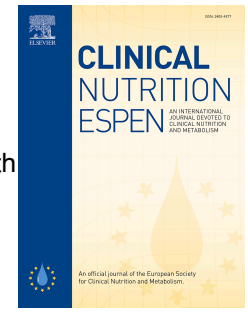

Nutrigenomics-guided lifestyle intervention programmes: A critical scoping review with directions for future research

Saba Aljasir, , Noura Eid, Emanuela V. Volpi, Ihab Tewfik

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Nutrigenomics-guided lifestyle intervention programmes: A critical scoping review with directions for future research

[1, 2] Saba Aljasir*, [2]Noura Eid, [1]Emanuela V. Volpi and [1]Ihab Tewfik

[1]School of Life Sciences, University of Westminster, 115 New Cavendish Street, W1W 6UW London, United Kingdom

[2]Clinical Nutrition Department, Faculty of Applied Medical Sciences, King Abdulaziz University, PO Box 80215, Jeddah, 21589, Saudi Arabia

*Corresponding Author: Saba Aljasir, email address: S.Aljasir@westminster.ac.uk

Abstract:

Genetic testing is increasingly used in clinical practice to provide personalized information and recommendations about health risks and lifestyle habits at a relatively low cost. Research on the effectiveness of nutrigenomics-guided lifestyle interventions is growing. A scoping review approach was adopted to identify pertinent published studies on nutrigenomics-guided intervention programmes from 2007 to 2023. The review shows that despite the growing interest in nutrigenomics-guided lifestyle interventions, there are still few empirically supported studies, primarily based on developed countries. Furthermore, the findings on the impact of personalised genetic advice are mixed, leaving the field unclear. Existing studies have some empirical strength, contributing to further understanding of the relationship between food and gene expression. However, some limitations that affect the robustness of findings exist, such as a small sample size, insufficient monitoring of the data collection process, and a short follow-up period. Future research needs to address reliability concerns and provide more robust practical evidence.

Keywords:

Nutrigenetics; nutrigenomics; nutrition intervention; gene expression

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Keywords:

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Background:

The advancement in understanding the science of the interaction between individual genetic variation, dietary intake and changes in gene expression, structure and function (nutrigenomics and nutrigenetics) has led to a growing research interest in nutrigenomics-guided lifestyle intervention [1, 2, 3, 4, 5]. Genetic testing is increasingly used in clinical practice to provide personalized information and recommendations about health risks and lifestyle habits at a relatively low cost [6, 7]. Many specialised companies can now offer genetic testing services without the involvement of clinicians, focusing on predicting the risk of developing complex diseases during one's life course and then making nutritional recommendations on personal lifestyle changes [8]. The genetic testing investigation can be focused on health-related outcomes such as fitness, pharmacogenetics and nutrigenetics [3, 9, 10]. In nutrigenetics, genetic testing could provide personalised nutrition recommendations for weight control, food intolerance and sensitivity [3, 11].

Personalised nutrition recommendations offer great potential for optimising outcomes of weight management intervention [12]. However, research lacks human intervention studies [2, 12, 13]. Further, there is a positive consumer attitude towards genetic-based nutritional advice, partly explaining the growing interest in this field [14]. Notwithstanding, consumers believe the potential benefits of nutrigenomics outweigh the risks [15]. Other studies have also shown that the receptivity of genetic-based dietary advice is higher, considering that a one-size-fits-all approach to weight management and fitness is not optimal [12, 14, 16]. Hence, nutrigenomics-guided lifestyle intervention programmes result in long-term adherence to dietary guidelines/recommendations [16]. As such, there is potential for genetically guided, actionable nutrition recommendations to help motivate changes in dietary behaviours [8, 13, 16]. In a study on genetic testing and behaviour change, adequate dietary intake is the most promising lifestyle component that could be motivated through personalised genetic-based advice [2]. However, the effectiveness of genetic testing in promoting changes in lifestyle habits has conflicting results, too [14, 17, 18, 19]. For instance, changes in dietary fat quality due to personal genetic information affecting health behaviour were short-lived [14,19]. Thus, further research is "required to determine how to utilize genotype-based health information and how to efficiently achieve sustainable long-term changes in the prevention of lifestyle-related diseases" [18, p. 161].

Aim and Objectives

This scoping review aims to build context to study the effectiveness of personalized nutrition intervention on body weight management among females [18-24 years old] in Jeddah Kingdom of Saudi Arabia by critically evaluating existing studies on nutrigenomics-guided lifestyle intervention programmes.

The research objectives of the study which guided the search of the literature are:

1. To investigate the impact of personalized genetic-based nutritional programmes on weight management of obese individuals.
2. To determine the effectiveness of a nutrigenomics-guided lifestyle programme on sustainable weight management.
3. To evaluate the strengths, constraints and receptivity of genetic-based nutritional programmes on weight management.

Method:

The scoping review approach has been chosen as it helps to address the broad aim of this study. [20] argue that scoping reviews are more flexible and allow for the inclusion of a diverse range of study designs. In mapping and summarising evidence, scoping reviews can also help to inform future research and contribute to policy implications [21]. The scoping framework proposed by [20] has been adopted in this research. This process includes identifying the research question, finding relevant studies, selecting studies meeting inclusion criteria, and collating, summarising and reporting the results.

Search Strategy

The Population, Intervention, Comparison and Outcome (PICO) format was used firstly to define the PICO question and then to help plan our search strategy following the Arksey and O'Malley methodological framework [20]. Table 1 shows the PICO search elements with related keywords/phrases to aid the literature search.

Table 1: PICO elements

PICO ELEMENT	KEYWORDS/PHRASES	Key Terms	Search Number
P (Population)	Individual living with obesity and considering weight management intervention	Obese adults OR overweight AND weight management	S1
I (Intervention)	A personalized genetic-based nutritional programme	nutrigenomics OR Genetic-based OR nutrigenomics-based OR genotype-based AND intervention OR programme	S2
C (Comparison)	Non-genetic-based nutrition intervention	Non-genetic-based OR standard-based OR population-based	S3
O (Outcome)	Sustainable reduction of body weight	Body weight OR body mass index OR Fat composition OR body circumference AND reduction OR loss AND Sustained OR Long term	S4
Final search	S1+S2+S3+S4 = Results		

The intervention was defined as providing personalised genetic-based nutritional information for weight management. The comparison is, therefore, against non-genetic-based nutritional interventions/programmes or population/standard-based interventions, which do not involve providing genetic information. The desired outcome from the personalised genetic-based nutrition intervention is a sustainable reduction of body weight (body mass index, body composition, body circumference).

The search using key terms from the PICO table was conducted via electronic searches of databases, including PubMed and Medline, on the Westminster University Library database. The PubMed MeSH search involved three main concepts: nutrigenomics (genetic-based, genetics*), obesity (body weight/body mass index), and weight loss*. The searches in the databases were structured using Boolean operators ("OR" and "AND"). This was useful in broadening the results.

The inclusion Criteria

The inclusion criteria detail the basis on which sources were considered for inclusion in the scoping review to address the research objectives [21]. Utilising the PICO framework, the inclusion criteria were developed as follows:

- Adult Individuals (18+) living with obesity and considering weight management intervention.
- Weight management interventions involving genetic-based (nutrigenomics guided) information/advice.
- Published literature on any research design

- Published literature in the English Language or translated into English.
- Studies in the period 2007 to 2023

The exclusion criteria

- Animal studies (non-human studies)
- Studies not involving adults (less than 18 years)
- Studies not involving genetic-based information (i.e., standard or population-based weight management intervention)
- Studies on genetic-based interventions not involving obesity/weight loss.
- Studies not published or translated into the English language.
- Studies published before 2007.

The search strategy aimed to identify published nutrigenomics-guided intervention studies relevant to the research objectives from 2007 to 2023. As such, the literature search aimed to identify and review empirical studies that demonstrate the impact of genetic-based nutritional intervention in weight management. The examined studies were not restricted to one age group but to all adults. In addition, the search for studies was not limited to any region/country.

Data Extraction

The relevant studies identified were transferred to Mendeley's referencing software, which helped locate duplications across the searched databases. After removing the duplications, 76 articles were placed for initial screening. The articles' titles and abstracts were screened. This resulted in only 11 articles meeting the criteria. To identify further studies not possibly captured in the database search, a manual check of the reference lists of the included studies was conducted to determine any other studies that meet the inclusion criteria. This resulted in 2 additional articles. In reviewing the full article text, Microsoft Excel was used to chart the data by applying the relevant aspects of the Critical Appraisal Skills Programme (CASP) checklist [22]. The search strategy that resulted in 13 relevant articles is presented using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram in Figure 1.

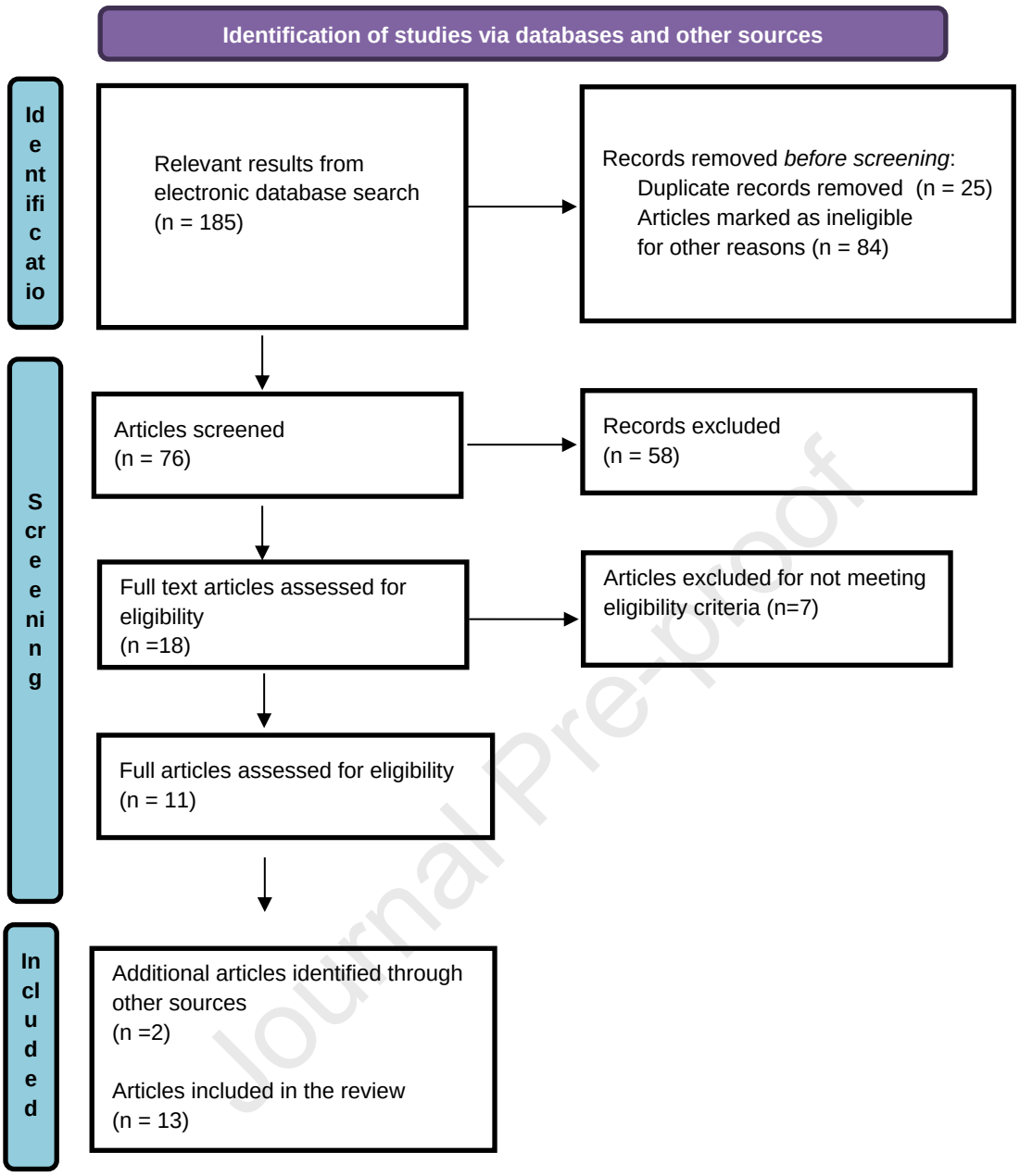

Figure 1: PRISMA flow chart showing the articles identified for critical review.

Results:

Table 3 below summarises the relevant studies on genetic-based personalised health interventions for obesity/overweight, satisfying the selection criteria developed following Arksey and O'Malley's framework. All studies were randomised clinical trials except 1 [23], a scoping review. The strengths and weaknesses of these studies have also been included. The authors' critical reflections on the findings are discussed in context with the existing body of knowledge.

179 **Table 3: Published interventions on weight reduction programmes [behavioural modification with Genetic-based**
180 **intervention]**

Author/s (year)	Title	Aim	Participants (baseline; follow-up)	Intervention	Comparison group	Target condition (gene tested)	Follow-up	Lifestyle habit assessed	Outcome	Strength	Weakness
[13]	A comparative analysis: improved weight management using nutrigenetically tailored diet among Indians.	The study examined whether a nutrigenetically tailored diet could improve an individual's compliance with long-term weight management	106 (54 intervention groups, 52 comparisons)	Genetic based (nutrigenetic test)	Standard/population-based	Weight loss (FTO, AG, LIPC, MC4R, PPARGC1A, CD36,ADIPOQ,PPARG, CD36,MTHFR,APOA5	30 days, 60 days, 90 days, 120 days	Body mass index and waist circumference,	The intervention group was more likely to maintain some weight loss (82%) than the comparison group (21%). Motivation and willingness to lose weight were also higher than the comparison group.	The study focussed on Indian participants in a non-western context. 15 variants in 10 genes associated with body weight and metabolism were tested.	Not all participants were obese. Only 69.8% of participants in the intervention group were obese. The reliability of the results was weak. A more detailed analysis of the results was needed.
[24]	A double-blinded, randomized, parallel intervention to evaluate biomarker-based nutrition plans for weight loss: The PREVENTOMICS study.	The study evaluated the efficacy of the PREVENTOMCIS platform—which uses metabolomic and genetic information to classify individuals into different	Adults (18-65) (b=100, f=82)	Genetic-based (metabolome and genotype)	Standard/population-based	Obesity (Not specified)	Ten weeks	Fat mass, weight, waist circumference, lipid profile, glucose homeostasis markers, inflammatory markers,	The study found no differences between groups in the changes in body weight, body fat percentage, and waist circumference and no	The study examined the efficacy of personalised recommendation diets (based on genetic, nutritional, biochemical,	The study relies on the effectiveness of the platform (preventomcis) . The study has a problem with the reliability of results since

		'metabolic clusters' and create personalized dietary plans—for improving health outcomes in subjects with overweight or obesity.						blood pressure, physical activity, stress and eating behaviour.	interactions with genotype or baseline insulin secretion.	physiological and behavioural factors). The approach used is different from that of other studies.	participants were not monitored but asked to self-report. The sample size is small, and the follow-up period was relatively short (10 weeks). Strong adherence to behavioural change takes time. The study examines too many aspects. Each of these aspects requires more than one observation.
[16]	Change in Weight, BMI, and Body Composition in a Population-Based Intervention Versus Genetic-Based Intervention: The NOW Trial.	To compare changes in body fat percentage (BFP), weight, and BMI between a standard intervention and	Adults (b = 140, f=38)	Genetic-based personalised lifestyle advice	Population-based lifestyle advice	Obesity (Body fat percentage, weight and BMI) (12 gene variants – FTO, UCP1,	3, 6 and 12 months	BFP, weight and BMI	The nutrigenomics group experienced significantly more significant reductions in per cent and absolute BFP at	The study provides strong evidence of change in BFP and BMI based on genetic-based	The sample size was relatively small compared to other studies (e.g. [27]. The sample size would be

		a nutrigenomics intervention.				TCF7L2, APOA2, ACE, MC4R, ADRB3, NRF2, GSTP1, NFIA-AS2, ACNT3)			the 3-month follow-up and per cent BFP at the 6-month follow-up compared with the standard group.	lifestyle evidence. Also, the number of genes tested was relatively higher than in other studies (e.g., [27]. See Appendix 1	estimated to be above 275. Also, the participants included in the study were already part of a weight management programme.
[25]	Exploring attitudes, subjective norms and perceived behavioural control in a genetic-based and a population-based weight management intervention: A one-year randomized controlled trial.	To determine the impact of providing genetically tailored and population-based lifestyle advice on key constructs of the Theory of Planned Behaviour (TPB)	Caucasian female adults (b = 140, f=70)	Genetic-based personalised lifestyle advice	Population-based lifestyle advice	Overweight/ body fat percentage (FTO)	3, 6 and 12 months	Attitudes, subjective norms and perceived behavioural control	Significant changes in attitudes, subjective norms, and perceived behavioural control tended to be short-term in the population-based group and long-term for the genetic-based group.	Provided some good empirical insight on the effect of personalised genetic data provision and applied a behavioural theory (TPB) Also, follow-ups were done at different levels, though 12 months is not a long-term change.	Observing attitudes, subjective norms or perceived behavioural control is affected by several factors, and it is hard to distinguish whether genetic-based advice was the sole or primary contributor in this case. The sample size is also tiny, and the focus was on

											one gene (FTO)
[23]	Assessing the effectiveness of actionable nutrigenomics and lifestyle genomics interventions for weight management in clinical practice: A critical, scoping review with directions for future research.	A scoping review was conducted to summarize and evaluate the current knowledge on the effectiveness of providing DNA-based lifestyle advice on weight-related outcomes to provide direction for future research.	N/A	N/A	N/A	Weight management	N/A	Weight management	Research in this area is promising but limited. Identified some limitations of prior studies: e.g., study designs, the nature of the recommendations provided to participants, small (underpowered) sample sizes, the use of self-reported weight/BMI data and lack of consideration of important confounding factors.	Provided an excellent scoping review of existing studies	Not an empirical primary study to show the impact of genetic-based intervention
[26]	Enhanced long-term dietary change and adherence in a nutrigenomics-guided lifestyle intervention compared to a population-based	To determine if a nutrigenomics-guided lifestyle intervention programme could be used to motivate greater dietary adherence and change in	Adults (b = 140)	Genetic-based personalised lifestyle advice	Standard population-based weight management intervention	Overweight/ obesity (UCP1, FTO, TCF7L2, APOA2, PPARγ2 and MC4R)	3, 6 and 12 months. 24-hour recalls	Dietary adherence and change in dietary intake (short-term, moderate-term term	Only the genetically guided intervention group significantly reduced their total fat intake from baseline to	The use of the theory of planned behaviour in exploring the impact of genetically based intervention.	The study was confined to participants already on a weight management programme (group lifestyle

	(GLB/DPP) lifestyle intervention for weight management: results from the NOW randomised controlled trial.	dietary intake short-term, moderate-term and long-term compared to the gold standard population-based weight management intervention (Group Lifestyle Balance (GLB)/Diabetes Prevention Programme (DPP)).						and long-term)	12-month follow-up. Long-term dietary adherence to total fat and saturated fat guidelines were also significantly more significant in the genetically guided group compared to the standard/population-based weight management group	The study considered short-term and long-term dietary changes and adherence to dietary guidelines.	balance programme). Only a few participants (i.e., 140)
[27]	Can genetic-based advice help you lose weight? Findings from the Food4Me European randomized controlled trial.	To determine whether the provision of FTO genotype information affected obesity-related traits across different levels of personalized nutrition, and between risk and non-risk FTO genotypes	Adults (b=583)	High-risk genetic results	Non-risk genetic result	Overweight/ obese (FTO)	3 and 6 months	Nutrition, physical activity	High-risk FTO genotype group had significantly greater reductions in weight and WC compared with the control group (standard, nonpersonalized lifestyle advice);	The sample size in this study was relatively higher than other studies (e.g., [16]) The relative strength of the observed change in weight reduction was also higher.	The follow-up in this study was only 3 and 6 months. Thus, some long-term weight and waist circumference (WC) changes might not be observed.

[19]	Changes in physical activity following a genetic-based internet-delivered personalized intervention: randomized controlled trial	The purpose of this study was to determine if disclosing FTO risk had an impact on change in PA following a 6-month intervention.	Adults (b = 265; f=130)	High-risk genetic results	Non-risk genetic result	Overweight/ obesity (FTO)	Six months	Physical activity	No significant change in subjective or objective physical activity with the provision of FTO genotype risk info	The sample size in this study was large compared to other studies. The study was more focused on fat mass and obesity-associated (FTO) genotype and provided empirical evidence.	The study only examined changes in physical activity without also considering the change in dietary adherence as these affect the predisposition to overweight. Also, the provision of genetic-based information/advice was web-based, which could affect the impact on participants.
[28]	Genetic susceptibility testing and readiness to control weight: Results from a randomized controlled trial	To test the hypothesis that adding obesity gene feedback (FTO) to simple weight control advice at a life stage with a raised risk of weight gain (university)	Young Adults (b = 1,016; f=279)	Genetic results	No genetic testing	Obesity (FTO)	One month	Nutrition (adherence to a variety of eating behaviours) and Physical activity	There was no significant change in nutrition and physical activity (pooled) between groups. Adding FTO feedback to weight control	The sample size in this study was relatively high (b=1,016 and f=279). Also, targeted young adults are more susceptible to	The follow-up in this study was too short (1 month only). Subsequent follow-ups were needed.

		increases readiness to control weight.							advice enhanced readiness to control weight, without evidence for genetic determinism, but had no more effect on behaviour than weight control advice alone.	weight gain (university level) The study examined both nutrition/dietary change and physical activity, which is good as these are two critical factors in obesity.	
[29]	Effects of a web-based personalized intervention on physical activity in European adults: a randomized controlled trial.	To investigate the impact of different levels of personalization on PA change, using phenotypic and genotypic information to tailor the PA advice	Adults (b-1480, f-1233)	High-risk genetic result	Non-risk genetic result	Overweight/ obesity (FTO)	Six months	Physical activity	There is no evidence that personalized advice is more effective than conventional "one size fits all" guidelines to promote changes in PA in our Web-based intervention when PA was measured objectively.	The sample size in this study was high (b-1480), though this was all self-reported and web-based.	Focussed more on physical activity without considering 'diet'. Both diet and physical activity are critical drivers of obesity.
[18]	An intervention study of individual, apoE genotype-based dietary and physical-activity	To assess the behavioral effects of receiving personal genetic information, use	Adults (b-151, f-130)	Genetic testing	No genetic testing	Overweight/ obesity, cardiovascular disease (apoE)	Ten weeks, six months,	Diet/nutrition, alcohol consumption, physical activity	Personal genetic information affects health behaviour. Dietary fat	This study's sample size was relatively small compared to	The study did not focus specifically on obesity/overweight but on

	advice: impact on health behavior.	apoE genotypes to promote lifestyle changes.					12 months		quality improved more in the high-risk group than in the low-risk and control groups after personal, genotype-based health advice.	other studies, e.g. (29). Examination of dietary behaviour and physical activity was considered, in addition to alcohol consumption.	susceptibility to cardiovascular diseases in addition to overweight.
[30]	Differences in weight loss between persons on standard balanced vs nutrigenetic diets in a randomized controlled trial.	To determine whether more participants who followed a nutrigenetic-guided diet lost more significantly than 5% of their body weight than participants on a standard diet	Adults (b=51)	Nutrigenetic-guided diet	Standard balanced diet	Obesity (APOA2, ADIPOQ, FTO, KCTD10, LIPC, MMAB, PPARG	Eight weeks, 24 weeks	Weight loss	There was no significant difference in the percentage of participants on the balanced diet vs the nutrigenetic-guided diet who lost 5% of their body weight. Both groups had difficulty adhering to the diets.	Study shows that adherence to diet is a challenge regardless of the information provided. However, weight loss is more when a nutrigenetic-guided diet is followed.	The study concentrates on age groups 46 and above. Also, physical activity was not incorporated. The sample size is too small relative to other studies.
[31]	Is the information on genetic determinants of obesity helpful or harmful for obese people?—A	To assess the positive and negative effects of informing obese people about the genetic	Adults (b-410, f-294	Genetic testing and consultation	Consultation only	Obesity	Six months	Nutrition (restraint eating)	No negative effects (e.g., loss of self-efficacy/self-control, increase of	The sample size in this study was high, improving the	The study concentrates on 'feelings' about the state of participants following the

	randomized clinical trial.	etiology of being overweight.							body weight) were observed to inform obese people about the genetic etiology of being overweight. The consultation resulted in long-term improvement of negative mood if it included genetic information in the case of participants with a family history of obesity and if it included no genetic information in the case of obese people without a family history of obesity.	reliability of the findings. Gives a unique perspective on participants' attitudes or feelings about themselves following genetic information provision.	provision of genetic information about susceptibility to obesity. The study did not specifically address adherence to a healthy diet or change in physical activity. Feelings after consultation are subject to change.

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Discussion:

Critical observation

The search for studies on nutrigenomics-guided lifestyle intervention programs on weight management revealed that there are few directed studies despite the many studies on the effectiveness of weight management intervention (i.e., with no genetic information associated). In most cases, the focus on the provision of genetic information was aimed at addressing other health issues (e.g., cardiovascular diseases, hypertension, cancer), not specifically obesity/overweight health issues [1, 2, 7]. This scoping review focuses on nutrigenomics-guided studies in weight management.

The findings show that most studies were based in developed countries where gene services are becoming widely available. However, this does not necessarily limit the conduct of nutrigenomics-guided lifestyle intervention programmes to geographical regions. Specialised genetic testing services can also be provided to international customers [11]. In such a case, a cost-benefit analysis, risk assessment, and ethical consideration become even more necessary due to data protection law, potential cost implications, and findings' reliability when samples are transported across long distances between continents.

A general observation also highlights, in part, the effect of the COVID-19 pandemic (from 2020). Only two studies were identified as useful/relevant post-COVID. This suggests that the COVID-19 period caused a significant gap in the conduct of randomised clinical trials on genetic-based intervention programmes. As such, a ‘big gap’ exists to be filled in terms of empirically supported studies on the effectiveness of genetic-based nutrition intervention.

Authors critical reflection on presented studies:

There are mixed results concerning the effect of the provision of personalised genetic information in obesity/overweight intervention programmes. In a study on the impact of genetically based personalised lifestyle advice involving 140 adults in the baseline phase and 38 adults in the follow-up phase, [16] investigated the changes in body fat percentage (BFP), weight and body mass index (BMI) between a group with genetically based personalised lifestyle advice and standard intervention group. Their study tested 12 gene variants (FTO, UCP1, TCF7L2, APOA2, ACE, MC4R, ADRB3, NRF2, GSTP1, NFIA-AS2, ACNT3) and had 3, 6 and 12 months follow-up periods. [16] found a statistically significant change in a reduction in BFP (in per cent and absolute terms) between the two groups. The group with genetic-based personalised lifestyle advice outperformed the standard intervention groups. The positive effects of genetic-based personalised lifestyle advice were also observed in the [27] study that involved 583 participants with one group provided with FTO genotype information and personalised nutritional advice and a standard group (non-risk FTO genotype). [27]

found that the high-risk FTO genotype group significantly reduced weight and weight circumference.

Further, positive changes in attitude, nutritional adherence and physical activity in the long term have been found in some studies when personalised genetic-based advice is provided [25, 26]. This is significant considering that lifestyle changes for weight management are preferred in the long term than the short term [32]. [25] explored attitudes, subjective norms, and perceived behavioural control from the perspective of planned behaviour theory. The study found significant changes in attitudes, subjective norms and behavioural control that were long-term oriented for groups with personalised genetic-based lifestyle advice compared to the standard/population-based group that tended to be short-term oriented. In this respect, the provision of personalised genetic information was vital in influencing the long-term behavioural changes of participants, providing motivation to adhere to dietary guidance over a long time. These results were further reinforced in [26] study that aimed to determine if a nutrigenomics-guided lifestyle intervention programme could motivate greater dietary adherence and change in dietary intake in the short-term, moderate-term and long-term. The study found that dietary adherence and change in dietary intake were significantly more significant in the long term when personalised genetic-based information was provided to participants. In other words, genetic-based personalised lifestyle advice positively influenced participants to adhere to dietary guidelines in the long term. This is also consistent with the observation in the [18] study, in which personalised genetic-based information improved the quality of dietary fat and health behaviour. The health behaviour related to physical activity, dietary intake and alcohol consumption, with participants most at risk based on their genotype making significant changes.

On the contrary, other studies have found no significant difference in the impact of personalised genetic-based information on weight management [19, 24, 28]. [24] assessed the fat mass, weight, waist circumference, lipid profile, glucose homeostasis markers, inflammatory markers, blood pressure, physical activity, stress and eating behaviour of 100 participants. They found no statistically significant difference between the group with genetic information and the control group with no information about their genotype. Behavioural changes concerning physical activity were examined in [19] and [28] studies, which found that participants did not change their behavioural patterns despite being given personalised genetic information about their risk susceptibility. For instance, [19] examined whether disclosing FTO risk had an impact on change in physical activity following a 6-month intervention and found no statistically significant change in subjective or objective physical activity despite the provision of FTO genotype risk information. These observations were also found in [29] and [28], as behavioural change concerning physical activity did not change despite the provision of genetic information and the related risk profile. Adherence to nutrition advice (dietary intake) for weight management did not change either, despite participants being provided with personalised genetic-based nutritional advice in these

studies. Thus, [29] argue that 'one size fits all' guidelines are equally practical in weight management even without genetic information. This perception can also be seen in [31] study that disclosing genetic information and subsequent consultation did not negatively affect some key psychological attributes (e.g., loss of self-efficacy or self-control). In other words, participants seem to have accepted their obesity/overweight predisposition, and no additional information motivated them to change their behaviour.

Strengths and weaknesses of studies

Given the mixture of results, it is imperative that a critical evaluation of the strengths and limitations of the reviewed studies is discussed. This helps to highlight not only the existing gaps in the literature but also directs attention to areas for further investigation. A significant contribution to the literature on the effect of personalised genetic-based information has been provided by [16, 23, 25, 26]. These studies have provided solid empirical evidence showing the positive impacts of genetic-based nutritional advice. These studies provided strong empirical evidence and engaged well with theoretical perspectives explaining the observed behavioural change. In particular, the theory of planned behaviour was utilised in understanding the attitudes, subjective norms and perceived behaviour controls in [25]. The supportive results of [27] show that the relative strength of observed change in weight reduction was higher, and the sample size (583 adults) was significantly large. Sample size impacts the statistical inference of results, with results strengthened when sample sizes are large and participants are randomised into groups [33]. In this respect, some strength of studies [19, 27-29, 31] lie in their large sample size. A critical appraisal of sample size determination shows that when population size is unknown, the estimated sample size to achieve a 95% confidence level, 5% margin of error and 50% population proportion of characteristic/attribute would be 385 (see www.calculator.net). In this respect, there is a relative strength that emanates from the size of the sample sizes in [27], [28], [29] and [31] studies that had 583, 1,016, 1,480 and 410 participants respectively. Similarly, some criticism can be revealed regarding the reliability of findings in the studies with small sample sizes. For instance, [16, 25, 26] studies all had small sample sizes (i.e.,140 participants). However, as [33] argue, the population size impacts the sample size requirement and affects the reliability of findings.

In genetic-based interventions, identifying the relevant genotype associated with the target condition is necessary (Goodarzi, 2018). Identifying the relevant focus genotype strengthens some of the studies reviewed. [19], for instance, tested for the FTO genotype, similar to [28] and [27], while [18] examined the apoE genotype. Figure 2 below (appendix) highlights that the number of genes associated with obesity and overweight are numerous, affecting different aspects of the health issue [34]. Thus, some strength of studies lies in examining more than one genotype. For instance, [16] examined 12 gene variants, [26] examined six gene variants, and [13] examined 15 variants in 10 genes, giving relative strength to these studies. On the contrary, the study by [24] did not specify which genotype was examined. Nonetheless, considering

the many gene variants associated with the health issue of obesity, the reviewed studies have a weakness in not expanding their focus to consider more gene variants.

Obesity prevention strategies require dietary changes and physical activities [35, 36]. Thus, there is a strength in some studies [18, 24, 27, 28] that assessed both aspects: nutritional adherence and physical activity. On the contrary, the limitations can be argued for studies that focussed on only one of the aspects, i.e., physical activity [19, 29] or dietary change [13, 26, 30, 31] as this gives an incomplete assessment in weight management.

There is a further limitation in some studies [16, 25-27] concerning the population and sample selection. The participants for these randomised controlled trials were all drawn from an existing weight management programme. As such, the provision of genetic information would be expected to provide additional motivation along the continuum of positive behavioural change. [16, 23, 26] participants were drawn from the Group Lifestyle Balance (GLB) Program, designed for non-diabetic, overweight individuals aged 18 and older [37]. The program aims to achieve a 7% weight loss through healthy eating and promoting 150 minutes of brisk physical activity each week [37]. In this respect, any participants from this group would have committed to the program's goals. [27] study participants were part of the Food4Me project, an EU-funded research project to understand the relationship between food and gene expression [38]. Thus, instead of participants already on a weight management programme, it would have been insightful to see the impact of such information provision to non-participants on a weight management programme. This would be useful in identifying whether the provision of personalised genetic information and risk susceptibility provided the incentive to overcome the inertia (resistance) for behavioural change. Nonetheless, it could also be argued that the true impact of personalised genetic-based nutritional advice is on whether it provided additional momentum (imperative) to the existing path to behavioural change.

Some criticism can also be levelled against studies such as [24] and [27] for the limited monitoring. These studies relied significantly on self-reporting and self-recruitment, which was internet-based. As such, the rigorous monitoring process that helps improve the reliability of findings of randomised clinical trials [33] is reduced. The challenge lies in the provision of ‘accurate information’ and, thus, the importance of monitoring or tracking processes in any randomised clinical trial. This would help strengthen the findings and contribution to the field. This has been aptly observed by the Food4Me project, which states that “there is a need to comprehensively analyse the opportunities and challenges in the field of personalised nutrition” [38, p. 1]. This remains a challenge in genetic-based randomised clinical trials [39].

Further, some studies [13, 24, 28] had very short follow-up periods, which arguably does not give sufficient time to observe the effect of behavioural change. [24] and [28] had follow-up periods of 10 weeks and one (1) month, respectively. The importance of the observation period is demonstrated in [32] study, which found that twelve (12)

months for the weight loss programme was more effective than six (6) months as solid adherence to behavioural change takes time. The study of [24] can also be criticised for focusing on the effectiveness of a nutritional platform (PREVENTOM CIS) instead of genetic-based information. Further, [25] study that explored attitudes, subjective norms, and perceived behavioural control could be criticised because several factors affect attitudes and norms [40]. Thus, it is hard to distinguish whether the provision of genetic-based advice was the primary or sole contributor to the observed change.

Conclusion:

The scoping review has highlighted that the research landscape of nutrigenomics-guided lifestyle intervention programmes is still growing. The evidence on the effectiveness of nutrigenomics-guided lifestyle intervention programmes is mixed. Thus, more research is needed to demonstrate whether the provision of personalised genetic-based nutritional advice significantly influences health behavioural changes. A key aspect of further research is considering the reliability/validity of the randomised clinical trials and issues such as sample selection, follow-up periods, and monitoring tools. Further research is warranted to incorporate physical activity and dietary adherence, as these aspects are essential to sustain weight management.

Further, most studies have been based in developed countries, providing a research gap to understand not only the attitudes or receptivity of nutrigenomics-guided lifestyle intervention programmes but also their effectiveness and contribution to the unclear (mixed) empirical evidence. This scoping review has identified a research gap through re-directing the focus on emerging countries and also on young adults who may be exposed to packed lifestyle-related risk factors for overweight/obesity. The limitations arise mainly from the nature of a scoping review (unlike systematic reviews), in that quality assessment of the included studies is not comprehensively undertaken.

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Authors' contributions

Saba Aljasir and Ihab Tewfik designed the study and collected the data. All authors analysed the data and prepared the manuscript. All authors read and approved the final manuscript.

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Conflict of interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

Not applicable

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List of abbreviation:

BFP	-	Body Fat Percentage
BMI	-	Body Mass Index
22	-	Critical Appraisal Skills Programme
GLB	-	Group Lifestyle Balance
PICO	-	Population, Intervention, Comparison and Outcome

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Appendix 1

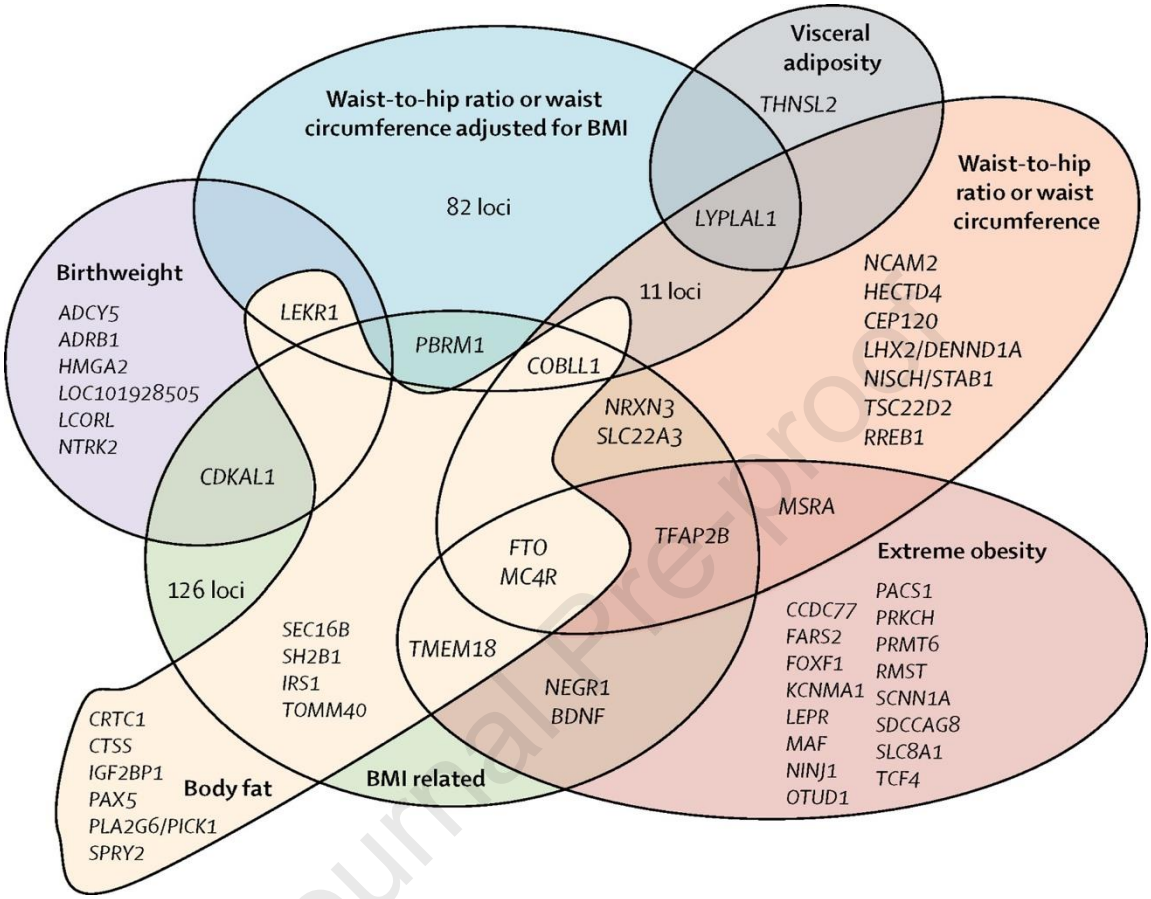

Figure 2: Selected genes associated with obesity. *[Source: Goodarzi, 2018]*

Appendix 2: PRIMA Checklist

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review	2

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
		questions/objectives lend themselves to a scoping review approach.	
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	2-3
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	N/A
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	4-5
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	3-4
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	5-6
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	5-6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	N/A
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	7-15, 16-20
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	7-15
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	6
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	7-15
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	7-15

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Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	7-15
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	7-15
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	16-20
Limitations	20	Discuss the limitations of the scoping review process.	20
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	20
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	N/A

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