 79 years, and all but one study [11] included both male and female participants (Table 1). Three were conducted in the US, [17, 24, 25] three were in Canada, [11-13] and five were in Europe. [9, 14, 15, 26, 27] The duration of follow-up ranged from three months or less, [11, 24, 26, 27], six months, [9, 14, 17, 25] to 12 months. [12, 13, 15]. Five studies provided dietary advice based on genotype alone [11, 12, 15, 24, 25], one study provided dietary advice based on current diet only [27] and four studies provided advice based on a combination of current diet, phenotype and/or genotype [9, 14, 17, 26]. Comparator groups included generalised dietary advice based on a number of

145 nutrients and/or foods [9, 12-15, 17, 24] or generalised dietary and lifestyle advice. [11, 25-
 146 27] Five studies provided genotype-based advice related to disease risk, [15, 17, 24-26] while
 147 five provided genotype-based advice related to metabolism. [9, 11-14] Two studies were
 148 weight management interventions that specifically recruited participants with a
 149 BMI>25kg/m². [13, 27]

150 Five studies incorporated behaviour change techniques into their study design. Celis-Morales
 151 et al. [9] and Livingstone et al. [22] included a total of 17 behaviour change techniques to
 152 support sustained changes in dietary intake in the Food4Me Study, while Sparks et al. [17]
 153 used motivational interviewing techniques in one-on-one education for the intervention
 154 group. The two weight management interventions included techniques based on either the
 155 theory of planned behaviour or a combination of motivational interviewing, action and
 156 coping plans and implementation intentions. [13, 27] Conversely, the remaining studies did
 157 not report any specific behaviour change techniques. One study reported use of theory-based
 158 models but did not specify which theory was used to inform the intervention. [24]

159 Six studies focused on dietary intake as a primary outcome. [9, 11, 12, 14, 15, 24] As shown
 160 in Table 2, dietary intake was measured using diverse instruments including 24-hour dietary
 161 recalls, food frequency questionnaires and brief dietary questionnaires. Foods and/or nutrients
 162 were measured as dietary outcomes in all included studies, whereas an overall dietary pattern
 163 (2010 Healthy Eating Index and Mediterranean Diet Score) were measured in two studies
 164 only. [9, 14] The most commonly reported dietary outcome was change in fruit and vegetable
 165 intake.

166 Outcomes from the quality appraisal of included studies are shown in Supplemental Table 3.

167 All studies received a 'positive' overall rating indicating that inclusion and exclusion criteria

were defined, bias was low and that data collection and data analysis procedures were appropriate. (20)

As shown in Table 1, eight of the eleven studies reported improvements in dietary intake following PN advice compared with the control group. These improvements were observed in one or more dietary outcomes for at least one time point. Two Food4Me studies demonstrated that personalized advice (based on current diet, phenotype and genotype) improved overall dietary patterns at six months, as well as the intake of total energy, red meat, salt, saturated fat and folate. [9, 14] However, only one of these studies indicated that genotypic information may enhance the effectiveness of the PN advice above that achieved by PN based on analysis of current diet and phenotype.

The studies that investigated the effects of PN using genotype or/and phenotype-based estimates of chronic disease risk and based on nutrient metabolism showed mixed results. Hendershot et al. reported reduced alcohol intake following genotype-based advice on alcohol-related cancer risks [24]. Additionally, Sparks et al. tested the effectiveness of education on personalized rheumatoid arthritis risks based on a combination of genotype, phenotype and behavioural factors, and observed increased intakes of fish and fruit. [17] In contrast, one study that communicated genetic-based T2DM risks did not demonstrate any effect on dietary intake. [26] Similarly, while Kullo et al. showed no additional effect of providing a CVD genetic risk score on dietary fat intake, [25] Hietaranta-Luoma et al. observed improved fat quality at 6 months following advice based on CVD genetic risk but this improvement was not sustained at 12 months. [15] Roke et al. found no effect of communicating a fat metabolism related genotype [11], whereas Nielsen et al. showed a reduction in sodium intake at 12 months in individuals who were informed that they had a genotype (risk version of the *ACE* gene) linked to higher sodium sensitivity. [12] Moreover,

Horne et al. demonstrated that nutrigenomics-based macronutrient recommendation(s) to enhance weight loss reduced dietary fat intake more than the standard advice. [13]

DISCUSSION

This systematic review aimed to evaluate the effect of personalized interventions on changes in dietary intake. We observed some evidence for improvements in dietary intake in participants randomised to receive PN advice compared to the control group. Given the clinical heterogeneity in the RCTs, future PN interventions of comparable designs are needed to facilitate meta-analysis of change in dietary intake. Additional recommendations for PN interventions include incorporating appropriate behaviour change techniques, including comparisons between different bases of personalization and standardising reporting of dietary outcomes.

Although all studies in this review included genetic information as one element of the basis for personalized advice, there was little evidence that genotypic information was effective in improving dietary intake. This is consistent with recent meta-analyses on the effect of genetic advice. [16, 28, 29] Hollands et al. concluded that communicating genetic-based risk had little or no impact in reducing health risk behaviours, [28] while Li et al. found no evidence that communication of genetic-based risk improved dietary or exercise behaviours of participants. [29] In contrast, although Horne et al. found that the genetic-based interventions provided to participants were overall of “poor” quality, they indicated that the evidence for lifestyle behaviour change was most promising for genetic testing to improve dietary intake. [16] The authors speculated this was due to most genetic testing leading to recommendations for changing diet, rather than other lifestyle behaviours. However, findings from the present review found limited evidence to support benefits of genotype-based advice on changes in dietary intake as superior or more effective than other forms of personalisation. Future RCTs

are needed to test the effect of PN advice based on genotyping compared with PN advice derived on other individual participant characteristic(s). Moreover, research on genotype-based advice has been based on both single genotypes and on genetic risk scores that combine multiple SNPs of interest. To date, it is not clear which is the better approach. Use of single genotypes has the advantage that there may be evidence of specific diet-gene interactions that can provide objective guidance on dietary advice. [30] Conversely, given that multiple genetic variants influence risk of chronic diseases, the use of genetic risk scores will capture more of the genetic predisposition to disease at the cost of less certainty about what dietary changes are most appropriate.

Evidence suggests that phenotypic characteristics, such as drivers of taste preferences and metabolomics, might be beneficial to include in the design of PN advice. [31] Recent research in a UK cohort of 1,002 twins has advanced understanding of inter-individual variability in postprandial response to food intake, [7] supporting the need to leverage different features of human variability in the design of PN advice. Moreover, it will be important to address the psychological, social, economic and cultural factors that influence eating patterns and that differ considerably between individuals. [32, 33] In particular, there is a need to better understand the role of behavioural influences on the design and update of PN advice.

We propose that a key factor influencing the success of the PN interventions was the use of theory to underpin the intervention, consistent with the broader behaviour change literature. [34, 35] Two studies within our review incorporated behaviour change theories into their study design, which may have contributed to the observed improvements in dietary intakes following the intervention. A recent systematic review of genetic-based trials by Horne et al. found that lifestyle changes were more effective when studies implemented a model of

behaviour change. [16] Of the studies that provided genotype only advice, the two studies that showed large improvements in dietary intake were Neilson et al. [12] and Heitaranta-Luoma et al. [15] Both studies also had the longest duration of follow up (12-months) and so demonstrated sustained behaviour change. Although neither study specified the use of particular behaviour change techniques, the success of one of these studies may be attributable to consideration of health behaviours. Heitaranta-Luoma et al. [15] designed health risk messages based on a 4-step model of response efficacy, self-efficacy, susceptibility, and severity. When designing future nutrigenomics-based PN interventions, researchers should ensure their studies are based on sound theories of behaviour change known to motivate behaviour change. [36]

The demographics of participants included in the interventions differed between studies. While young adults may be more inclined to adopt change, they may be less likely to maintain it. (34) Conversely, older adults may find it more difficult to adopt a new health behaviour but may be more motivated to maintain the change. [36, 37] It is well established that females are more likely to participate in nutrition-related research than males, partially explained by a greater interest in health and nutrition. [38, 39] Moreover, findings from the Food4Me study suggest that males are less likely to be interested in, and to benefit from, a PN intervention. [22, 40] Thus, given that all studies contained a higher proportion of female participants (range 52 – 100%), the design of future PN interventions should consider accommodating motivators of behaviour change specific to males. Participants in the Food4Me study were broadly representative of the European adult population in regards to their diet and lifestyle behaviours; [40] however, similar to the majority of the studies within our review, most were participants with high levels of education or grade of employment. A large proportion of the customer base for direct-to-consumer genetic testing is highly educated and of high socioeconomic status. [41] In general, population groups with lower

socioeconomic status have poorer diets and experience higher prevalence of obesity and chronic diseases [42, 43] and will thus experience different challenges in making dietary changes. Moreover, PN interventions are being increasingly targeted to the general population and will thus need to account for any changes in eating habits in everyday life as a result of influences from family, society and socioeconomic conditions. [43, 44] Of the eleven studies in the present review, only three were in non-white or mixed-ethnicity participants. [11, 12, 24] Consequently, given differences in behavioural and biological characteristics between different ethnic groups, [45] future studies should investigate the efficacy of PN nutrition approaches in different ethnic groups and explore the participant characteristics that are most appropriate for personalizing nutrition interventions in such groups. [46]

Our review suggests that the design of the PN intervention may impact on the degree of dietary change observed. At least for older people, evidence from dietary interventions suggests that changes seen at six months are likely to be sustained for at least 12 months. [36] Moreover, the frequency of feedback has been shown to impact on dietary changes, where more frequent PN feedback amplified changes in dietary intake but also increased drop-out rates. [47] The design of the dietary advice and subsequent analysis should also be considered. In two of the included studies, [9, 12] not all participants received the same targeted dietary advice and so the investigators also ran analyses for each dietary outcome restricted to the participants who were provided with advice about that dietary outcome. These findings emphasise the scope for future research to explore the optimal features of PN intervention study design, while also incorporating existing best practice behaviour change principles. [6]

The studies included in this review measured a variety of dietary outcomes using either FFQs or brief diet questions. Some studies focused on specific nutrients, such as omega-3 FAs, [11] alcohol, [24] caffeine, vitamin C, added sugar and sodium, [12] while others included intake of nutrients, food groups (9,16,19,20) and overall dietary patterns. [9] A broader range of dietary outcomes investigated would enable a more rigorous appraisal of changes in dietary intakes, including investigating whether intakes of specific nutrients, specific food groups or entire dietary patterns are affected differentially following PN advice. While a focus on individual nutrients may offer insights into particular nutrient-disease relationships in specialised population groups, foods and nutrients are not eaten in isolation, and dietary guidelines and policies internationally have an increasing focus on dietary patterns. [5, 48, 49] Future research should thus consider the effect of PN advice on overall dietary patterns and eating occasions and should use appropriate dietary assessment tools to capture this additional information. [50, 51] This information will be particularly important for understanding the feasibility of implementing PN advice based on dietary patterns, given that changing some dietary components (e.g. increasing vegetable intake) may be achieved more easily than others (e.g. reducing fat intake). In addition, achieving one goal at a time may be more successful than implementing multiple changes at once. [52] However, from a population health perspective, improving the overall dietary pattern is likely to be the major goal.

This review has a number of strengths. It included a systematic review of a broad range of PN RCTs, providing qualitative insights into the benefit of PN approaches to improve dietary intake. In addition, we have investigated the features of effective PN interventions, thus informing the design of future PN interventions. A further strength of this study is the use of a clear definition of PN to inform the selection of included studies, which provided a framework for evaluating and comparing PN intervention designs. This study followed the

PRISMA guidelines and included a risk of bias assessment, which showed that the majority of studies included were given a positive rating.

Our review has several limitations. Firstly, the nature of PN interventions makes blinding challenging. [53] Moreover, given that the studies included in this review utilised self-reported measures of dietary intake, results may be subject to recall and social desirability biases. [50, 54] Detail on dietary intake was limited in most studies, given that brief dietary questions and FFQs were the most commonly used dietary assessment methodologies. Nonetheless, social desirability bias is expected to be less prevalent in the two web-based interventions included in this review given that perceived anonymity is higher. [9, 17]. Dietary change requires conscious cognitive effort by participants to make multiple choices daily that align with the prescribed changes. Compliance was not reported for half of the included studies, [11, 12, 15, 17, 24, 25] and thus we recommend that future PN interventions report results according to the Consolidated Standards of Reporting Trials guidelines. [55] Lastly, the heterogeneity of PN RCTs conducted to date preclude meta-analysis.

In conclusion, the present review provides evidence that the provision of PN advice based on a combination of dietary information, phenotype, genotype and/or lifestyle factors improved dietary intakes in healthy adult populations when compared with generalised dietary advice. These findings have implications for the design of future PN interventions aiming to improve healthy eating behaviours. More well-designed and executed RCTs are required to strengthen the evidence base for PN so that, if appropriate, these strategies can be effectively incorporated into healthcare. To optimise public health benefit, research should examine PN interventions to improve overall dietary patterns as well as intakes of individual foods and nutrients. Moreover, future PN interventions should consider a wider range of individual

characteristics that influence both food intake and the capacity to make, and sustain, dietary changes and should incorporate relevant behaviour change techniques.

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FIGURE LEGENDS

Fig 1. PRISMA flow diagram of studies included

SUMMARY

Personalized nutrition advice improves dietary intakes in healthy adults: a systematic review of randomized controlled trials

Table 1. Characteristics of studies included (n=11)

Authors, date	Participants (n baseline) Age Country	Study design, Follow-up	Outcomes measured	Intervention group(s) conditions	Comparison group(s) conditions	Dietary results	Author's Conclusion
Celis-Morales et al. 2016 [9]	1488 (618 M/ 870 F) 18-79 years Ireland, Spain, Poland, Netherlands, UK, Greece, Germany	RCT 6 months	Dietary intake ² , anthropometrics and biomarkers	L1: Dietary advice based on current diet; L2: Dietary advice based on current diet and phenotype (anthropometry, blood markers); L3: Dietary advice based on current diet, phenotype and genotype (5 diet-responsive genetic variants). Advice designed using 17 BCTs.	Dietary advice based on generalised dietary guidelines	Greater improvement in dietary pattern (2010 Healthy Eating Index), intake of energy, red meat, salt, saturated fat and folate in participants who received personalized advice (L1+L1+L3) compared to the control at 6 months.	PN was more effective at improving dietary intake than population-based guidelines. No evidence that using phenotype and/or genotype increased effectiveness compared to advice based on current diet alone.
Godino et al. 2016 [26]	569 (268 M/ 301 F) 39-55 years England	RCT 2 months	Physical activity ² , dietary intake, weight, health- related behaviour and attitudes	Phenotypic-based T2DM risk (Cambridge Diabetes Risk Score based on age, sex, smoking status, family history of diabetes, prescription of steroid or antihypertensive medication) or genotype-based T2DM risk (23 diabetes susceptibility SNPs).	No provision of phenotype or genotype	No effect of communicating genetic or phenotypic estimates of T2DM on fruit and vegetable consumption	Communication of T2DM risk estimates based on genotype or phenotype did not result in changes in dietary intake.
Hendershot et al. 2010 [24]	200 (93 M/ 107 F) 19-22 years US	RCT 1 month	Alcohol consumption, risk perception, motivation and behavioural intention	Genotype-based risk for alcohol- related cancer and alcohol dependence (ALDH2)	Non-Genotype based feedback relating to normal college student behaviours.	Greater reduction in peak alcohol intake, typical weekend alcohol intake and alcohol intake frequency among the high-risk alcohol-related cancer intervention group compared to the control group.	This study provides initial evidence for the feasibility of genetic risk estimates in alcohol-related health interventions.
Hietaranta- Luoma et al. 2014 [15]	107 (33 M/ 74 F) ¹ 20-67 years Finland	RCT 12 months	Dietary intake, alcohol consumption, physical activity, health and taste attitudes	Genotype-based risk for CVD (apoE)	General health information on lifestyle and CVD risk	Improvement in fat quality in high-risk genetic group compared to control at 6 months. NS difference between groups at 12 months for fruit and vegetables; Decrease in high-fat/high-sugar foods intake in low-risk genetic group compared to control at 12 months.	Personalized genetic information may affect fat quality within the diet, but more research is required to determine how to use genotype-based health information and achieve long- term changes.

Authors, date	Participants (n baseline) Age range Country	Study design, Follow-up period	Outcomes measured	Intervention group(s) conditions	Comparison group(s) conditions	Dietary outcomes	Author's Conclusion
Kullo et al. 2016 [25]	203 (97 M/ 106 F) ¹ 45-65 years US	RCT 6 months	LDL-C, ² dietary intake, physical activity and anxiety	Genetic risk score (28 CHD-susceptibility SNPs) for 10-year probability of CHD	Non-genetic risk score for 10-year probability of CHD	No effect of communicating a genetic risk score of CHD on total fat intake compared to a conventional risk score alone.	Providing genetic-based CHD risk estimates resulted in decreases in LDL-C levels compared to conventional CHD risk estimates. No effect on dietary fat intake.
Livingstone et al. 2016 [14]	1480 (614 M/ 866 F) 18-79 years Ireland, Spain, Poland, Netherlands, UK, Greece, Germany	RCT 6 months	Dietary intake	L1: Dietary advice based on current diet; L2: Dietary advice based on current diet and phenotype (anthropometry, blood markers); L3: Dietary advice based on current diet, phenotype and genotype (5 diet-responsive genetic variants). Advice designed using 17 BCTs.	Dietary advice based on generalised dietary guidelines	Greater improvement in Mediterranean Diet Score in participants who received personalized advice (L1+L1+L3) compared to control at 6 months. Also, greater improvement in participants who received L3 dietary advice compared to L2 at month 6.	After the intervention, Mediterranean Diet Scores were greater in individuals randomly assigned to receive PN than in controls, with the addition of DNA-based dietary advice resulting in the largest differences.
Nielsen and El-Sohemy 2014 [12]	138 (32 M/ 106 F) 23-35 years Canada	RCT 12 months	Dietary intake	Genotype-based advice for caffeine, vitamin C, added sugars & sodium (CYP1A2, GSTM2 + GSTT1, TAS1R2, ACE). Gave advice on specific dietary components and examined whether participants adhered to them.	Generalised dietary advice for caffeine, vitamin C, added sugars & sodium	Greater reduction in sodium intake among the high-risk intervention group compared to the control group at 12 months; NS difference in caffeine, vitamin C, added sugar intake between the high-risk intervention group and control group at 12 months.	DNA-based dietary advice was shown to impact dietary intake to a greater extent than general population-based recommendations.
Roke et al. 2017 [11]	57 (57 F) 18-25 years Canada	RCT 3 months	Dietary intake ² , biomarkers and anthropometrics	Genotype-based advice (FADS1)	No genotype-based advice	No effect of communicating a genotype (FADS1) on EPA and DHA intake.	The provision of personal FADS1 genetic information did not significantly change intake of dietary omega-3 FAs compared to the non-genetic group.
Sparks et al. 2018 [17]	238 (56 M/ 182 F) 28-70 years US	RCT 6 months	Motivation ² , dietary intake, dental, physical activity and smoking	PRE-RA arm: genotype (HLA-DRB1) and phenotype (autoantibody RF/CCP) based personalized RA risk; PRE-RA Plus arm: PRE-RA arm + 1-on-1 education. Advice designed using motivational interviewing BCTs.	Standard education about RA epidemiology, symptoms, and diagnosis	Participants in the PRE-RA arm and the PRE-RA Plus arm reported increased fish intake compared to participants in the control group at 6 months; Participants in the PRE-RA Plus arm reported increased fruits intake compared to participants in the control group at 6 months.	The provision of personalized genotype and phenotype-based RA and a corresponding education increased motivation to improve RA risk-related behaviours.

Authors, date	Participants (n baseline) Age range Country BMI	Study design, Follow-up period	Outcomes measured	Intervention group(s) conditions	Comparison group(s) conditions	Dietary outcomes	Author's Conclusion
Weight management interventions							
Horne et al. 2020 [13]	140 (18 M/ 122 F) Control: 56.4 (SD 12.1) years Intervention: 53.5 (SD 13.6) years Canada BMI ≥ 25 kg/m ²	RCT 12 months	Dietary Intake and dietary adherence	Genotype-based advice: UCP1 (rs1800592), FTO (rs9939609), TCF7L2 (rs7903146), APOA2 (rs5082), PPAR γ 2 (rs1801282), and MC4R (rs17782313). Participants were advised to focus on the macronutrient recommendation(s) that was/were highlighted in their genetic report to enhance weight loss response. Advice designed using theory of planned behaviour BCT.	A calorie-controlled, moderately low fat (25% kcal) nutrition plan	Participants in the intervention arm reported lower total fat intake (%E) compared to the control at 12 months; NS changes in calories or %E from protein, SFA or unsaturated fat. Participants in the intervention arm had greater adherence to recommendation for total fat, SFA and protein intake compared to participants in the control group at 12 months; NS differences in adherence for calories.	A nutrigenomics weight management intervention can motivate greater long-term dietary change compared to population-based recommendations.
Anderson et al. 2018 [27]	78 (9 M/ 69 F) 18-72 years Scotland BMI ≥ 25 kg/m ²	RCT 3 months	Feasibility ² , weight, physical activity, dietary intake and psychosocial measures	A personalised diet based on current diet (600 kcal deficit dietary intake as recommended by the Scottish Intercollegiate Guidelines Network). Advice designed using motivational interviewing, action and coping plans and implementation intentions BCTs.	Usual care - lifestyle booklet	Participants in the intervention arm reported lower total fat intake compared to participants in the control group at 3 months; NS changes in unsaturated fat or fibre intake.	The intervention had a favourable effect on fat intake score. Further work is needed to refine intervention components, particularly dietary aspects that may need tailoring for ethnic groups.

1, numbers are for follow ups due to lack of baseline data. 2, indicates the primary outcome as identified in the publication. Absence indicates that no primary outcome was specified in the publication. BCT, Behavioural change technique; BP, blood pressure; CVD, cardiovascular disease; CHD, coronary heart disease; DHA, Docosahexaenoic acid; E, Energy; EPA, Eicosapentaenoic acid; FA, fatty acid; NS, non-significant; RCT, randomised control trial; RA, rheumatoid arthritis; SNP, Single nucleotide polymorphism; T2DM, Type 2 diabetes mellitus; LDL-C, low-density lipoprotein cholesterol

Table 2. Overview of dietary assessment methods and dietary outcomes used in the included studies

Authors, date	Dietary assessment method	Dietary outcome (s)
Horne et al. 2020 [13]	24-hour dietary recalls (2 weekday and 1 weekend day)	Nutrients – energy (kcal/day), protein (%E/day and g/day), total fat (%E/day and g/day), saturated fat (%E/day and g/day), unsaturated fat (%E/day)
Celis-Morales et al. 2016 [9]	FFQ (157-item semi-quantitative)	Nutrients – energy (MJ/day), saturated fat (%E/day), poly-unsaturated fat (%E/day), dietary fibre (g/day), salt (g/day), folate (µg/day) Food groups - fruits (g/day), vegetables (g/day), fruit and vegetables (g/day), whole grains (g/day), oily fish (g/day), red meat (g/day), low-fat dairy (g/day), salt (g/day)
Livingstone et al. 2016 [14]	FFQ (157-item semi-quantitative)	Dietary patterns – 2010 Healthy Eating Index Dietary patterns – Mediterranean Diet Score
Godino et al. 2016 [26]	FFQ (130-item semi-quantitative)	Food groups - Fruit and vegetables (g/day)
Nielsen and El-Sohemy. 2014 [12]	FFQ (196-item semi-quantitative)	Nutrients - Sodium (mg/day), caffeine (mg/day), vitamin C (mg/day), added sugars (%E/day)
Roke et al. 2017 [11]	FFQ (37-item semi-quantitative)	Nutrients - Eicosapentaenoic acid and docosahexaenoic acid (mg/day)
Anderson et al. 2018 [27]	FFQ (19-item semi-quantitative) and 7-day alcohol record	Nutrients – fat score, unsaturated fat score, fibre score Food groups – alcohol (units/day)
Hietaranta-Luoma et al. 2014 [15]	Brief dietary questions (4 questions)	Nutrients - Fat quality (scale 0 -27) Food groups - consumption of vegetables, fruits, and berries (portion/day), consumption of foods containing excessive fat and sugar (frequency/week), alcohol consumption (frequency/months or week, portion/week)
Sparks et al. 2018 [17]	Brief dietary questions (7 questions)	Food groups - Fish, fruit, vegetables, and beans/nuts, fats/oils, meat/poultry, and sugars (frequency/week)
Hendershot et al. 2010 [24]	Daily drinking questionnaire	Food groups - frequency of alcohol use (scale 1-7), maximum drinks consumed, typical number of drinks on weekend nights
Kullo et al. 2016 [25]	Brief dietary questions (1 question)	Nutrients - total fat scale (0 - no fat intake to 110 - indicative of very high dietary fat intake)

FFQ, Food Frequency Questionnaire; kcal, kilocalorie

REFERENCES

1. Australian Institute of Health and Welfare. Deaths in Australia. Australian Government [Internet]. 2018 20 January 2020. Available from: <https://www.aihw.gov.au/reports/life-expectancy-death/deaths-in-australia/contents/summary>.
2. Interagency Committee on Human Nutrition Research. National Nutrition Research Roadmap 2016–2021: Advancing Nutrition Research to Improve and Sustain Health. 2016. Washington DC.
3. The Lancet. 2019: the year for nutrition. The Lancet. 2019;393:200.
4. Australian Bureau of Statistics. 4364.0.55.007 - Australian Health Survey: Nutrition First Results - Foods and Nutrients, 2011-12.2014. Accessed 17 July 2019. Available from: <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4364.0.55.007main+features22011-12>.
5. Australian Government National Health and Medical Research Council Department of Health and Ageing. Eat for Health. Australian Dietary Guidelines 2013 21 October 2016. Available from: https://www.eatforhealth.gov.au/sites/default/files/files/the_guidelines/n55_australian_dietary_guidelines.pdf.
6. Ordovas JM, Ferguson LR, Tai ES, Mathers JC. Personalised nutrition and health. BMJ. 2018;361.
7. Berry SE, Valdes AM, Drew DA, Asnicar F, Mazidi M, Wolf J, Capdevila J, Hadjigeorgiou G, Davies R, Al Khatib H, et al. Human postprandial responses to food and potential for precision nutrition. Nat Med. 2020;26(6):964-73.
8. Bush CL, Blumberg JB, El-Sohemy A, Minich DM, Ordovas JM, Reed DG, Behm VAY. Toward the Definition of Personalized Nutrition: A Proposal by The American Nutrition Association. Journal of the American College of Nutrition. 2020;39(1):5-15.
9. Celis-Morales C, Livingstone KM, Marsaux CF, Macready AL, Fallaize R, O'Donovan CB, Woolhead C, Forster H, Walsh MC, Navas-Carretero S. Effect of personalized nutrition on health-related behaviour change: evidence from the Food4me European randomized controlled trial. International Journal of Epidemiology. 2016;46(2):578-88.
10. Ferguson LR, De Caterina R, Görman U, Allayee H, Kohlmeier M, Prasad C, Choi MS, Curi R, De Luis DA, Gil Á. Guide and position of the international society of nutrigenetics/nutrigenomics on personalised nutrition: part 1-fields of precision nutrition. Lifestyle Genomics. 2016;9(1):12-27.
11. Roke K, Walton K, Klingel SL, Harnett A, Subedi S, Haines J, Mutch DM. Evaluating Changes in Omega-3 Fatty Acid Intake after Receiving Personal FADS1 Genetic Information: A Randomized Nutrigenetic Intervention. Nutrients. 2017;9(3):240.
12. Nielsen DE, El-Sohemy A. Disclosure of genetic information and change in dietary intake: a randomized controlled trial. PloS one. 2014;9(11):e112665.
13. Horne J, Gilliland J, O'Connor C, Seabrook J, Madill J. Enhanced long-term dietary change and adherence in a nutrigenomics-guided lifestyle intervention compared to a population-based (GLB/DPP) lifestyle intervention for weight management: results from the NOW randomised controlled trial. BMJ Nutrition, Prevention & Health. 2020:bmjnph-2020-000073.
14. Livingstone KM, Celis-Morales C, Navas-Carretero S, San-Cristobal R, Macready AL, Fallaize R, Forster H, Woolhead C, O'Donovan CB, Marsaux CF, et al. Effect of an Internet-based, personalized nutrition randomized trial on dietary changes associated with the Mediterranean diet: the Food4Me Study. Amer J Clin Nutr. 2016;104:288-97.
15. Hietaranta-Luoma H-L, Tahvonen R, Iso-Touru T, Puolijoki H, Hopia A. An intervention study of individual, apoE genotype-based dietary and physical-activity advice: impact on health behavior. Journal of Nutrigenetics & Nutrigenomics. 2014;7(3):161-74.
16. Horne J, Madill J, O'Connor C, Shelley J, Gilliland J. A Systematic Review of Genetic Testing and Lifestyle Behaviour Change: Are We Using High-Quality Genetic Interventions and Considering Behaviour Change Theory? Lifestyle Genomics. 2018;11(1):49-63.

17. Sparks JA, Iversen MD, Yu Z, Triedman NA, Prado MG, Miller Kroouze R, Kalia SS, Atkinson ML, Mody EA, Helfgott SM, et al. Disclosure of Personalized Rheumatoid Arthritis Risk Using Genetics, Biomarkers, and Lifestyle Factors to Motivate Health Behavior Improvements: A Randomized Controlled Trial. *Arthritis Care & Research*. 2018;70(6):823-33.
18. Guasch-Ferré M, Dashti HS, Merino J. Nutritional Genomics and Direct-to-Consumer Genetic Testing: An Overview. *Advances in Nutrition*. 2018;9(2):128-35.
19. Higgins JP, S. G. Cochrane Collaboration: Cochrane handbook for systematic reviews of interventions. Chichester, West Sussex: Wiley-Blackwell. 2008.
20. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. 2009;339:b2535.
21. Marteau TM, French DP, Griffin SJ, Prevost AT, Sutton S, Watkinson C, Attwood S, Hollands GJ. Effects of communicating DNA-based disease risk estimates on risk-reducing behaviours. *Cochrane Database of Systematic Reviews*. 2010(10).
22. Livingstone KM, Celis-Morales C, Navas-Carretero S, San-Cristobal R, Forster H, Woolhead C, O'Donovan CB, Moschonis G, Manios Y, Traczyk I, et al. Characteristics of participants who benefit most from personalised nutrition: findings from the pan-European Food4Me randomised controlled trial. *Br J Nutr*. 2020;123(12):1396-405.
23. Academy of Nutrition and Dietetics. Evidence Analysis Manual. Accessed 11 July 2019. Available from: <https://www.andeal.org/evidence-analysis-manual>.
24. Hendershot CS, Otto JM, Collins SE, Liang T, Wall TL. Evaluation of a brief web-based genetic feedback intervention for reducing alcohol-related health risks associated with ALDH2. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine*. 2010;40(1):77-88.
25. Kullo IJ, Jouni H, Austin EE, Brown SA, Kruisselbrink TM, Isseh IN, Haddad RA, Marroush TS, Shameer K, Olson JE, et al. Incorporating a Genetic Risk Score Into Coronary Heart Disease Risk Estimates: Effect on Low-Density Lipoprotein Cholesterol Levels (the MI-GENES Clinical Trial). *Circulation*. 2016;133(12):1181-8.
26. Godino JG, van Sluijs EMF, Marteau TM, Sutton S, Sharp SJ, Griffin SJ. Lifestyle Advice Combined with Personalized Estimates of Genetic or Phenotypic Risk of Type 2 Diabetes, and Objectively Measured Physical Activity: A Randomized Controlled Trial. *PLoS Medicine*. 2016;13(11):1-15.
27. Anderson AS, Dunlop J, Gallant S, Macleod M, Miedzybrodzka Z, Mutrie N, O'Carroll RE, Stead M, Steele RJC, Taylor RS, et al. Feasibility study to assess the impact of a lifestyle intervention ('LivingWELL') in people having an assessment of their family history of colorectal or breast cancer. *BMJ Open*. 2018;8(2):e019410.
28. Hollands GJ, French DP, Griffin SJ, Prevost AT, Sutton S, King S, Marteau TM. The impact of communicating genetic risks of disease on risk-reducing health behaviour: systematic review with meta-analysis. *BMJ*. 2016;352:i1102.
29. Li SX, Ye Z, Whelan K, Truby H. The effect of communicating the genetic risk of cardiometabolic disorders on motivation and actual engagement in preventative lifestyle modification and clinical outcome: a systematic review and meta-analysis of randomised controlled trials. *British Journal of Nutrition*. 2016;116(5):924-34.
30. Grimaldi KA, van Ommen B, Ordovas JM, Parnell LD, Mathers JC, Bendik I, Brennan L, Celis-Morales C, Cirillo E, Daniel H, et al. Proposed guidelines to evaluate scientific validity and evidence for genotype-based dietary advice. *Genes Nutr*. 2017;12:35.
31. Biesiekierski JR, Livingstone KM, Moschonis G. Personalised Nutrition: Updates, Gaps and Next Steps. *Nutrients*. 2019;11(8):1793.
32. Higgs S, Thomas J. Social influences on eating. *Current Opinion in Behavioral Sciences*. 2016;9:1-6.
33. Mathers JC. Paving the way to better population health through personalised nutrition. *EFSA Journal*. 2019;17(S1):e17071.
34. McDermott MS, Oliver M, Simnadis T, Beck E, Coltman T, Iverson D, Caputi P, Sharma R. The Theory of Planned Behaviour and dietary patterns: A systematic review and meta-analysis. *Preventive Medicine*. 2015;81:150-6.

35. Ajzen I. The theory of planned behaviour: reactions and reflections. Taylor & Francis; 2011.
36. Lara J, Evans EH, O'Brien N, Moynihan PJ, Meyer TD, Adamson AJ, Errington L, Sniehotta FF, White M, Mathers JC. Association of behaviour change techniques with effectiveness of dietary interventions among adults of retirement age: a systematic review and meta-analysis of randomised controlled trials. *BMC medicine*. 2014;12(1):177.
37. Carstensen LL, Hartel CR. When I'm 64: National Academies Press; 2006.
38. Ryan J, Lopian L, Le B, Edney S, Van Kessel G, Plotnikoff R, Vandelanotte C, Olds T, Maher C. It's not raining men: a mixed-methods study investigating methods of improving male recruitment to health behaviour research. *BMC Public Health*. 2019;19(1):814.
39. Taylor PJ, Kolt GS, Vandelanotte C, Caperchione CM, Mummery WK, George ES, Karunanithi M, Noakes MJ. A review of the nature and effectiveness of nutrition interventions in adult males--a guide for intervention strategies. *Int J Behav Nutr Phys Act*. 2013;10:13-.
40. Livingstone KM, Celis-Morales C, Navas-Carretero S, San-Cristobal R, O'Donovan CB, Forster H, Woolhead C, Marsaux CF, Macready AL, Fallaize R. Profile of European adults interested in internet-based personalised nutrition: the Food4Me study. *European Journal of Nutrition*. 2016;55(2):759-69.
41. Kaufman DJ, Bollinger JM, Dvoskin RL, Scott JA. Risky business: risk perception and the use of medical services among customers of DTC personal genetic testing. *Journal of genetic counseling*. 2012;21(3):413-22.
42. Rehm CD, Peñalvo JL, Afshin A, Mozaffarian D. Dietary Intake Among US Adults, 1999-2012. *JAMA*. 2016;315(23):2542-53.
43. Livingstone KM, Olstad DL, Leech RM, Ball K, Meertens B, Potter J, Cleanthous X, Reynolds R, McNaughton SA. Socioeconomic Inequities in Diet Quality and Nutrient Intakes among Australian Adults: Findings from a Nationally Representative Cross-Sectional Study. 2017;9(10):1092.
44. Schulze MB, Martínez-González MA, Fung TT, Lichtenstein AH, Forouhi NG. Food based dietary patterns and chronic disease prevention. *BMJ*. 2018;361:k2396.
45. Institute of Medicine Committee on Assessing Interactions Among Social B, Genetic Factors in H. The National Academies Collection: Reports funded by National Institutes of Health. In: Hernandez LM, Blazer DG, editors. *Genes, Behavior, and the Social Environment: Moving Beyond the Nature/Nurture Debate*. Washington (DC): National Academies Press (US) Copyright © 2006, National Academy of Sciences.; 2006.
46. Di Cesare M, Khang Y-H, Asaria P, Blakely T, Cowan MJ, Farzadfar F, Guerrero R, Ikeda N, Kyobutungi C, Msyamboza KP. Inequalities in non-communicable diseases and effective responses. *The Lancet*. 2013;381(9866):585-97.
47. Celis-Morales C, Livingstone KM, Petermann-Rocha F, Navas-Carretero S, San-Cristobal R, O'Donovan CB, Moschonis G, Manios Y, Traczyk I, Drevon CA, et al. Frequent Nutritional Feedback, Personalized Advice, and Behavioral Changes: Findings from the European Food4Me Internet-Based RCT. *American journal of preventive medicine*. 2019;57(2):209-19.
48. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015 – 2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at <https://health.gov/our-work/food-and-nutrition/2015-2020-dietary-guidelines/>.
49. National Committee for Nutrition. Nourishing Australia: a decadal plan for the science of nutrition (Australian Academy of Science). 2019.
50. Adamson AJ, Mathers JC. Effecting dietary change. *Proceedings of the Nutrition Society*. 2004;63(4):537-47.
51. Leech RM, Worsley A, Timperio A, McNaughton SA. Understanding meal patterns: definitions, methodology and impact on nutrient intake and diet quality. *Nutrition Research Reviews*. 2015;28(1):1-21.
52. Ashton LM, Sharkey T, Whatnall MC, Williams RL, Bezzina A, Aguiar EJ, Collins CE, Hutchesson MJ. Effectiveness of Interventions and Behaviour Change Techniques for

Improving Dietary Intake in Young Adults: A Systematic Review and Meta-Analysis of RCTs. *Nutrients*. 2019;11(4):825.

53. Schulz KF, Grimes DA. Blinding in randomised trials: hiding who got what. *The Lancet*. 2002;359(9307):696-700.

54. Kirkpatrick SI, Collins CE, Keogh RH, Krebs-Smith SM, Neuhauser ML, Wallace A. Assessing Dietary Outcomes in Intervention Studies: Pitfalls, Strategies, and Research Needs. 2018;10(8):1001.

55. Moher D, Hopewell S, Schulz KF, Montori V, Gøtzsche PC, Devereaux PJ, Elbourne D, Egger M, Altman DG. CONSORT 2010 Explanation and Elaboration: updated guidelines for reporting parallel group randomised trials. 2010;340:c869.

Fig 1.

Supplemental Table 1. PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	1
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	4, 26-27
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	4
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6

Does personalized nutrition advice improve dietary intakes in healthy adults? A systematic review of randomized controlled trials - Rachael Jinnette – Online Supplementary Material

Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	5
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	5-6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supplementary material
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Table 1
Synthesis of results	21	Present the main results of the review. If meta-analyses are done, include for each, confidence intervals and measures of consistency	6-8
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	7
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	8

Does personalized nutrition advice improve dietary intakes in healthy adults? A systematic review of randomized controlled trials - Rachael Jinnette – Online Supplementary Material

Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	12
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	13
 FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Title page

Supplemental Table 2. Database specific search terms

Embase	PubMed	CINAHL
#1 'personalized nutrition':ab,kw,ti	((((((("personalized nutrition"[Title/Abstract]	Search modes: Boolean/Phrase
#2 'precision':ab,kw,ti	OR "personalised nutrition"[Title/Abstract] OR	
#3 'genomics':ab,kw,ti	precision[Title/Abstract] OR	("personalized nutrition" OR
#4 'gene':ab,kw,ti	genomics[Title/Abstract] OR	"personalised nutrition" OR
#5 'genes':ab,kw,ti	gene[Title/Abstract] OR	precision OR
#6 'genetic*':ab,kw,ti	genes[Title/Abstract] OR	genomics OR
#7 'phenotype':ab,kw,ti	genetic[Title/Abstract] OR	gene OR
#8 'genotype':ab,kw,ti	genetics[Title/Abstract] OR	genes OR
#9 'dna':ab,kw,ti	phenotype[Title/Abstract] OR	genetic OR
#10 #1 OR #2 OR #3 OR #4 OR #5 OR #6	genotype[Title/Abstract] OR	genetics OR
OR #7 OR #8 OR #9	DNA[Title/Abstract]))	phenotype OR
#11 nutrition:ab,kw,ti	AND (nutrition[Title/Abstract] OR	genotype OR
#12 diet*:ab,kw,ti	diet[Title/Abstract] OR	DNA) AND
#13 #11 OR #12	diets[Title/Abstract] OR	(nutrition OR
#14 change*:ab,kw,ti	dietary[Title/Abstract]))	diet OR
#15 effect*:ab,kw,ti	AND (change*[Title/Abstract] OR	diets or dietary) AND
#16 impact*:ab,kw,ti	effect*[Title/Abstract] OR	(change* OR
#17 modif*:ab,kw,ti	impact*[Title/Abstract] OR	effect* OR
#18 #14 OR #15 OR #16 OR #17	modif*[Title/Abstract])) AND	impact* OR
#19 information:ab,kw,ti	(Information[Title/Abstract] OR	modif*) AND (Information OR
#20 recommendation*:ab,kw,ti	recommendation*[Title/Abstract] OR	recommendation* OR
#21 advice:ab,kw,ti	advice[Title/Abstract] OR	advice OR
#22 intervention*:ab,kw,ti	intervention*[Title/Abstract] OR	intervention* OR
#23 program*:ab,kw,ti	program*[Title/Abstract] OR	program* OR counsel*) AND
#24 counsel*:ab,kw,ti	counsel*[Title/Abstract]))	("randomized controlled trial" OR
#25 #19 OR #20 OR #21 OR #22 OR #23	AND (((((randomized controlled trial[Publication	"controlled clinical trial" OR
OR #24	Type] OR controlled clinical trial[Publication	randomized OR
#26 #10 AND #13 AND #18 AND #25	Type])) OR (randomized[Title/Abstract] OR	randomly OR
#27 'crossover procedure':de OR 'double-	randomly[Title/Abstract] OR	trial OR
blind procedure':de OR 'randomized	trial[Title/Abstract] OR	groups)
controlled trial':de OR 'single-blind	groups[Title/Abstract]))	
procedure':de OR random*:de,ab,ti OR		

Does personalized nutrition advice improve dietary intakes in healthy adults? A systematic review of randomized controlled trials - Rachael Jinnette – Online Supplementary Material

factorial*:de,ab,ti OR crossover*:de,ab,ti OR NOT ((animals[MeSH Terms]) NOT
((cross NEXT/1 over*):de,ab,ti) OR humans[MeSH Terms]))
placebo*:de,ab,ti OR ((doubl* NEAR/1
blind*):de,ab,ti) OR ((singl* NEAR/1
blind*):de,ab,ti) OR assign*:de,ab,ti OR
allocat*:de,ab,ti OR volunteer*:de,ab,ti
#28 #26 AND #27
#29 ('animal'/exp OR 'nonhuman'/exp) NOT
'human'/exp
#30 #28 NOT #29

Supplemental Table 3. Evidence Analysis Library (EAL) quality criteria checklist - risk of bias

AUTHOR (Year)	QUESTIONS (Y =Yes, N= No, U=Unclear)														
	Relevance Questions				Validity Questions										
	1. Improved outcome	2. Relevant outcome	3. Dietetic concern	4. Feasible intervention	1. Research question stated	2. Subjects free from bias	3. Comparable study groups	4. Withdrawal method described	5. Blinding to prevent bias	6. Intervening factors described	7. Defined outcomes	8. Appropriate statistical analysis	9. Conclusions supported by results	10. Unlikely bias due to funding/sponsorship	OVERALL
Anderson et al. [27]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Positive
Celis-Morales et al. [9]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Positive
Godino et al. [26]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Positive
Hendershot et al. [24]	Y	Y	Y	Y	Y	U	Y	N	N	Y	Y	Y	Y	Y	Positive
Hietaranta-Luoma et al. [15]	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	Positive
Horne et al.[13]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Positive
Kullo et al. [25]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Positive
Livingstone et al. [14]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Positive
Nielsen et al. [12]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Positive
Roke et al. [11]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Positive
Sparks et al. [17]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Positive