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Symposium 1: New technologies in dietary assessment**

Measuring diet in the 21st century: use of new technologies

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The advent of the internet and smartphone technology has allowed dietary assessment to reach the 21st century! The variety of foods available on the supermarket shelf is now greater than ever before. New approaches to measuring diet may help to reduce measurement error and advance our understanding of nutritional determinants of disease. This advance provides the potential to capture detailed dietary data on large numbers of individuals without the need for costly and time-consuming manual nutrition coding. This aim of the present paper is to review the need for new technologies to measure diet with an overview of tools available. The three main areas will be addressed: (1) development of web-based tools to measure diet; (2) use of smartphone apps to self-monitor diet; (3) improving the quality of dietary assessment through development of an online library of tools. A practical example of the development of a web-based tool to assess diet myfood24 (www.myfood24.org) will be given exploring its potential, limitations and challenges. The development of a new food composition database using back-of-pack information will be described. Smartphone apps used to measure diet with a focus on obesity will be reviewed. Many apps are unreliable in terms of tracking, and most are not evaluated. Accurate and consistent measurement of diet is needed for public health and epidemiology. The choice of the most appropriate dietary assessment method tends to rely on experience. The DIET@NET partnership has developed best practice guidelines for selection of dietary assessment tools, which aim to improve the quality, consistency and comparability of dietary data. These developments provide us with a step-change in our ability to reliably characterise food and nutrient intake in population studies. The need for high-quality, validated systems will be important to fully realise the benefits of new technologies.

Diet: Nutrition assessment: Internet: Nutritional epidemiology

Why do we need new methods and what new methods are available?

Key to understand the relationship between diet and health outcomes is an accurate assessment of dietary intake[1,2]. Dietary measurement is fraught with challenges meaning that measurement error is always a potential problem[3]. Existing methods lack precision due to problems with recall and cognitive complexity. Food tables linked to dietary assessment tools are often limited or out of date and do not reflect the wide range of branded products and ready meals on our supermarket shelves. Food reflecting different cultural habits may not be available in the database or measurement tool. Underreporting is a common problem[3]. Study participants may be embarrassed to report actual intakes directly to a researcher[4]. A higher BMI is associated with increased underreporting[5]. Camera-based methods may reduce potential for embarrassment in recording for adolescents[6]. There are also no true reference methods[7] with only a limited number of recovery biomarkers, such as urinary nitrogen, potassium and sodium. Experience has shown that dietary assessment tools have often been developed in a haphazard fashion with limited validation and lack of clear guidance in terms of usability and reporting making comparison of studies in systematic reviews challenging. Reviews of studies using or validating traditional dietary assessment methods has

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shown a range of quality scores, some scoring poorly[8]. A review of paper-based dietary assessment tools used in studies exploring the relationship of prostate cancer and dietary fat found thirty-five FFQ. Of these, twenty-five (68 %) had not been validated, and eleven (30 %) did not report the nutrient database used to code the FFQ[9]. To strengthen associations between diet and disease, new and more robust methods of assessing diet are needed.

There has been dynamic growth of technology use across the world. In the UK, 88 % (45·9 million) of the adult population had used the internet in the last 3 months[10]. Smartphone take up has grown rapidly, 93 % of the UK population owns a mobile phone, with 76 % owning a smartphone[11]. The average UK adult now spends more time engaged in media or communications activity (8 h 41 min/d) than sleeping (8 h 21 min/d)[12]. Self-monitoring of diet using new technologies is now a practical alternative to paper-based systems.

New technologies can be broadly categorised according to the type of technology being used: online tools (web-based); mobile systems (apps); camera-based tools; and ‘other’ which includes consumer data and wearable sensors (Table 1). Depending on the system the tools require more or less input from the user. On the whole, users prefer the new technology approach to the traditional interviewer or paper-based systems[6,13–16]. However, this may depend on technology readiness and experience with online systems[1,16]. The present paper will focus on the first two categories: web-based and mobile phone systems.

Table 1. Types of new technology for dietary assessment

Technology category	Types	References
Web-based, computer	• Web based 24 h recall/diary/FFQ (e.g. ASA24, myfood24) • Non-web-based	(1,22)
Mobile phone	• Self-monitoring apps (My Meal Mate; My Fitness Pal etc.) • Tweets – geo location	(37,38)
Camera	• Non-automated cameras • Automated cameras (e.g. SenseCam, DietCam)	(43)
Others	• Consumer data (‘big’ data) • Bar code scanner • Wearable sensors (chewing, swallowing)	(44)

Development of web-based tools to measure diet

Online dietary assessment tools have used similar approaches to standard methods and include FFQ[17–19], 24 h recalls[20–22] and dietary records[1,23]. Some tools are a hybrid method such as the Oxford WebQ, which is presented as a 24 h recall but relies on reporting of twenty-one food groups[24] over a 24 h period.

The development of tools using new technologies requires special considerations relating to website creation. Visual design is important, providing a balance between graphics, text and white space. The effort required by the user should be minimised by simplifying the interaction required reducing the need for instructions. A consistent look and navigation style is needed with a clear indication of what is clickable. Pull-down menus should be avoided since they prevent users from seeing all the choices prior to taking action. As an example, the development of myfood24 required a number of stages, including focus groups with different age participants; development and testing of a β-version of the website; usability testing followed by the launch of the live myfood24 and ongoing studies[1]. Screenshots from some example tools are shown in Fig. 1, contrasting the food frequency approach of the Oxford WebQ[24], the multiple-pass approach required by ASA24[22], and the search strategy focused screen of myfood24[1].

Most systems are likely to have three main components: an administrator area; a researcher area; a participant area. In myfood24, the researcher area allows for customisation, including project-specific text and logos; tailored invitation and reminder emails; set recall/diary/interview options; export food and nutrient analysis. The participant area includes the search function; portion size selection area; recipe builder; help; review and submit screens[1]. Data security and ethical issues around who has access to which type of information, should be clear to protect users. New technology presents opportunities to improve on manual systems. Particular attention should be paid to searching the food list to ensure that users can find foods they consumed. Some systems use food categories to aid searching. Brand names and misspellings should be included. Where food tables are limited, the closest food match needs to be selected. Automated prompts for potentially forgotten items can be programmed as well as suggestions for ‘commonly consumed with’ items. The search function in myfood24 presents users with generic items first, followed by branded items in alphabetical order, to speed up food selection.

The completeness of the food composition tables attached at the back end of the tools is vital. According to the Food Marketing Institute, there were about 42 000 items carried in an average supermarket in 2014, with the majority being food items. In the UK, the standard food composition tables only includes about 3500 items, clearly well below the numbers of foods available[25]. This limits the potential for study participants to select foods, which have been consumed, increasing the likelihood of measurement error. We have developed a new approach to developing food composition tables, by mapping back of pack nutrient information from over 40 000 branded UK food products to generic food items in order to fill in missing nutrient information[26]. This provides a larger range of food items for the user while ensuring that all nutrients are available for analysis. The new food table has been included in the myfood24 tool to provide a greater choice of foods for study participant selection. The challenge presented by this approach is maintaining an up-to-date database with relevant portion sizes since product reformulation

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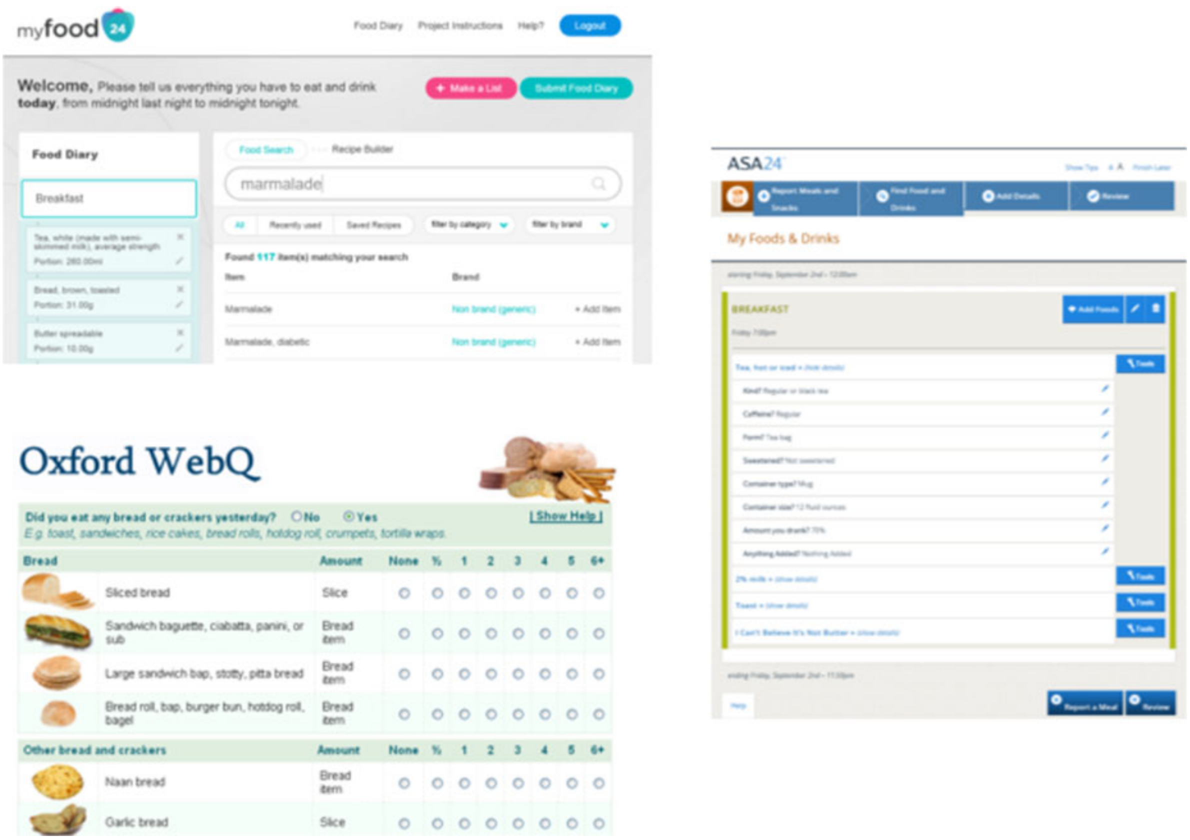

Fig. 1. (Colour online). Screenshots from example web-based tools.

will influence values. However, by making use of product nutrient labels it is possible to maintain a more current database than can be represented by the standard food tables. Other online tools have more limited food tables, for example, INTAKE24 uses a database of about 1560 foods from the National Diet and Nutrition Survey nutrient databank, which is linked to the UK generic food tables[21]; Food4Me only asks about 157 foods[17]; Diet Day for the USA has 9349 food items[27].

New technologies can support portion size assessment, which is often a challenge in dietary assessment. Many FFQ simply assume standard portions while 24 h recall methods with interviewers may use household measures or books of photos. Online systems can include multiple options for portion selection to support the user. These can include standard pack or unit sizes; average portion sizes; food photographs; or entry of actual weights. Choices available may depend upon the food selected, so that tools may have varying presentations of portion selection depending upon the food selected. Food photographs with multiple portion sizes are particularly useful for foods without a standard portion size and are an important element in myfood24[1], INTAKE24[21], DietDay[28], ASA24[22], Food4Me[17] and NutriNet Sante[29]. The Oxford WebQ uses standard categories of amounts of foods, with portion sizes described as a serving. Details of serving sizes for foods without a natural portion are given in the help section. Participants are expected to adjust their reporting of amounts in relation to the standard serving[24]. There is limited knowledge regarding the accuracy of self-reported portion sizes in fully automated systems[30]. Links with photographic systems such as the eButton may provide more accurate estimates of food volume[31].

Consideration of the potential technology readiness of the user is important. Adolescents and young adults particularly find new technologies attractive and easy to use[20,21]. However, older adults may struggle if not familiar with computer technology. Touch screen systems, such as Novel Assessment of Nutrition and Ageing, may be helpful for people with no prior computer experience since they can be used without a mouse or keyboard[32] although, that particular system needs further automation.

Response rate is also an issue. Although, in general, once individuals have used a web-based tool to record their diet they find the approach highly acceptable; however, researchers should not expect response rates to be higher than with other methods. In a test of repeated invitations to complete the Oxford WebQ, 53 % of those invited completed the online version at least once; 66 % completed it more than once but only 16 % completed it on the requested four occasions[33]. It is important to build in specific contact from researchers to participants explaining the need to complete the tool and not just expect a response to a link in an email or other online questionnaire.

Ideally, we would like to know whether these new tools perform as well or better than standard tools, in

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comparison with independent biomarkers. To date, few tools have undergone this rigorous evaluation. The DietDay 24 h recall was compared with the doubly labelled water method in 233 adults to estimate total energy intake; the difference in means was 974 kJ/d (233 kcal/d) with DietDay providing lower intakes[28]. The other tool, a web-based food record, which has been compared with doubly labelled water in nine women also showed a lower-energy intake of 1535 kJ/d (367 kcal/d)[34]. Some tools have been compared with alternative self-reporting methods using paper/pencil-type recording. A selection of some online tools, which have had energy intake from a comparison method for relative or actual validity assessed are presented in Table 2. In general, agreement between web-based tools and standard methods are close, although often comparisons have used the same underlying food databases for the same day of recording, ensuring that agreement is likely to be high.

Use of smartphone apps to self-monitor diet

There is a growing interest in use of smartphones to deliver nutrition interventions and to collect data on intakes. Web-based tools described earlier may be optimised for use on mobile phones; alternatively, other apps are downloadable onto the phone and do not require internet access to operate. With such ubiquitous access to the internet and smartphones, self-monitoring of diet using a mobile phone has become a real option for many people.

Many apps which purport to allow dietary self-monitoring have been developed. However, there are few evaluations of the quality and reliability of these apps with regard to dietary assessment[35]. Apps are often linked to supporting weight loss, similarly to web-based tools the ability to self-monitor and provide a tailored experience is attractive. In addition, portability of phones with availability to the user regardless of location or setting are further advantages. This may give a greater potential for behaviour change interventions through real-time feedback. One review of 204 weight loss apps found that only 43 % of the apps recommended or provided a tool for keeping a food diary and only 12 % allowed tracking of fruit and vegetable intakes[36]. A review of 800-rated Health & Fitness category apps from free and paid sections of Google Play and iTunes App Store in Australia found only fifty-five which met the inclusion criteria of focussing on weight management with a facility to record diet and be in English. Of these, twenty-eight were reviewed in detail with others excluded due to duplication, lack of tracking or not being stand alone[35]. A 3-d food diary was entered into each app, twenty-three apps provided outputs, which could be compared with the food diary. The mean absolute energy difference when compared against the food diary was 127 kJ (95 % CI −45, 299) and mean percentage energy difference was 1·9 % (95 % CI −0·5, 4·4). This small difference hides some larger differences for individual apps, Calorie Counter by FatSecret and Points Calculator & Weekly Weight Loss had the greatest discrepancy in reported energy intake values, with 1001 kJ (14 %) greater- and 700 kJ (10 %) lower-energy differences, respectively.

These apps often have limited evidence informed content, potentially reducing their effectiveness. One app, MyMealMate, which was developed using an evidence-based behavioural approach, and incorporates goal setting, self-monitoring of diet and activity and feedback was shown to lead to greater weight loss in a randomised controlled trial than self-monitoring of diet by website or pencil and paper[37]. However, use of a leading US app, MyFitnessPal, did not result in greater weight loss than usual care in a randomised controlled trial, although use of the app dropped sharply after the first month and 14 % of the control group had also downloaded and used the app[38].

In addition to dietary self-monitoring apps, other diet related interventions are being delivered by app. These include the FoodSwitch and SaltSwitch apps, which enable users to scan the barcode of packaged foods and receive an immediate interpretive, traffic light nutrition label on screen, along with a list of alternative healthier lower-salt alternatives[39]. For these apps, barcode scanning technology was identified as the optimal mechanism for interaction of the mobile phone with the food database[40].

Improving the quality of dietary assessment

Researchers who wish to measure diet should not expect new technologies to solve all of the challenges of dietary assessment. Dietary measurement is complex, and accurate and consistent measurement methods are needed. To support researchers in the selection of the most appropriate dietary assessment tool for their needs, the DIET@NET partnership has generated expert consensus from a Delphi process on Best Practice Guidelines for dietary assessment in health research[41]. The guidelines include four stages with eight questions for researchers to consider. (1) Define what you want to measure: what? who? when?; (2) Investigate the different dietary assessment tools and their suitability; (3) Evaluate existing tools to fine tune choice of dietary assessment tool; (4) Think through implementation of the chosen dietary assessment tool. The Best Practice Guidelines will be made available on the Nutritools website. These guidelines will be for researchers to use at the start of a project and will complement the new STROBE-nut guidelines, which is an extension of the STROBE statement on strengthening the reporting of observational studies in epidemiology[42].

The DIET@NET project is a partnership across eight UK Universities and research organisations. It aims to improve quality and comparability of dietary data. It will do this by providing access to valid tools measuring food and nutrient intakes with data entry and analysis. Creating a web-based version of tools, which were originally paper and pencil where necessary. In addition, the website will host a food questionnaire creator allowing researchers to

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Table 2. Comparison of online dietary assessment tools with standard tools or biomarker

On-line tool	Features	Comparison	Results	Difference in kJ (kcal) new tool *v.* comparison	Ref
ASA24	24 h recall with online dynamic user interface. Meal-based quick list. Food search; meal gap; detail pass; prompts	True intake and plate waste from three meals forty-two women	Mean intake 8112 kJ (1939 kcal) Difference: *v.* small	−2 kJ (−0·5 kcal) 95 % CI 987, −992 kJ; 236, −237 kcal	[22]
DHQ	Web-based pictorial diet history questionnaire. 124 items. Frequency over past year and amount assessed	2 × 24 h recalls 213 computer literate adults	Mean intake 7351 kJ (1757 kcal) Difference: web-DHQ lower	−803 kJ (−193 kcal)	[45]
DietDay	Multipass recall. 9349 foods, 7000 images	Doubly labelled water 233 adults	Mean intake 9296 kJ (2222 kcal) Difference: DietDay lower	−974 kJ (−233 kcal)	[28]
FFQ	Web-FFQ. 136 questions with picture portion options	3 d food record Sixty-nine adults	Mean intake 9472 (SD 2973) kJ (2264 (SD 702) kcal) Difference: web-FFQ higher	+83 kJ (+20 kcal)	[19]
Food4Me	Web-FFQ, based on EPIC Norfolk FFQ. 157 foods, for seven EU countries. Frequencies & portion pictures	EPIC Norfolk FFQ 113 adults	Mean intake 9857 (SD 3384) kJ (2356 (SD 809) kcal) Difference: Food4Me higher	+2828 kJ (+676 kcal)	[17]
Food Record	Web-based, 9 d record requiring 30 min training session	Doubly labelled water Nine overweight/obese University staff or students	Mean intake 8351 (SD 1225) kJ (1996 (SD 293) kcal) Difference: food record lower	−2301 (SD 1535) kJ (550 (SD 367) kcal)	[34]
INTAKE24	Multipass recall for 11–24 years old. National Diet and Nutrition Survey nutrient databank with 3000 photographs	Interviewer led MPR for the same day × 4 d 52 × 11–16 year olds 116 × 7–24 year olds	Mean intake 6677 kJ (1596 kcal) (11–16 years) 7409 kJ (1771 kcal) (17–24 years) Difference INTAKE24 lower	−142 kJ (−34 kcal) (11–16 years) −108 kJ (−26 kcal) (17–24 years)	[21]
myfood24	Multipass recall designed for adolescents, adults, elderly. 45 000 foods including brand named. 5669 food images	Interviewer led MPR 75 × 11–18 year olds	Mean intake 8368 (SD 3874) kJ (2000 (SD 926) kcal) Difference myfood24 lower	−230 kJ (−55 kcal), 95 % CI 7, −117	[20]
NANA	Touch screen system aimed at elderly. Does not automatically code selected items. This is done later by a nutritionist	4 d food diary forty adults, mean age 72 years	Mean intake 8238 (SD 1380) kJ (1696 (SD 330) kcal) Difference NANA lower	−251 kJ, 95 % CI −1711, 1213 (−60 kcal, 95 % CI −409, 290	[32]
NutriNet-Sante	Web-based 24 h diet record. Food portion pictures for 250 foods	Interviewer led 24 h recall 60 × men 87 × women	Mean intake 8857 (SD 2586) k J (2117 (SD 618) kcal) (men) 7213 (SD 2468) kJ (1724 (SD 590) kcal) (women)	−142 kJ (−34 kcal) (men) +20.92 kJ (+5 kcal) (women)	[16]
Oxford WebQ	Web-based questionnaire. Twenty-one food groups with detail screens. Standard portion categories	Interviewer led MPR for same day as Oxford WebQ 116 adults	Mean intake 8711 (SD 589) kJ (2082 (SD 589) kcal)	+12 kJ (+3 kcal)	[24]

MPR, multiple pass recall.

create their own FFQ from scratch if nothing suitable which has already been validated is available. This resource will add to existing dietary assessment tool libraries such as the National Collaborative on Childhood Obesity Research, the Australasian Child and Adolescent Obesity Research Network, the National Cancer Institute Dietary Assessment Calibration/Validation Register and the Diet and Physical Activity Measurement toolkit. These websites generally provide access to information on validation studies, which have used dietary assessment tools and ACAORN also has a database of tool names with contact details. Diet and Physical Activity Measurement provides basic concepts on measuring diet with advice on selecting a method. None of them host tools for use directly. DIET@NET will provide access to validated dietary assessment tools for use through the nutritools website, which has not previously been widely available.

Conclusion

New technologies provide great opportunities for nutritionists to measure in detail food and nutrient intakes from large populations at relatively low cost and in real time. Challenges still exist, including the accuracy and range of nutrients reported; the size and scope of the food composition tables underlying the tool; portion size estimation; searchability of the database; and technology readiness of the user. Online tools and apps are becoming more widely available; care needs to be taken to ensure evidence-based and validated tools are used.

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Conflicts of Interest

The University of Leeds is currently developing a spin-out company to support ongoing sustainability of myfood24.

Authorship

The author was solely responsible for all aspects of preparation of this paper.

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