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Personalised nutrition: the role of new dietary assessment methods

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Food records or diaries, dietary recalls and FFQ are methods traditionally used to measure dietary intake; however, advancing technologies and growing awareness in personalised health have heightened interest in the application of new technologies to assess dietary intake. Dietary intake data can be used in epidemiology, dietary interventions and in the delivery of personalised nutrition advice. Compared with traditional dietary assessment methods, new technologies have many advantages, including their ability to automatically process data and provide personalised dietary feedback advice. This review examines the new technologies presently under development for the assessment of dietary intakes, and their utilisation and efficacy for personalising dietary advice. New technology-based methods of dietary assessment can broadly be categorised into three key areas: online (web-based) methods, mobile methods and sensor technologies. Several studies have demonstrated that utilising new technologies to provide tailored advice can result in positive dietary changes and have a significant impact on selected nutrient and food group intakes. However, comparison across studies indicates that the magnitude of change is variable and may be influenced by several factors, including the frequency and type of feedback provided. Future work should establish the most effective combinations of these factors in facilitating dietary changes across different population groups.

Personalised nutrition: Dietary assessment: Dietary feedback: Diet: Food habits

Worldwide, the prevalence of overweight and obesity has escalated by 27·5 % in adults from 1980 to 2013[(1)], with more than 1·6 billion adults presently considered to be overweight or obese globally[(2)]. Poor dietary profiles characterised by energy dense, high-fat diets, with low fruit and vegetable intakes, are associated with increased risk of diet-related non-communicable diseases such as CVD, type 2 diabetes and some cancers[(3)], and are modifiable factors for reducing obesity risk[(4)]. Face-to-face behavioural change programmes or intervention studies, which aim to alter dietary intake and/or increase physical activity have been shown to result in significant weight loss[(5)]. However, the feasibility of these programmes on a large scale, required to stimulate widespread changes in diet and physical activity, and help reduce the rising prevalence of obesity is limited, indicating that there is a growing need for alternative effective strategies.

Advances in the field of nutritional science have facilitated the shift from the ‘one size fits all’ general population-based guidelines to more personalised dietary recommendations[(6,7)]. Existing nutrient intake recommendations are presently differentiated for subgroups of the population based on factors including age, sex and physiological status[(6,8,9)]. However, growing evidence has demonstrated that providing individuals with more specific personalised feedback advice can be more effective than generic information in improving a variety of dietary outcomes, including reducing fat intakes and increasing fruit and vegetable intakes[(10–12)]. To provide personalised advice, an appropriate method for measuring and assessing dietary intake is required.

Traditionally dietary intakes have been assessed using weighed or non-weighed food diaries, paper-based FFQ and telephone or in-person administered 24 h

Abbreviations: app, application; FFQ; PDA, personal digital assistant.
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recalls[13,14]. However, with advances in technology and growth of consumer interest in personal health, there is increasing research into the application of new technology-based dietary assessment methods for providing personalised dietary advice more efficiently[3,15–17]. Compared with traditional dietary assessment methods, these instruments can collect dietary intake data more easily across large geographically dispersed populations[18], and therefore have greater potential to provide personalised dietary advice on the large scale. Furthermore, in contrast with the traditional methods of dietary assessment, technology-based methods are less expensive, can be completed at the participants' convenience and are associated with reduced researcher burden as nutrient intakes can be generated automatically[19–21]. This has the further advantage of enabling feedback advice to be pre-programmed and potentially delivered in real-time[22]. The objectives of the present review are to (i) examine the range of new technologies developed for the assessment of dietary intakes and (ii) assess the utilisation and efficacy of new technologies for providing personalised dietary advice.

New technologies for dietary assessment

The digital revolution has evolved the process in which dietary assessment methods are administered and dietary intakes are measured, resulting in a rise in the development of new technology-based instruments for assessing dietary intakes[23–28]. These new instruments can be broadly categorised into three key areas: online (web-based) methods; mobile methods; sensor technologies. Evidence has demonstrated several of these newer methods of dietary assessment to be preferred over traditional methods by an array of population groups, including adolescents and adults[21,22,29,30]. Furthermore, the feasibility of utilising technology-based methods to collect dietary intake data within specific population groups is also being explored with novel tools being developed for both children and older adults[31,32]. As new technologies for dietary assessment are frequently used in nutrition research and increasingly utilised to provide personalised dietary advice, it is important that they are designed to facilitate fundamental updates, such as the updating of nutritional composition data, to prevent them from becoming swiftly redundant and replaced by improved versions.

Online (web-based) methods of dietary assessment

Global increases in Internet usage and availability over the past decade have resulted in online (web-based) methods of dietary assessment becoming popular for assessing dietary intakes for both research and commercial purposes[33]. Unlike the traditional paper-based methods of dietary assessment, online methods possess many benefits: they can be pre-programmed with plausibility and completeness checks, probing questions and can be developed to incorporate food photographs to enhance food recognition and portion size estimation[18,19,21]. As illustrated in Table 1, the majority of tools developed to date are centred around 24 h recalls and FFQ, with fewer examples of food diaries/records[22]. Nonetheless, studies have shown online food records to be comparable with paper-based records in their ability to estimate energy intake and subsequent associated levels of underreporting[22,34].

To date, numerous online (web-based) 24 h recalls have been developed for the collection of dietary intake data both within adults and children[21,35–39]. As outlined in Table 1, ASA24, DietDay, NutriNet Sante and the Oxford WebQ are web-based 24 h recalls developed for the assessment of dietary intake data for adults, which have been shown to be comparable with other methods of dietary assessment[21,38–41]. ASA24 is a web-based 24 h recall based on the automated multiple-pass method that is available for use by clinicians, educators and researchers[38]. The tool has a dynamic user interface which features an animated guide and audio and visual cues[38], and has been demonstrated to have reasonable agreement with an interview-administered automated multiple-pass method for selected nutrients and food groups[41]. DietDay is similar to ASA24, as it also applies multipasses analogous to the automated multiple-pass method[42]. DietDay consists of 9349 food items and more than 7000 food images[42], and has been shown to have greater validity than a paper-based FFQ using the doubly labelled water method[39].

Several studies have also been published regarding the development and use of online FFQ for the estimation of dietary intake, with the majority of online FFQ based on previously validated FFQ or country-specific food guides[19,20,25,30,33,43–45]. Like the traditional paper-based FFQ, online FFQ vary in their population of interest, inclusion of photographs and number of food items. Key features for several of the online FFQ developed for collecting dietary intake data within adults are presented in Table 1. The online Food4Me FFQ was recently developed for the collection of dietary intake data across seven European countries and has been translated into six languages[33]. This FFQ lists food items (157 in the English-language version) and requires a response regarding the frequency and portion size consumption of each individual food item over the past month[33]. Although the Food4Me FFQ is similar in format to traditional FFQ, online FFQ also have the flexibility to differ from this conventional list-style format. For example, GraFFS is a recently developed algorithm-driven FFQ which presents users with thumbnail illustrations of food items within a food category; from these users then select the food items which they have consumed at least once in the past month, and only these food items are further questioned[25]. Thus far, evidence examining the validity of online FFQ to other dietary assessment methods has been varied. Several studies have found online FFQ to be highly correlated with 24 h recalls and comparable with food records[19,25]. For example, the Food4Me FFQ has been shown to have good agreement with a paper-based FFQ and moderate agreement with a 4-d weighed food record for estimating both nutrient and food group intakes[30,33]. Meanwhile, other studies have

Table 1. Online (web-based) dietary assessment tools for the collection of dietary intake data in adults

Author	Online Tool	Key features	Validation/comparison method
Kirkpatrick *et al.*[41], Subar *et al.*[38]	24 h recall (ASA24)	Based on AMPM Meal-based approach; collects data on preparation methods, and supplement use Includes animated guide and audio and visual cues Photographs to aid portion estimation Available in English and Spanish	Interview-administered AMPM
Touvier *et al.*[21]	24 h recall (NutriNet Sante)	User guide, video and tips in questionnaire Meal-based approach Photographs to aid portion estimation	Dietitian-conducted 24 h recall
Arab *et al.*[39]	24 h recall (DietDay)	Multi-pass meal-based approach; collects data on preparation methods and use of condiments and supplements Contains 9349 food items >7000 photographs to aid portion estimation	Doubly labelled water method and paper-based FFQ
Liu *et al.*[40]	24 h recall (Oxford WebQ)	Structured questionnaire regarding consumption of foods from twenty-one food groups	Interview-administered 24 h recall
Kristal *et al.*[25]	FFQ (GraFFS)	Consists of 156 food items Collects data on preparation methods, food formulations and use of condiments Designed to minimise participant burden Photographs to aid portion estimation	Six 24 h recalls
Forster *et al.*[33], Fallaize *et al.*[30]	FFQ (Food4Me)	Consists of 157 food items Collects data on use of condiments and supplements Photographs to aid portion estimation Translated into six languages	Paper-based FFQ and a 4-d weighed food record
Labonte *et al.*[19]	FFQ	Contains 136 questions Collects data on supplement consumption Photographs to aid portion estimation Available in English and French	Interview-administered FFQ and a 3-d food record
Beasley *et al.*[44]	DHQ	Consists of 124 food items Photographs to aid portion estimation	Paper-based DHQ and a 4-d food record
Hutchesson *et al.*[34]	Food record	Self-monitoring tool used in SP Health Weight Loss Platform Portion sizes recorded as weight/volume, household measures or standard sizes	Doubly labelled water method

ASA24, automated self-administered 24-h recall; AMPM, automated multiple-pass method; DHQ, diet history questionnaire.

shown online FFQ to result in poorer estimation of food groups when compared with traditionally administered dietary recalls and weighed food records[20,45]. This variability is commonly observed with FFQ regardless of their mode of administration, and usability analyses have indicated that individuals would be more willing to complete online methods of dietary assessment over the traditional methods[21,30].

Mobile methods of dietary assessment

Initially, personal digital assistants (PDA) were the leading mobile method for assessing dietary intakes, being utilised from the mid-1990s. These devices contained an integrated pre-defined drop-down list of foods, typically ranging from 180 to >4000 items[18], and have been demonstrated to be comparable with traditional methods of dietary assessment[46–48]. Progressions in technology have however resulted in smartphone use surpassing PDA as the foremost mobile method of dietary assessment[16,26,49], with growing research emerging into the use of smartphones to measure dietary intakes using both applications (app) and image-based methods[50].

Smartphones have huge potential in the measurement of dietary intake and delivery of low-cost interventions to large population groups[51]. Statistics show their use/ownership is increasing among a variety of age groups and they are usually carried by the individual, enabling users to record data conveniently and discretely in real-time[26,52,53].

App for tracking dietary intake can be solely dietary based or integrated into other app such as physical activity app e.g. My Fitness Pal[54]. Although many smartphone app are available for tracking dietary intake, publications regarding the validity and accuracy of many of these app are limited[54]. ‘My Meal Mate’ is an exception; this electronic food diary smartphone app is designed to facilitate weight loss and consists of a 40 000 food item database containing both generic and branded food items[26]. Although this app has been shown to be well correlated with two 24 h recalls for estimating energy and macronutrient intakes, it was demonstrated to have large variability in estimating individual energy intakes[26]. Therefore, considering many smartphone app are used and targeted to the individual, there is a need for future studies to establish the validity

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of utilising smartphone app for the assessment of dietary intakes at the individual level. Notwithstanding their ability to accurately capture dietary intake data, evidence examining use of mobile app have found them to be more effective than paper diaries in reducing energy intakes after 6 months[55], highlighting their potential for dietary interventions.

Advances in technology have also led to the utilisation of smartphones for image-based methods of dietary assessment[56]. These image-based methods require the user to photograph their foods/meals along with a fiducial marker before and after eating, and therefore have the potential to diminish the burden to the user that is commonly associated with other methods of dietary assessment[28]. Presently, two approaches for image-based assessment have been described in the literature: those requiring human input (e.g. remote food photography method) and those not requiring human input (e.g. the technology assisted dietary assessment mobile phone food record and DietCam)[28,52,57,58]. With the remote food photography method images are sent wirelessly to a Food Photography Application where trained analysts compare the sent images with a catalogue of images of foods of known portion sizes to estimate food intake[58,59]. Evidence has demonstrated that this method underestimated energy intake by only 3·7 % compared with the doubly labelled water method[59]. Furthermore, comparisons of nutrient intake estimates from the remote food photography method and two laboratory-based weighed meals showed no significant differences for energy, macro or micronutrient intakes with the exception of vitamin A and cholesterol ($P < 0{\cdot}01$)[59]. In contrast, the technology assisted dietary assessment mobile phone food record uses built in integrated image classification, analysis and visualisation tools to automatically estimate the amount of food and nutrients consumed at each meal[28,60]. This method has been shown to be more limited in its ability to distinguish between similarly shaped and coloured food items e.g. brownies and chocolate cake[60]. However, image-based methods are being designed to incorporate developments such as voice recognition, to overcome many errors associated with automated food item classification[50].

Sensor technologies

In recent years, use of wearable sensor technologies for measurement of dietary intake has emerged[27]. These devices take photographic images while being worn, which capture a range of data and health activities, and can be used to estimate nutritional intake without self-reporting[24]. Some of these devices, such as the Microsoft SenseCam, have been used in conjunction with other methods of dietary assessment to help improve their accuracy by capturing information that may be incorrectly estimated or unreported e.g. left overs, portion sizes and unrecalled food items[61]. Evidence has shown that the application of a paper diary together with the Microsoft SenseCam resulted in more accurate estimations of portion size data and subsequent energy intakes when compared with using the diary alone[61]. In this study, forty-seven participants were recruited and requested to wear the SenseCam for 1 d while simultaneously recording a 1-d food diary[61]. Data from the SenseCam and food diary were reviewed by a dietitian and any discrepancies between the methods were identified[61]. Moving forward from this concept, the eButton is another sensor device that has been recently developed, which can automatically estimate the nutritional composition of food items through integrated food segmentation, volume estimation, modelling and fitting processes[27]. This device is a small lightweight decorative button, worn on the chest, which encompasses a camera and passively photographs foods every 2 s to record the eating process[27]. Although there is future potential for such devices in estimating dietary intake, the ability to automatically estimate the nutritional composition of the wide variety of foods and meals consumed on a daily basis from food photographs is a complex process. Recent accuracy evaluations for the eButton demonstrated its error rate to be about 30 % for regularly shaped foods, and significantly larger for irregularly shaped or occluded food items[27], indicating that further development is required before these devices will be applied for automatically estimating nutritional intakes.

Application of new technology-based dietary assessment tools for personalised nutrition

These technology-based dietary assessment instruments can be developed into or integrated with tools which provide personalised or tailored dietary feedback advice, and therefore have the potential to help individuals to make positive sustainable changes to their dietary behaviours. These instruments are being increasingly utilised in intervention studies to provide personalised or tailored feedback, with numerous randomised controlled trials demonstrating this personalised advice to be more effective than generic advice in improving selected dietary outcomes[17,62,63].

As illustrated in Table 2, PDA, online FFQ and web-based dietary questionnaires have all been utilised for providing personalised dietary advice, with studies in recent years also examining the potential for smartphone app to provide tailored or personalised feedback advice[15,16]. A smartphone app that can capture dietary and physical activity information and provide personalised recommendations has been developed for use in the EVIDENT II trial[16]. This app encompasses a food diary to enable users to record their daily food intake, evaluates the user's food intake, and provides personalised recommendations to help facilitate changes in dietary habits[16]. In addition, smartphones applying image-based assessment (requiring input from trained analysts) have recently been used in the Connecting Health and Technology project to assess nutritional intake and provide tailored feedback advice and text messages to young adults to promote changes in consumption of fruit, vegetables and junk food[15]. Results regarding the efficacy of utilising these

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Table 2. Summary of randomised controlled trials utilising new technology-based dietary assessment instruments to provide personalised/tailored advice

Author	Tool	Intervention length	Population group	Tailored/ personalised advice	Frequency of feedback	Significant effects of tailoring
Recio-Rodriguez *et al.*[16]	Smartphone app	12 months	Adults (*n* 1533)	Mediterranean diet	Daily	–
Kerr *et al.*[15]	Mobile food record	6 months	Young adults (*n* 300)	Fruit, vegetables, junk food	Weekly	–
Celis-Morales *et al.*[3]	Online FFQ	6 months	Adults (*n* 1607)	Three nutrient-related goals selected from seventeen nutrients	Baseline and 3 months	–
Sternfeld *et al.*[62]	Web-based dietary questionnaire	16 weeks	Adults (*n* 787)	Fat, sugar, fruit, vegetables	Weekly for first 8 weeks then every 2nd week	Increased fruit and vegetables, and reduced fat immediately and 4 months post-intervention
Springvloet *et al.*[17]	Online FFQ	6 weeks	Adults (*n* 1349)	Fat, fruit, vegetables, junk food	Three sessions	Reduced fat and high-energy snacks. Limited reduction effects for fruit
Maes *et al.*[64]	Online FFQ	3 months	Adolescents (*n* 1298)	Fat, fibre, vitamin C, calcium, iron	Baseline and 1 month	Reduced fat in overweight participants only
Ambeba *et al.*[63]	PDA	24 months	Adults (*n* 210)	Energy and fat	Daily in real-time	Reduced energy and saturated fat

PDA, personal digital assistant.

smartphone-based tools to provide personalised advice are yet to be published.

Efficacy of technology-based tools in providing personalised dietary advice

To date, several studies have utilised online FFQ to assess dietary intake to aid the provision of personalised dietary advice (Table 2). In 2011, Maes *et al.* demonstrated that using an online FFQ, consisting of 137 food items, to collect dietary data and provide tailored advice for fibre, vitamin C, calcium, iron and fat, to adolescents (*n* 713), only resulted in significant improvements in fat intake in overweight adolescents[45,64]. Online FFQ have also recently been used to measure dietary intake and provide tailored advice as part of a nutrition education intervention within adults, as illustrated in Table 2[17]. However, this study showed similar variation in the efficacy of tailored advice for improving nutrient and food group intakes. Following the intervention, participants receiving tailored advice reported significantly lower saturated fat and high-energy snack intakes, compared with participants receiving non-tailored advice. However, the tailored advice had no effect on vegetable intakes and only limited impact on changes in fruit intake[17]. The validated FFQ utilised to assess fruit, vegetable, fat and high-fat snack intakes used six, four, thirty-five and twenty-one food items to measure intakes of each of these dietary outcomes, respectively. Therefore, it is possible that the ability of these instruments to identify changes in fruit and vegetable intakes between the control and intervention groups was limited by the low number of food items used to assess fruit and vegetable intakes. However, Sternfeld *et al.*[62] have previously demonstrated that using an online dietary questionnaire, consisting of only thirty-five food items, to assess dietary intake and provide tailored feedback advice for fruit and vegetables and fat and sugar, resulted in significant improvements to saturated fat, *trans* fat and fruit and vegetable intakes both immediately and 4 months post-intervention. This would therefore indicate that numerous other factors, relating more directly to the feedback itself and the target population, also influence the efficacy of utilising technology-based instruments to provide effective personalised advice, as illustrated in Fig. 1.

As detailed in Table 2, in the study by Sternfeld *et al.*[62], the intervention was a 16-week email program during which intervention participants firstly chose the area they wanted to target and secondly chose one to two goals to achieve each week. Providing individuals with the opportunity to choose the goals they want to target may be an important factor influencing the efficacy of tailored/personalised dietary feedback and magnitude of behaviour change. This is because individuals will tend to choose goals that are of more interest to them and are subsequently more likely to achieve. Another factor, however, that also differed between this study and the two previously discussed, was the frequency in which feedback was provided. The study where feedback was provided more frequently was associated with greater changes in a variety of dietary outcomes. Concurrent with this, recent evidence has shown the application of PDA to provide daily tailored advice to have a considerable impact on dietary behaviours[63]. Participants who received daily tailored energy and fat feedback messages delivered remotely on a PDA in real-time significantly reduced their energy ($P = 0{\cdot}03$) and saturated fat intake ($P = 0{\cdot}04$) after 24 months compared with participants receiving no daily feedback

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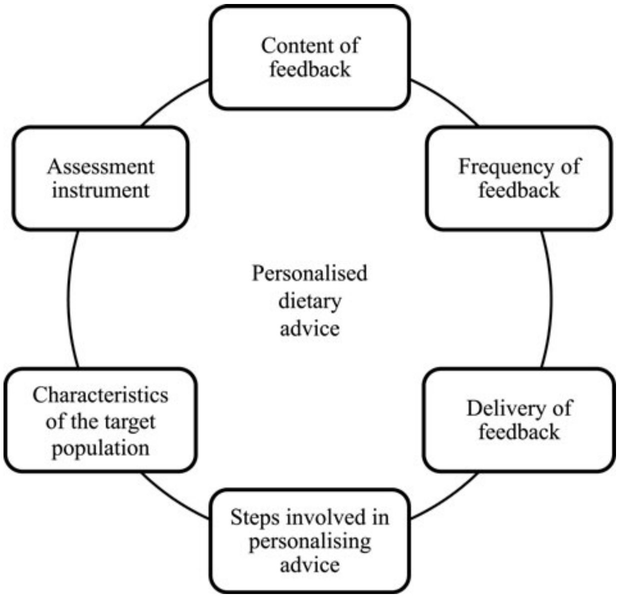

Fig. 1. Factors influencing the efficacy of new technology-based instruments in providing personalised/tailored advice to improve dietary intake.

messages[63]. Mean differences in energy and fat intake at 24 months were −9·3 and −12·7 % greater, respectively, for those who received the daily tailored feedback messages compared with those receiving no daily feedback messages[63].

In addition to the frequency of feedback, the mode of delivery of personalised advice is another element that could influence the efficacy of personalised dietary advice. Personalised feedback advice can be delivered to users in a variety of formats, such as onscreen messages or detailed reports. The format in which advice is delivered is often dependent on the method of assessment: with smartphones or PDA feedback advice is customarily delivered as onscreen messages[63], whereas with online tools feedback advice could either be delivered in the form of a report or made available on a personalised homepage[62]. An earlier study examining the impact of delivering interactive (designed to mimic web-based tailored feedback), print-delivered computer-tailored feedback advice and generic feedback information on saturated fat intake found the two tailored feedback conditions to have similar short-term reduction effects[65]. However, after 6 months, reduction effects were maintained only in participants receiving the print-delivered tailored feedback. One possible explanation is that it is potentially easier and less burdensome to read and reread printed information more thoroughly than on-screen information[65,66]. However, latter studies have shown the Internet to be a successful method for delivering tailored or personalised advice[17,62]. Furthermore, using the Internet to administer personalised advice can enable greater interactivity with the feedback provided as there is the potential to encompass additional tools including homepages and discussion forums[67,68].

In summary, although several studies have demonstrated that technology-based dietary assessment tools can be used to provide tailored/personalised advice that is more effective in changing dietary behaviours than generic information, evaluation across studies would indicate that the magnitude of change is variable and may be affected by several factors as summarised in Fig. 1. This is in agreement with a systematic review which identified several factors, such as target population, target behaviours and mode of delivery, as potential contributors to the variable effectiveness of e-learning interventions on improving dietary behaviours.[69]

Translating nutrient intake data into personalised advice

Although progressively more dietary assessment instruments are being used to provide tailored or personalised dietary advice, literature regarding the processes in which personalised advice is generated by these tools is largely limited. A simplified process for generating computer-tailored dietary messages was outlined in 1999: results from a baseline questionnaire are entered into a data file which is subsequently linked by computer software (using pre-programmed algorithms) to an appropriate feedback message(s)[68]. The appropriate message(s) are selected from a message archive and then assembled into a predefined format. However since then, developments in technology have advanced this process; nutritional intake data are automatically generated from new technology-based dietary assessment instruments and algorithms can be used to automatically generate feedback advice. Several studies have briefly referred to the use of decision tree algorithms to generate appropriate feedback advice from nutritional intake data[63,64]. The web-based computer-tailored nutrition intervention, developed for adolescents in the HELENA study, consisted of three key components: a validated FFQ, a food composition database and a decision tree algorithm to provide tailored advice[64]. The decision tree algorithm was designed to compare reported nutrient intakes with recommendations and provide food-based advice when intakes differed from recommendations[64]. More complex systems have since been developed which enable feedback advice to be transmitted in real-time. For example, an automated investigator-developed algorithm linking dietary intake data from PDA devices to feedback messages was recently constructed in four time-related categories which were further differentiated into five sections resembling goal attainment, enabling feedback messages to be delivered in real-time[63]. Largely as illustrated in Table 2, the majority of studies utilising technology-based dietary assessment tools have been developed to provide tailored or personalised advice for a small selection of nutrients/food groups only[15,17,62,63], with limited studies personalising advice for extended lists of nutrients[3,64]. Personalised advice is most commonly provided for nutrients and food groups considered to be important constituents of a healthy/unhealthy diet, predominately saturated fat, fruit and vegetables[70]. The Food4Me study is one of the few exceptions that developed a multi-step system for personalising advice for a larger range of nutrients. In this study, an online FFQ was used to assess dietary intake. Decision trees were developed to link

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nutritional intake data from the FFQ to feedback messages, and provide participants with personalised feedback advice for three nutrient-related goals[3]. The three nutrient-related goals were derived based on their risk status (deviations from recommendations) and selected from a possible seventeen nutrients[3].

Furthermore, given that behaviour change is considered to be a multi-stage process, strategies to help increase motivation and stimulate changes in dietary behaviour may often be incorporated in both the process of generating personalised feedback and in the content of feedback[71,72]. For example identifying an individual's stage of change may function as a diagnostic variable for determining specific messages to be given in tailored feedback[67,71,73]. Feedback that is tailored based on both present dietary intakes and stage of change may be considered to be more motivational and may be more effective in promoting change than advice that is tailored based on dietary intakes only[73]. To date elements from a variety of behavioural models have been applied in personalising dietary advice, including goal-setting, social marketing and the transtheoretical model[62]. Evidence has shown that interventions incorporating specific behaviour change techniques, such as goal setting and use of prompts, demonstrated greater effects on fruit and vegetable intakes when compared with studies without these techniques[74]. In tandem with this concept, another important factor which could be central to the efficacy of new technology-based tools in providing personalised advice is whether individuals respond differently to varying types of feedback (content, delivery and frequency). For example, some individuals may prefer and respond greater to receiving brief feedback more frequently, whereas others may benefit more from detailed feedback sent less frequently.

Content of personalised dietary advice

Evidently a fundamental feature of any tailored feedback report is that it is personalised to the individual. Research suggests that addressing the individual's name and other recognisable personal characteristics leads to increased involvement with the feedback messages[68]. Specific feedback provided in tailored or personalised interventions is often varied. Many studies to date have included graphs to compare intakes with recommended levels; with intakes of peers of same age/sex; and to display improvements from previously attained levels[62,66,67,75]. The combination of providing an individual with personal feedback on their own fat intake along with normative feedback (ones level in relation to their peers or average national intakes) and actions for how to change their intake was previously shown to be beneficial to improve awareness of and induce changes in fat intake[67]. However, it has also been demonstrated that a combination of comparing intakes with guideline amounts and providing recommendations for improvement can help towards promoting changes in dietary behaviours[62]. Randomised controlled trials have delivered feedback advice consisting of suggestions for improvement, including top sources of problematic nutrients[62], food-based messages to help improve nutrient-intakes[3] and information relating to potential barriers to change[17]. Although the specific content of messages is important, another aspect that must be considered, particularly when feedback is delivered frequently, relates to how often message content is renewed. Previous studies have shown that feedback message content and structure need to be refreshed at regular intervals to prevent individuals becoming desensitised to feedback messages, and therefore sustain long-term changes[63,76].

Conclusion

Numerous new technology-based instruments have been established for the assessment of dietary intakes, and are presently under varying stages of development. These instruments have considerable advantages for the assessment of dietary intakes, including reduced burden to both users and researchers. Although evidence has shown several of these instruments, predominately online methods, to be reliable approaches for assessing nutrient intakes, there is a need to further examine the validity and usability of the wider variety of these instruments e.g. mobile methods and sensor technologies, across different population groups. New technology-based instruments have large potential for providing personalised nutrition advice, and improving dietary and lifestyle choices on a widespread level. Presently several randomised controlled trials have examined the use of these instruments for providing tailored or personalised advice, and demonstrated varying levels of effectiveness. Comparisons across studies would however indicate that the efficacy of utilising new technology-based dietary assessment tools to provide effective personalised advice is dependent on a number of factors, including feedback content, frequency and delivery, population group, sensitivity of the assessment instrument to changes in dietary outcomes, and the processes involved in personalising feedback. Future work should ascertain the most effective combinations of these factors in promoting sustained dietary changes across different population groups.

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Conflicts of Interest

None.

Authorship

H. F. drafted the manuscript. M. C. W., M. J. G., L. B. and E. R. G. critically evaluated the manuscript. All authors approved the final version.

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