Personalized dietary recommendations for weight loss

A scientific perspective from various angles

Christina Holzapfel, Christine Dawczynski, Andrea Henze, Marie-Christine Simon

Abstract

Given that the metabolic response to meals differs from person to person and given that physiological mechanisms are of a complex nature, the need for tailored dietary recommendations is obvious. Furthermore, weight trajectories exhibit inter-individual variation even when individuals receive the same standardized energy-reduced diet. Personalized nutrition is currently very topical and it is an area that both patients and experts are increasingly focusing on. To date, there is no single, universally accepted definition of personalized nutrition. Various approaches that take genetics, microbiota, physiology and phenotype into account are currently being discussed and such approaches are also offered by some commercial providers as personalized nutritional concepts. Upon closer inspection of these personalized dietary recommendations with regard to scientific evidence and clinical relevance, it becomes clear that the personalized dietary recommendations that are primarily offered by companies are not evidence-based. Currently, it is not yet possible to provide personalized dietary recommendations based on factors such as a person's genetic background or the composition of their microbiome. However, providing personalized dietary recommendations that take phenotypic characteristics such as age, gender, physical activity, health status and everyday life situation into account is a robust approach that is already being used by qualified nutrition experts and should continue to be used.

Keywords: personalized nutrition, genetics, microbiome, proteome, dietary behavior

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Background

In recent years, the one size fits all approach to weight loss has come under increasing criticism both in society in general and among experts. It is an outdated approach. Personalized dietary recommendations are gaining ground. Both the lay community and experts are showing an increased interest in exploring various weight loss diets (such as reduced carbohydrate, reduced fat, or Mediterranean diets) and various guidance strategies (such as online, app-based, or face-to-face guidance). The need to explore the promising approach of personalized dietary recommendations is all the more pressing due to the increasing prevalence of overweight and obesity.

We have a wide range of food products available, which affords us the opportunity to implement different types of diets and nutritional concepts. Plant-based diets are gaining more and more attention as an alternative to traditional diets, such as the omnivorous, healthy diet recommended by the German Nutrition Society called "*Vollwertige Ernährung*". The spectrum of plant-based diets spans from flexitarians to ovo-lacto vegetarians to vegans who only eat foods derived from plants. In addition, the media frequently cover other diets, such as low-carbohydrate diets or the Paleolithic diet. Factors that play a role in the implementation of different diets in practice include the availability of foods, personal preferences and aversions, food intolerances and allergies, life circumstances and personal ideas about optimal health. Therefore, there is a need for development and validation of personalized recipes, consumption recommendations and product recommendations, as well as personalized dietary recommendations that are tailored to the individual's preferences, health needs, metabolism, genetics and microbiome.

However, approaches to personalized nutrition and definitions thereof vary, and may include a wide range of different aspects such as genetics and epigenetics, the microbiome, metab-

olism, food selection, environment, environmental influences, age and sex (◆ Figure 1) [1–3].

Studies in humans have demonstrated that there are large differences in metabolic responses to standardized test meals between individuals. For example, a study conducted in Israel investigated

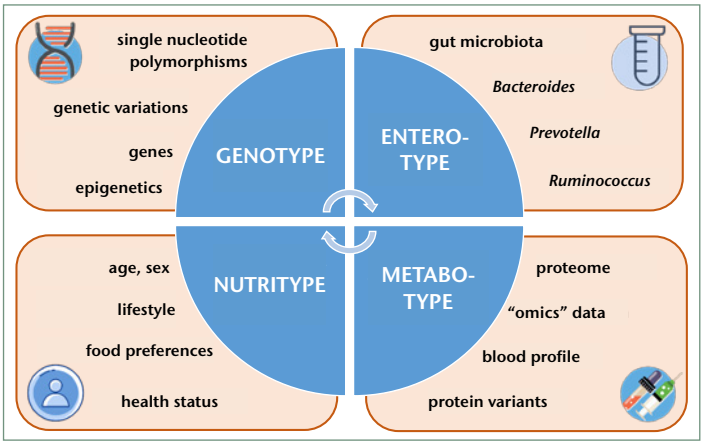

Fig. 1: **Selected aspects of personalized nutrition**

the blood glucose responses of 800 healthy study participants. The study showed that the measured blood glucose values and trajectories were very heterogeneous and exhibited a large degree of variability between individual study participants [4]. Similarly, heterogeneous metabolic responses were also found in the HuMet (Human Metabolome) study [5]. Studies are currently conducted to investigate the question of whether this variability could be explained by genetic variants such as single nucleotide polymorphisms (SNPs), the microbiome as an endocrine organ, or the proteome as a reflection of cellular metabolism [6, 7], and if so, to what extent. Furthermore, it is still unclear whether personalized dietary recommendations in the form of nutritional concepts (e.g. a fiber-rich nutritional concept) promote weight loss.

The aim of this article is to summarize current literature on personalized nutrition in the context of weight loss and to discuss its potential for practical application. This article will focus on a selection of aspects: genetics, the microbiome, the proteome, and tailored nutritional concepts and their potential for use in the context of personalized nutrition.

Genetics (genotype)

One aspect of personalized nutrition is gen-based dietary recommendations for weight loss – i.e. dietary recommendations based on a person's individual genetic makeup. The fact that body weight is in part determined by genetics as well as the fact that several hundred genes associated with anthropometric parameters have been identified [8] give rise to the hypothesis that the variation in weight loss success between individuals also has a genetic component. A systematic literature review has compiled data on the extent to which nutrient intake is associated with the *fat mass and obesity associated (FTO)* gene. Carriers of the *FTO* risk allele exhibit a higher fat and protein intake and a lower total energy intake of six kilocalories per day per risk allele [9]. Another systematic literature review found no evidence of an association between genetic factors and intake of fat, carbohydrates or energy [10]. A representative survey of 1,357 people in Germany showed that consumers would consider using gene-based dietary recommendations for weight loss and that there is a market for this service [11].

Studies in humans

A systematic review and meta-analysis by Livingstone et al. came to the conclusion that carriers of the risk allele of a certain variant of the *FTO* gene achieved similar weight loss results to those who were not carriers of the risk allele through nutritional, exercise or drug-based interventions [12]. In the DIETFITS (Diet Intervention Examining The Factors Interacting with Treatment Success) study, a randomized, controlled human study with a 12-month low-fat or low-carbohydrate dietary intervention in 609 overweight adults, there was no difference in weight loss between the intervention groups and weight loss was independent of the investigated genotypes, the type of diet and insulin sensitivity [13]. It should be noted that the DIETFITS study only included three different SNPs in the analysis. Therefore, the results from this study cannot be used to make general statements, especially given that the POUNDS LOST (Preventing Overweight Using Novel Dietary Strategies) study for instance found an association between individual genotypes and changes in anthropometric parameters [14, 15]. Furthermore, it should also be noted that these are individual findings that cannot reflect the genetic complexity of body weight. Genome-wide investigations without hypotheses in the context of large weight loss studies would be helpful in identifying genotypes that are linked to weight loss.

Potential and limitations

In recent years, new companies offering genetic analysis to consumers have entered the market. These companies offer consumers "direct to consumer" (DTC) genetic tests that require the customer to provide their own samples of oral mucosal cells (saliva samples), which the company then uses as the basis for dietary recommendations based on the customer's genetics. These recommendations are usually based on SNPs that are associated with certain disease risks or metabolic adaptations. There is currently almost no scientific evidence for these DTC genetic tests. Various professional associa-

tions have stated their positions on DTC tests accordingly. The German Society of Human Genetics *(Deutsche Gesellschaft für Humangenetik)* has stated that it rejects the use of genetic tests that *"have no health relevance or no validated health relevance"*. The American Academy of Nutrition and Dietetics (ADA) has spoken out against gene-based dietary recommendations in a position paper [16]. At present, there is no evidence of a clinically relevant association between genetic factors and the extent of weight loss. Although gene-based dietary recommendations for weight loss appear promising and are very popular among consumers, there is currently not enough evidence from scientific studies to allow this approach to be recommended for use in practice [3]. What is needed for future research activities are to combine interventional studies with genetic approaches in order to develop appropriate algorithms and to demonstrate their efficacy.

Microbiome (enterotype)

A variety of associations between gut microbiota and nutrition, and between gut microbiota and the occurrence of diseases such as obesity have now been demonstrated. These associations suggest that personalized nutrition based on an individual's gut microbiota may represent a possible approach to weight loss. For example, there are increasing indications that changes in host metabolism brought about by nutrition interventions are specific to the person and that this heterogeneity is attributable to a unique "microbiome signature" as well as the host's physiology [17].

Studies in humans

One possible approach to understand the microbiome is the attempt to predict various metabolic responses which are based on the microbiome. Eran Elinav's research group in Israel published the first, pioneering study using this approach. The authors were able to demonstrate that individual postprandial glucose level responses are largely dependent on the composition of the gut microbiota, along with other clinical parameters. Based on the results, the researchers developed an algorithm that allowed postprandial glucose levels to be predicted [4, 18]. The results of the Israeli study were recently replicated for the first time in a study published in the USA [19]. In addition, other studies have shown that stratification of gut microbiomes into two or three enterotypes according to the dominant bacteria present (either dominance of the genus *Prevotella* or dominance of the genus *Bacteroides* or, in the case of three enterotypes, dominance of *Rominococcus* as the third type) may be useful in predicting responses to nutrition [20]. In this context, research is focusing on the significance of the two enterotypes *Prevotella* and *Bacteroides* in terms of pathogenesis of obesity and the success of various diets [21, 22]. For example, it was demonstrated that people with the *Prevotella* enterotype lost more weight than people with the *Bacteroides* enterotype on a fiber-rich diet. Furthermore, multiplication of bifidobacteria in the gut – supported by the use of probiotics, for instance – has a positive effect on metabolic parameters in people with the *Bacteroides* enterotype, which means that this approach could be used as an alternative personalized weight loss strategy [20]. The approach of using prebiotics and probiotics to alter the composition of the gut microbiota is itself nothing new, but in the context of personalized nutrition, it may make it possible to achieve better results [17].

Potential and limitations

Overall, personalized nutrition based on a person's microbiome has great potential to bring about changes in the host's physiology, including in the context of the development and progression of diseases [17, 23]. However, a critical view should be taken of dietary recommendations for weight loss that are based on a person's gut microbiome due to the complexity of the matter and the limited data available. Thus far, it has been a challenge to develop robust and clinically relevant dietary recommendations based on current knowledge about the gut microbiome because the associations are yet to be fully clarified in detail. In addition, there are certain limitations inherent in the uniform evaluation and analysis of large volumes of data (big data), which in turn limits the possibilities in terms of clinical interpretation of the data and translation into interventions [17, 24]. Companies that provide individual dietary recommendations based on a person's microbiome already exist on the market. However, these services are currently not evidence-based since there is insufficient data to support their use.

Proteome (metabotype)

The term "proteome" refers to the total sum of all proteins in a cell, a tissue or an organism. An individual's proteome is based on its genome and it includes a plethora of proteoforms (protein variants), which significantly increase the complexity of the proteome. The proteome adapts to endogenous and exogenous influences in a dynamic manner and thus determines both the functional status and the individual phenotype of a cell or organism [25].

Nutrition is a particularly important factor in determining the composition of the proteome – for example, nutrition can mediate increases in protein synthesis or protein catabolism. Equally, every nutrition-related process – such

as digestion, absorption, distribution and metabolism – depends on the interaction of many different proteins, which means that the proteome controls or regulates the flow of nutrients and metabolites [26]. For this reason, proteomic analyses are used to explain physiological changes related to nutrition at a molecular level and to identify biomarkers that are relevant to nutrition [27, 28]. For example, the proteome analyses conducted in the human intervention study LIPGENE demonstrated that the fat composition of food has varying effects on the proteome. The analyses showed that diets rich in saturated fatty acids have an unfavorable effect on the protein profile and promote postprandial oxidative stress and increased blood coagulation (procoagulant effect) [29]. Given the importance of proteins for metabolic regulation and the expression of the individual phenotype, analysis of the proteome has great potential in the field of personalized nutrition. In addition, analyses of the proteome allow the detection of several proteins at once, as well as the differentiation between proteoforms. It is therefore very efficient – especially compared to traditional immunoassays – in terms of the samples and the time required for analysis.

In terms of regulation of body weight, proteomic analyses are helpful in areas such as clarification of the mechanisms of adipogenesis, overweight and obesity as well as weight loss, weight gain and weight maintenance. Particularly in vitro approaches (using both cell culture, animal and human tissues) have provided a deeper understanding of the various processes of adipocyte differentiation, such as remodeling of the cytoskeleton and the extracellular matrix as well as translocation of nuclear proteins. In this context, proteomic analysis in an adipocyte cell line (3T3-L1) revealed that weight loss, and especially rapid weight loss, can affect the proteome profile and therefore also the phenotype of differentiating adipocytes. If these findings are applied to the in vivo situation – for which no studies are available at present – this mechanism presumably favors a metabolic state that promotes rapid re-storage of fat in the adipocytes. It therefore represents a possible explanation for weight gain or the "yo-yo-effect" [30].

Studies in humans

In order to better understand the mechanisms underlying individual regulation of body weight and the different courses that weight loss takes in different people [31], and to enable in vitro study results to be transferred to the in vivo context, proteome analyses were carried out in various human intervention studies. These studies showed that weight loss is associated with complex changes in the proteome of the white adipose tissue, which is associated with increased lipolysis and mitochondrial β-oxidation, among other changes [32]. The plasma proteome also undergoes significant changes during weight loss. The proteins regulated here are primarily proteins associated with the weight loss itself or with the reduction of fat mass, inflammation and insulin sensitivity [33, 34]. In this context, proteome analyses have also demonstrated the importance of the proteins proteoglycan 4, proline rich acidic protein 1 (PRAP1) and cluster of differentiation 109 (CD109) for the regulation of body weight [33, 34].

Thrush et al. also investigated the potential of the plasma proteome to distinguish between diet-sensitive and diet-resistant individuals in the context of weight loss [35]. It was found that the study participants principally differed in terms of the proteins associated with mitochondrial metabolism of the skeletal muscle, oxidative status, regulation of translation and of fatty acid oxidation, the citric acid cycle and the respiratory chain.

Thus far, the performed proteome analyses have been mainly "untargeted proteomic analyses" (= recording of all proteins in a sample) in an attempt to understand the mechanisms underlying weight loss and to identify proteins as biomarkers. One of the insights gained from these systematic analyses is that there are major differences between individuals in terms of the plasma concentrations of most proteins even before weight loss. Therefore, in order to make a realistic assessment of the efficacy of weight loss measures in practice, the change in protein concentration over the course of the intervention should be assessed and the use of reference populations should be avoided [33]. In addition, when evaluating weight loss and its metabolic consequences, it is advisable to use a combination of different proteins (protein groups) for the evaluation, since this is superior to the use of individual marker proteins. For example, Geyer et al. suggested protein groups for the evaluation of insulin resistance (including adiponectin, apolipoprotein F, sex hormone-binding globulin and proteoglycan 4) and for the evaluation of inflammatory status (including C-reactive protein, serum amyloid A and α1-acid glycoprotein) [33]. In a clinical setting, this approach might allow the prediction of weight loss success (extent and sustainability) and might provide the opportunity for adjustments to the intervention.

Potential and limitations

Analysis of the proteome does indeed offer a wide range of advantages for nutrition research, as it makes it possible to perform simultaneous quantitative and qualitative analysis of a large number of proteins and therefore allows the identification of new metabolic relationships and the identification of biomarkers [25]. However, proteome analysis also comes with various limitations that make it difficult to implement in nutrition research. Such limitations include the large concentration gradient between proteins, the high dynamic range and the high variability in the proteome between individuals [33, 36]. In addition, the availability of biological material is limited, especially in human studies, although blood and blood cells can be used as surrogates if necessary [27]. Finally, the analysis

itself requires high-quality technical equipment, including access to high-resolution mass spectrometers, as well as the experience and the means to evaluate large volumes of data [37]. Proteomic analyses are currently being conducted in human studies and are the subject of ongoing research, but the results currently have no clinical relevance and cannot be used as the basis for personalized dietary recommendations. Instead, they can provide insights into the metabolism, which will then need to be investigated further in interventional studies.

Nutritional concepts (nutritype)

The importance of developing and validating tailored nutritional concepts is reflected in the results of the study published in January 2020 by the German Agricultural Society *(Deutsche Landwirtschafts-Gesellschaft e. V. – DLG)* "My Food – Personalization and Nutrition" [38]. One out of two survey respondents stated that he/she would like to improve his/her nutrition. In connection with this, 45% of respondents stated that they could see themselves using services based on personalized dietary recommendations. Going into greater detail, 18% of the respondents

Junior research group Nutritional Concepts

The research activities of the junior research group Nutritional Concepts are focused on the development and validation of nutritional concepts for those who eat an omnivorous diet, flexitarians, vegetarians and vegans that are characterized by an optimal composition of macronutrients and micronutrients and that contribute to the prevention and treatment of non-communicable diseases and especially cardiovascular diseases. Once developed, these concepts can be tailored to the specifications of weight management programs in order to counteract the development of overweight and obesity and to improve the treatment of these conditions.

The nutritional concepts that have been developed are based on daily eating plans (◆ Table 1) that provide detailed requirements and food preparation recommendations for each meal in the day (breakfast, morning snack, lunch, afternoon snack, dinner) and therefore ensure that nutrient intake targets are met in accordance with the German Nutrition Society reference values for nutrient intakes. The daily eating plans provide 40–70 g dietary fiber per day as well as a modified dietary fat intake based on the recommendations of international professional associations. Specifically, saturated fatty acid intake is reduced to 7% of daily energy intake and the proportion of monounsaturated and polyunsaturated fatty acids is set at 10% of daily energy intake. The eating plans that have been developed also ensure an adequate intake of n-3 fatty acids. Another special feature of the tailored daily eating plans is that energy intake is adapted to individual needs based on age, sex, resting energy expenditure and physical activity (physical activity level, PAL). The effects of the personalized daily eating plans on nutrient status and cardiovascular risk factors are evaluated in human studies.

Amount	Food
Breakfast	
1 (45 g)	wholegrain bread rolls
0.5 teaspoon (3 g)	margarine
1 teaspoon (5 g)	fruit jelly
40 g	hummus (with preparation recommendation)
Snack	
20 g	chocolate spread (with preparation recommendation)
2 slices (30 g)	crispbread
Lunch	
1 portion	cream of asparagus soup (with preparation recommendation)
1.5 slices (75 g)	wholegrain bread
Snack	
200 g	strawberries
25 g	apricot (dried)
15 g	walnut
300 g	yogurt alternative (fortified with vitamin B_{12})
Dinner	
1 portion	noodle salad with mango and vegetables (with preparation recommendation)

Tab. 1: **Vegan daily menu for a woman 25 to 51 years old** (Physical activity level [PAL]: 1.4; energy intake: 1,800 kcal)

had a particular interest in personalized recommendations for ingredients or nutrients, 17% of the study participants were interested in personalized recipes and 12% were interested in personalized nutrition plans (daily, weekly, or monthly plans; ◆ Box "Junior research group Nutritional Concepts"). In addition, 40% of the respondents said that they would buy personalized food products that the manufacturers had specifically adapted to their individual nutritional needs. These changes and trends among consumers represent a particular challenge for the food industry. Currently, 26% of companies see themselves as being in a position to provide personalized food products, whereas 69% of companies stated that they did not have the technical means to produce suitable personalized food products. Of the companies surveyed, 75% were still unclear about whether there is sufficient demand for personalized products or kits and sufficient willingness to pay for them.

Food4Me study

The results of the Food4Me study confirm that personalized dietary recommendations can motivate people to implement a healthier lifestyle. In this 6-month randomized, controlled trial, 1,607 study participants from seven European countries were randomized to one of three intervention arms (level 1: personalized dietary recommendations, adapted to individual dietary behavior; level 2: same as level 1, plus consideration of phenotypic data [biomarkers in the blood, anthropometric data]; level 3: same as level 2, plus inclusion of genetic data on five diet-responsive genetic variants). The control arm received non-personalized dietary recommendations based on nutritional guidelines. Regardless of the level, the participants who received personalized dietary recommendations consumed significantly less red meat, salt and saturated fat compared to the controls, and their folate intakes and Healthy Eating Index scores markedly increased. The data indicate that the inclusion of phenotype or genotype information did not result in any additional increase in the effectiveness of personalized dietary recommendations – i.e. the level of personalization did not matter [39]. Furthermore, the level of personalization also had no effect on the extent of weight loss, with all the personalized intervention groups performing better than the control group [40].

Potential and limitations

The approach of tailored nutritional concepts that take account of factors specific to the individual, such as energy needs, food preferences and lifestyle, is itself nothing new and is an approach that qualified nutrition professionals usually take. However, designing detailed, personalized daily eating plans is very time-consuming for nutrition professionals, as it usually requires a great deal of manual work. Although digitalization makes this work easier, as yet, there are no fully automated digital algorithms available that incorporate all aspects of personalized treatment. Approaches that make use of artificial intelligence (AI) are set to revolutionize personalized nutritional concepts and make the work of nutrition professionals much easier. In addition, it should be noted that not all clients want detailed daily eating plans and not all are able to implement them. Therefore, in the future, companies that supply personalized meals are set to play a major role in this context.

Research projects

As part of the funding of the Competence Clusters for Nutrition Research, four junior research groups were funded by the German Federal Ministry of Education and Research with the aim of investigating the topic of personalized nutrition from different perspectives (◆ Table 2).

In addition to the aspects focused on in this article – weight loss and the associated metabolic changes – the research activities of the four junior research groups also include the development and establishment of personalized concepts aimed at ensuring an optimal supply of nutrients in the context of the individual's specific diet, as well as support of treatment for disorders of lipid metabolism.

Discussion

This review has covered four different approaches to personalized nutrition (genotype, enterotype, metabotype and nutritype), using weight management as the example. It should be noted that the approaches covered here are only a selection of the possible approaches, and there are other approaches and parameters that would be valuable additions to the discussion. Factors such as chronobiology, sleep, stress and the environment have not been included in this article, but there is evidence that they are relevant in the context of personalized nutrition.

It is also worth noting that to date, there have been very few studies testing personalized dietary recommendations, and for most approaches, there is no evidence of an additional benefit over and above the benefit of standard dietary recommendations. This could be due to the fact that most of the studies used post-hoc analyses, and personalized nutrition was not explained and recommended to the study participants from the beginning. For all approaches (◆ Table 3), there is a lack of robust study results from randomized controlled trials that could provide a rationale for the use of personalized nutrition based on genetics, the microbiome, the proteome, metabolism, nutritype or a combination of these. In addition to the problem of a lack of study results, there is also a problem in terms of the practical applicability of these approaches since there is insufficient data on which to base recommendation algorithms or an artificial intelligence

	PeNut Personalized nutrition and eHealth
Project leader	Christina Holzapfel
Cluster	*enable*
Project	The aim of this project is to identify and investigate parameters that can be used in personalized nutrition. The focus here is on personalized nutrition in the context of weight management, which is being investigated in a lifestyle intervention study. In addition, a survey on personalized nutrition is being conducted, along with systematic reviews on gene-lifestyle interactions.
Website	www.enable-cluster.de/penut
	BonnGut Nutrition and the Microbiome
Project leader	Marie-Christine Simon
Cluster	Diet Body Brain (DietBB)
Project	The aim of this project is to apply knowledge gained from animal studies on the "microbiome-gut-brain axis" to human interventional studies using a translational approach with the aim of investigating the relationships between nutrition, the gut microbiome and cognition and identifying the underlying mechanisms. The overarching, long-term objective is to make it possible to provide personalized dietary recommendations based on this knowledge.
Website	www.diet-body-brain.de/research/bonngut-junior-research-group
	ProAID Protein oxidation as an indicator of the aging phenotype and target of a personalized dietary intervention
Project leader	Andrea Henze
Cluster	NutriAct
Project	The aim of this project is to determine the significance of oxidative modifications of endogenous proteins as indicators of the aging phenotype and their importance in terms of the individual's metabolic situation, in order to contribute to the creation of personalized and optimized dietary recommendations in the long-term.
Website	www.uni-potsdam.de/proaid
	NuCo Nutritional Concepts
Project leader	Christine Dawczynski
Cluster	nutriCARD
Project	The aim of this project is to develop and validate nutritional concepts. To this end, concepts for a variety of healthy persons with different nutritional habits (western diet, flexitarians, vegetarians, vegans) are being developed in order to ensure adequate nutrient supply. In addition, concepts for people with disorders of lipid metabolism are being prepared and evaluated as support for their treatment. Furthermore, nutrition-associated biomarkers and profiles that reflect certain eating patterns are being identified and validated.
Website	www.nuco.uni-jena.de

Tab. 2: **Overview of the research topics of the four junior research groups of the Competence Clusters for Nutrition Research**

approach. In future, the artificial intelligence approach is set to form the basis for development of a digital nutrition consultant that provides personalized dietary recommendations and is with the person wherever they go. It will record, analyze and evaluate data and then use this as the basis for personalized dietary recommendations. The US National Institutes of Health (NIH) have put personalized nutrition (precision nutrition) at the heart of their recently published 2020–2030 strategic plan for NIH nutrition research [41]. This is set to provide a huge boost to research activities in this field and advance the development of evidence-based algorithms for the practical implementation of personalized dietary recommendations.

Approach	Principle	Evaluation
Genotype	dietary recommendations based on genetic makeup	offered commercially by some companies (direct to consumer genetic tests); no scientific evidence of clinical relevance
Enterotype	dietary recommendations based on gut microbiota	offered commercially by some companies following analysis of a stool sample; no scientific evidence of clinical relevance
Metabotype	dietary recommendations based on proteome analyses/blood profile	not commercially available; an approach that currently has a place in research; no clinical relevance
Nutritype	dietary recommendations based on energy needs, adapted according to age, sex, physical activity, health status, food preferences and lifestyle	provided by qualified nutrition consultants; dietary recommendations in accordance with the relevant guidelines

Tab. 3: **Evaluation of approaches to personalized dietary recommendations for weight loss**

Conclusion

The literature shows that different people respond very differently to foods and that due to the very nature of the issue, there is no single dietary recommendation that can be universally prescribed for weight loss. Although commercial providers of personalized dietary recommendations for weight loss are currently becoming more common, there is no scientific evidence for this according to current scientific knowledge. Even though studies have shown that genetic factors or the microbiome can affect metabolic responses, there is still no corresponding evidence that individuals with a certain genetic background or certain gut flora profile derive any particular benefit from any particular dietary recommendation in terms of weight loss. For this reason, a critical view should be taken of DTC tests due to the lack of clinical evidence. Consequently, they should not be used for obesity prevention or treatment at present. Nevertheless, nutrition counseling should take the person's individual preferences and needs into account and the prescribed diet should be adapted to their energy, macronutrient and micronutrient needs accordingly. In the next few years, the continuing advancement of digitalization and the integration of AI approaches is set to expand personalized dietary recommendation options and drive them forward. The research results from the junior research groups of the German Competence Clusters for Nutrition Research will also contribute to these developments.

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Conflict of Interest
Christina Holzapfel is a member of the Scientific Advisory Board of 4sigma GmbH, Oberhaching. The other authors declare that there are no conflicts of interest.

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