Flinders UNIVERSITY

Characteristics of smartphone applications for nutrition improvement in community settings: a scoping review.[1]

Emma Tonkin, BND(Hons), Emma.Tonkin@menzies.edu.au [1,2]

Julie Brimblecombe, PhD, Julie.Brimblecombe@menzies.edu.au [2]

Thomas Philip Wycherley, PhD, Tom.Wycherley@unisa.edu.au [1,2]

[1] *Centre for Population Health Research, School of Health Sciences, University of South Australia, Adelaide, South Australia, Australia, 5000*

[2] *Nutrition Program, Wellbeing and Preventable Chronic Disease, Menzies School of Health Research, Casuarina, Northern Territory, Australia, 0810*

Corresponding author

Emma Tonkin

Nutrition Program

PO Box 41096

Casuarina, Northern Territory

Australia 0811

Phone: +61 8 8946 8514

Fax: +61 8 8946 8464

emma.tonkin@menzies.edu.au

Word count: 6461 words

[1] Supplemental Tables 1-4 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://advances.nutrition.org.

Number of figures: 1

Number of tables: 4

Running title: Apps for nutrition improvement in community settings

Funding: National Health and Medical Research Council project grant (631947); project titled 'Improving Chronic Disease outcomes for Indigenous Australians: Causes, Interventions, System Change'. JB was supported by a National Heart Foundation Future Leader Fellowship (100085). TW was supported by a National Health and Medical Research Council Early Career Fellowship (1053359). The information and opinions contained in this paper do not necessarily reflect the views or policy of the National Health and Medical Research Council or the National Heart Foundation.

Conflict of interest and funding disclosure: All authors declare no conflicts of interest.

Characteristics of smartphone applications for nutrition improvement in community settings: a scoping review.[2]

Abstract

Smartphone applications (apps) are increasingly being used to support nutrition improvement in community settings. However there is a scarcity of practical literature to support researchers and practitioners in choosing or developing health apps. This work maps the features, key content, theoretical approaches, and methods of consumer testing of apps intended for nutrition improvement in community settings. A systematic scoping review methodology was used to map published, peer-reviewed literature reporting on apps with a specific nutrition improvement focus intended for use in the community setting. After screening, articles were grouped into four categories: dietary-self monitoring trials, nutrition improvement trials, app description papers and qualitative app development studies. For mapping, studies were also grouped into categories based on the target population and aim of the app/program. Of the 4818 titles identified from the database search, 64 papers were included. The broad categories of features found to be included in apps generally corresponded to different behavior change support strategies common to many classical behavioral change models. Key content of apps generally focused on food composition, with tailored feedback most commonly used to deliver educational content. Consumer testing prior to app deployment was reported in just over half of the studies. Collaboration between practitioners and app developers promotes an appropriate balance of evidence based content and functionality. This work provides a unique resource for program development teams and practitioners seeking to use an app for nutrition improvement in community settings.

[2] Supplemental Tables 1-4 are available from the "Online Supporting Material" link in the online posting of the article and from the same link in the online table of contents at http://advances.nutrition.org.

Keywords: Behavior change; diet; features; health promotion; mHealth; mobile apps; public health

Introduction

The importance of improving nutritional intake to address the global burden of preventable non-communicable disease is well known (1). Nutrition improvement is here defined as any attempt to guide an individual's diet towards semblance with national healthy eating guidelines. The contributors to poor dietary intake extend from individual level factors through to social, physical and macro-level environmental factors (2). Public health nutrition improvement programs in community settings (i.e. for individuals living independently within a community) are often used to intervene at these different levels. However, such programs must overcome a number of unique challenges: large numbers of people must typically be reached to achieve a population benefit, thus less intensive health personnel involvement is essential to balance finite resources; often the populations with the greatest need are geographically dispersed and hard to reach; due to interventions typically being disseminated across socio-demographic groups, tailoring of information to best support behavior change may be difficult. More recently there has been a growing interest in the use of mobile health, in particular the use of smartphone software applications (hereafter apps) (3), to support nutrition improvement in community settings and overcome these unique challenges (4,5).

Mobile phone ownership is prevalent and continues to increase, in both developed and less developed nations, and across all socioeconomic groups (6,7). Smartphones are now ubiquitous and increasingly intertwined with daily life, (4,8) primarily owing to rapid advances in the capabilities of apps (8). Fostering sustained user engagement with apps is however a constant battle for app developers, and therefore in the context of apps for health behavior change, improvements can be short-lived (3,4,9). Hingle and Patrick (4) propose that an appropriate benchmark for heath-app success might not be frequency or consistency of use, but rather that the app characteristics (that is, app features and content) provide such an engaging user-experience that users return to using the app when it is most needed during the iterative process of nutrition improvement. However, guidelines regarding how to achieve this are lacking (9).

An overabundance of apps combined with a lack of scientific evaluation of them inhibits researchers and practitioners from determining the best approaches for choosing or developing health apps (4). In particular there is limited information regarding the best app characteristics for disadvantaged populations (5). There have been a number of early systematic reviews that examine the efficacy of health-app interventions, however these either focus on weight loss rather than nutrition improvement (10-14), exclude qualitative and descriptive studies (15,16) and/or include text messaging and web-based interventions (10,12,13,16-18), with none specifically relating to community settings. Similarly, scoping reviews on the topic exclusively focus on weight loss (19), include text messaging interventions (8,20) and have mapped the literature, rather than app characteristics. App content reviews examine features, content and incorporation of behavioral change theory in commercially available apps, but not apps that have been developed or used specifically for nutrition improvement programs (21-29). As such, a map of app characteristics and consumer evaluation of them, particularly incorporating a comparison of different population groups, will be an informative guide for future app development projects and practitioners seeking to choose appropriate apps for use in community settings.

Scoping reviews are well placed to examine research questions that go beyond intervention effectiveness (30), typically used to map the parameters of a particular body of knowledge (31). They are distinct from systematic reviews in that rather than seeking to answer a specific research question through examination of the outcomes and quality of a narrow selection of studies, scoping reviews explore how a topic has been studied or approached (32). This information is particularly useful in new and rapidly developing research areas where there has been a proliferation of ideas and approaches, and the evidence is complex and heterogeneous (30,33), as is the case with the topic under investigation here. This work used a systematic scoping review methodology to examine and map the characteristics of smartphone applications intended for nutrition improvement in community settings. The sub-objectives were

1. To identify the features, key educational content and strategic approach/behavioral change theory utilized in smartphone apps to improve nutrition in community settings
2. To report any information relating to user evaluation of these characteristics
3. To map the methods used in consumer testing of these apps.

This work provides a unique resource for program development teams and practitioners seeking to use an app for nutrition improvement in community settings. We present an overview of the methods used for the systematic search and review process, describe the studies that were identified and how their findings relate to each of the above sub-objectives, and discuss the key implications for app development teams, practitioners and researchers.

Methods

A scoping review was conducted consistent with the methods described by Arksey and O'Malley (32) and further elaborated by Levac et al. (30) and the Joanna Briggs Institute (JBI) (33). The research question addressed by the search was '*what features, key content, strategic and theoretical approaches, and methods of consumer testing have been used in smart phone applications intended for nutrition improvement in community settings?*' Detailed inclusion and exclusion criteria are listed in **Table 1**. Briefly, any published, peer-reviewed literature reporting on a smartphone app with a specific nutrition improvement focus intended for use in the community setting was considered for inclusion. Reviews and commercial app content analyses were however excluded. Smartphones were defined in line with others (34,35) and thus excluded Personal Digital Assistants (PDAs). However, reports not specifying the use of either a smartphone or PDA, generically using 'mobile phone' or 'mobile app', were included.

Search method

The three stage approach to searching for scoping reviews as outlined by the JBI was used (33). First stage limited searches to define keywords were conducted in Medline Ovid and ACM Digital Library. Second stage full computerised searches were conducted in nine databases (listed in **Figure 1**) up until

9th May 2016. Two concepts were used to structure search queries including smartphone apps (example keywords “mobile apps”, “mobile applications”, “smartphone”, “cell phone” and “mHealth”) and nutrition improvement (example keywords “nutrition”, “diet, food and nutrition”, “eating”, “food habits”, “health promotion”, “public health”). Search terms were comprehensive and broad to achieve high sensitivity as outlined in scoping review protocols (30,32,33). Database-specific terms (for example MeSH terms) were used where relevant, complemented by keyword searching of the concept terms and synonyms. Pearling strategies (using attributes of relevant articles to develop the search query in a recursive process) were used on retrieved articles to ensure all relevant studies were included. Third stage searching involved searching reference lists of retrieved articles and review articles for further reports (33). Searches were limited to the years 2008-current as the Apple App Store was initially released in July 2008 (Google Play 2012), and English language only due to practical constraints.

Data Extraction

Citations were exported to Endnote (Thomson Reuters, USA) for organization. Duplicates were removed and titles and abstracts screened for consistency with inclusion criteria in first pass-screening. Full text reports were retrieved and screened for inclusion by one reviewer (ET), with ambiguous reports being sent to two other authors (JB, TW) for a consensus decision. Articles were initially grouped according to report type: reports of controlled trials and other papers. These categories were further subdivided into the following four groups (hereafter referred to as study types) for data extraction:

1. Controlled dietary self-monitoring trials (no nutrition education provided in app)
2. Controlled nutrition improvement trials (nutrition content/education provided in app)
3. App description papers (with/without uncontrolled consumer usability testing)
4. Qualitative studies informing app development with consumer groups

Relevant data for each study type were extracted into summary tables by one reviewer (ET) (**Supplemental Tables 1-4**). Data extraction was structured around the review sub-objectives. Only a brief summary of results relating to study outcomes (for example weight loss) are reported in summary tables as many included studies were multi-component and therefore identifying the sole contribution of apps to these outcomes is impossible (5). Results relating to the evaluation of app characteristics were extracted. As this is a scoping review the risk of bias in studies, heterogeneity, and publication bias were not assessed (30,32,33).

Multiple reports of the same trials or projects were grouped. Articles from the same or similar research group reporting on app development and then controlled testing (for example (36,37)) were grouped within the relevant controlled trials study type (1 or 2 above). For mapping, studies were also grouped into categories based on the target population and aim of the app/program.

Results

Overview

The results of the search and screening processes are presented in Figure 1. Of the 4818 titles identified from the database search, 64 papers were included: nine reporting dietary self-monitoring trials (38-46), 18 reporting nutrition improvement trials (36,47-63), 30 reporting app development projects (37,64-92), and seven reporting qualitative studies with consumers (93-99). Five reports were published in 2016, 16 each in 2015 and 2014, 11 in 2013, and 16 between 2008 and 2012. Once organized according to our study types, these papers reported on seven controlled dietary self-monitoring trials, 13 controlled nutrition improvement trials, 21 discreet app development projects, and six qualitative studies with consumers (Supplemental Tables 1-4) (47 studies). Fifteen studies targeted the general adult population, 15 overweight/obese populations, eight young adults, six parents and low socioeconomic status (SES) families and three adolescents. Twenty-four studies aimed at general nutrition improvement, 11 weight loss, five grocery shopping support, four food access support and three parenting support. Five of the apps described were commercial apps

(*LoseIt!, FatSecret's Calorie Counter* and *The Eatery*) (38,40,41,43,78), while the remainder were developed by research teams (hereafter 'made to order'). Twenty-three studies were conducted in the United States, eight in Australia, six in the United Kingdom, two in Norway, and one each in Austria, Canada, Finland, Korea, Malaysia, the Netherlands, New Zealand and Portugal.

The following sections report the findings for each of the review sub-objectives. The reports of app characteristics (features, nutrition content and strategic approach/theory) are structured as follows: description of characteristic, characteristic mapped by study type, target population and aim of app/program, and finally relevant consumer evaluation data. A report of the approaches to consumer testing and a summary checklist for app development projects concludes the results section.

App features

All seven dietary self-monitoring trials (38-44), 13 nutrition improvement trials (36,47,48,50-53,56-58,60,62,63), 21 discreet app development projects (64,65,68,70,72-80,83,85,86,88-92), and six qualitative app development studies included apps with, or a discussion of, nutrition relevant features (93,95-99). **Table 2** demonstrates the great diversity in the app features used, and lists all features found within the reports. The broad types of features used in apps (hereafter referred to as feature domains) were dietary logging/tracking (for example detailed dietary diaries), social connectivity (the incorporation of social interaction, for example connecting with social networks, team participation and forums), reminder, encouragement and prompt (for example push notifications and rewards), goal setting and challenge (for example dietary goal setting), game element (the use of games or game-type features, for example use of avatars, narrative gaming and quizzes), environmental support (for example food/menu suggestions and locating local produce), and app development features like multiple interfaces (different app presentations and functions depending on the user) and crowdsourcing (for example the collection of data such as food product information from app users).

Food logging, either detailed meal entry or simple food group logging, was the most frequently incorporated feature, used in just over half of the studies (24/47). Push notifications (messages sent to

the user through the app), customizable and non-customizable, were the second most common feature (used in 20/47 studies) and were often used to prompt food logging. Other common features were automated graphical reports (graphs/images of food intake) based on food logging (17/47), real-time calorie/nutrient tracking (10/47), dietary goal setting (9/47), barcode scanning (9/47), and the ability to connect with social networking sites (8/47).

Study type

Table 2 demonstrates that different feature domains were emphasised between study types. No dietary self-monitoring trials, and only four nutrition improvement trials, used apps incorporating environmental support features, while these were frequently emphasised in app development projects (12/21). Conversely, social connectivity features were emphasised in dietary self-monitoring trials and not commonly found in nutrition improvement trials or app development projects. There were no major differences in the main feature domains used between single- and multi-component trials (self-monitoring or nutrition improvement), except that reminders, encouragement and prompts were more likely to be features incorporated into apps used in multi-component interventions, particularly in nutrition improvement trials.

Target population

The feature domains used in apps varied by target population. Game elements were incorporated into apps targeted towards low SES families (5/6) and young adults (4/8) more commonly than overweight/obese (3/15) or general adult (2/15) populations. The type of game also differed, with narrative style gaming with points only used in adolescent or low SES populations, and quiz type games used in adult populations. Environmental support features were more common in apps for low SES (5/6), general (8/15), and young adult (4/8) populations compared with adolescent (0/3) and overweight/obese (2/15) populations. The remaining feature domains were used with similar frequency across target populations. Apps targeted towards low SES families generally had the greatest variety of feature domains used, with those for adolescent populations the least.

Aim of app/program

The feature domains emphasised in apps also varied by app/program aim. Apps used in programs to support general nutrition improvement or weight loss commonly used dietary logging and tracking features (20/24 and 10/11 respectively), while these features were not as commonly utilized in apps aimed at supporting grocery shopping (1/5) and food access (1/4). Conversely, all apps supporting grocery shopping, food access and parenting practices used environmental support features (5/5, 4/4, and 3/3 respectively), while these features were less commonly found in general nutritional improvement (5/24) and weight loss apps (2/11). As apps to support grocery shopping and food access had very specific aims they typically had the least variety in feature domains incorporated, while apps to support parenting and general nutrition improvement typically incorporated the greatest variety of domains.

Evaluation of features

Results relating to consumers' evaluation of app features were found to be predominantly concerning app function, interface (app presentation) and tailoring, and food logging, games and social connectivity.

App function, interface, and tailoring

Interactive features, an attractive user interface and non-repetitive images and colors were particularly important to low SES and young adult populations for maintaining app engagement (73,74,77,95,98). Separate interfaces for carers and children were valued by carers but not children (50,77). The importance of the app being functional without an internet connection was expressed by all population groups (36,40,45,68,90,95,98), with data access particularly limited for adolescents (40). Excessive data entry for setup, and logins, were reportedly undesirable (36,93,98,99). Crowdsourcing data from users was useful for providing a comprehensive back-end food database (53,58), and tailoring feedback on meal healthiness (62). Within nutrition improvement trials it was found that

staggered deployment of features (rolling out new features over time) helped maintain participant engagement with the app (52).

Tailoring and personalisation of the app and its features were considered important or desirable across all population groups. While push notifications were valued, considering their timing was important, with user customization ideal (56,65,74), especially for adolescents (57). Personalised settings and the ability to turn off features was considered important across population groups (74,90,93). Personalisation of goals and challenges, and feedback based on these, were considered important by overweight and general adult populations (39,41,74,80,88). Similarly, using culturally relevant and favorite foods within games was desirable for low SES populations (50,79,89), and enabled transfer of learning to real life (85). Finally, information about local and seasonal foods was highly valued, while recipe suggestions were not (65).

Food logging, games, and social connectivity

Achieving a balance of simplicity and detail in food logging was important for all populations, with manual entry considered boring and burdensome (51,56,90,93,97). Auto-complete functions (41,93,98), crowdsourcing based semi-automated approaches (51), barcode scanners and drop-down menus (51,56), and comprehensive (exact products/brands) databases improved logging (93,98). Additionally, reports of progress based on logging commenting on overall diet quality, rather than just calorie tracking, were highly valued (38,43,93,95,97-99). Narrative game-style apps (typically games with a character and storyline) were more appealing to adolescents than adults and emotional and social realism were important for motivation (50,62,77,85,89). Adults and overweight populations generally valued quiz-style games if they were quick to play and included incentives like real rewards (70,74,85). Competition, team participation, and social interaction motivated engagement with apps across all population groups (48,50,77,78,80,90,99), but negative scoring of points was not well understood by low SES populations (77). Young adults in particular emphasised that social networking/sharing must be voluntary and not automatic (65,93,98,99).

Nutrition content

No dietary self-monitoring trials, all 13 nutrition improvement trials (36,47,48,50-53,56-58,60,62,63), all 21 discreet app development projects (64,65,68,70,72-80,83,85,86,88-92) and four of the six qualitative app development studies included apps with, or a discussion of, educational nutrition content to be delivered via an app (93,95,97,98). **Table 3** lists all the nutrition content areas targeted in the apps described in the reports, and the ways in which this information was delivered. The broad nutrition content delivered by apps covered food composition (targeted in 32/38 studies), diet-health links (13/38) and feeding practices (5/38). The broad education delivery strategies were feedback on activity (22/38), general information (5/38), nutrition tools (6/38) and environmental supports (11/38).

Study type

General healthy eating and diet-health links were the only content areas to be targeted across all study types. All nutrition improvement trials provided content about food composition (13/13), but single component trials were more likely to combine this with education about feeding practices (2/7), while multicomponent trials added diet-health link information (2/6). Education about diet-health links was more commonly provided in app development projects (9/21) and qualitative studies (2/4) compared with nutrition improvement trials (2/13).

The provision of tailored feedback about food logging or barcode scanning in the form of healthiness ratings (traffic light or star ratings), tips or personalised strategies, and links to additional information were the only content delivery strategies to be used across all study types. Tailored feedback was the delivery strategy most used across all study types, but was less commonly used in app development projects (9/21), compared with nutrition improvement trials (9/13) and qualitative studies (4/4).

Target population

The nutrition content areas addressed by apps varied little depending on the target population. However, apps targeted towards adolescents and young adults were more likely to incorporate diet-

health link education (1/2 and 5/7 respectively) compared with those targeted towards overweight (2/10) or low SES (1/6) populations.

Similarly, the education delivery strategies used did not substantially vary between different target populations. Feedback was used slightly more frequently in apps for overweight (8/10) compared to general adult populations (6/13), while environmental support strategies were more common in apps targeted towards low SES (3/6) and general adult (7/13) populations compared to overweight (0/10) and young adult (1/7) populations.

Aim of app/program

There was some variation in the nutrition content areas addressed between studies with different aims. In addition to food composition education, apps supporting general nutrition improvement, grocery shopping and food access more commonly included diet-health link education (8/20, 2/5 and 2/4 respectively), compared with apps supporting weight loss (1/6) or parenting practices (0/3). Similarly, apps supporting general nutrition improvement and food access were the only types to provide education regarding feeding practices (4/20 and 1/4 respectively).

Due to their specific aims, apps supporting grocery shopping and food access most commonly delivered nutrition content through environmental supports (5/5 and 2/4 respectively) and less so through feedback (2/5 and 1/4 respectively). Conversely, general nutrition improvement and weight loss apps relied more heavily on feedback strategies (12/20 and 5/6 respectively) compared to nutrition tools (4/20 and 1/6 respectively) or environmental supports (2/20 and 0/6 respectively).

Evaluation of content

Few reports described any consumer evaluation of the nutrition content delivered by apps. The evaluation that was reported pertained only to content tailoring and presentation. The tailoring of educational information and environmental supports, like food product recommendations, to match the nutritional needs of sub-populations (age/life-stage/SES/cultural heritage/disease status) was considered important for general (51) and young adult populations (95,97). Regarding tailored

feedback, both positive and negative reinforcement were considered motivating by overweight (90) and young adult populations (99), although young adults were clear this should not feel like 'telling off' (93). A user-friendly and age-appropriate presentation of content was important for adolescent and young adult populations (57,76), with star representations of healthfulness reportedly appealing to adults, and traffic-lights to adolescents (77). Images of portion sizing and rating the relative healthiness of meal options helped with nutrition knowledge development for young adults (76) and low SES populations (79). Finally, young adults also reported that information presented must be branded by a credible source (93,95).

Strategic approach/behavioral change theory

An explicit discussion of the strategic approach underpinning app development, in addition to a description of findings from existing literature, was provided in two of the seven dietary self-monitoring trials (42,44), nine of the 13 nutrition improvement trials (36,48,50-52,56,57,60,62), 15 of the 21 app development projects (65,68,70,72-74,77,79,80,85,86,88-90,92), and was mentioned in four of the six qualitative app development studies (93,95,96,98). Multiple strategies were used in one self-monitoring trial (42), five nutrition improvement trials (48,50-52,57), and six development projects (65,74,77,86,88,89).

Study Type

The most common strategic approach involved use of behavior change theory in app development, generally through the use of classical behavioral change models. The most commonly used models were used across both nutrition improvement trials and app description papers. These were Social Cognitive Theory which informed the development of seven apps (50-52,57,74,77,89), the Transtheoretical model (36,52,79) and Self-determination theory (57,74,89) both informing three apps, and Transportation theory (50,77) and the Health Action Process Approach (56,60), both informing the development of two apps. Additional models reported in nutrition improvement trials and app development projects were Control Systems Theory (44), Fogg's behavioral model (51,62),

the Behavior Change Wheel (72,86), the Health Belief Model (74,77), the Theory of Planned Behavior (48), the Elaboration Likelihood Model (77) and the Precaution Adoption Process Model (77).

Additionally, some app development projects and qualitative studies were not informed by a specific model, but were guided by the general principles of broader theoretical content areas. These included principles from goal setting theory (48), ecological momentary intervention (48), behavioral self-management (52), learning theory (51), motivational enhancement approaches (52), behavioral economic theory (65), Atkin and Michie's principles of individual behavior change (65), micro-learning principles (70), cognitive behavioral therapy (88), and health communication and education theory (85). Mindful eating, social engagement, low burden, low judgement approaches (80), self-regulation strategies of goal setting, self-monitoring and feedback (42,93,95), and highlighting affective consequences, providing information and rewards (98) were also suggested or used. Two qualitative studies recommended using both physical appearance and health related motivations to facilitate app engagement for young adults (98) and social support for older adults (96).

Finally, rather than or in addition to using behavior change theory, ten apps were developed through user involvement in app development, an iterative participatory design or after conducting a needs assessment (42,50,52,65,68,73,86,88,90,92). This approach was seen across all study types.

Target population

Any strategic approach was more likely to be used in apps targeted towards a specific population (adolescents 2/3, low SES groups 6/6 and overweight populations 10/15) compared with those for unspecified groups (young adults 4/8, general adult 8/15). This same pattern was also evident for the use of classical behavioral change models (adolescents 2/2, low SES groups 5/6 and young adults 0/4, general adults 3/8). Apps targeted towards low SES and overweight populations were also more likely to report involving users in their development process (3/6 and 4/10 respectively).

Aim of app/program

The frequency with which apps with different aims were developed using a strategic approach was similar (general nutrition improvement 15/24, weight loss 7/11, grocery shopping support 2/5, parenting practices support 3/3 and food access support 3/4). Those aiming to support parenting practices were more likely to be informed by classical behavior change models than those for grocery shopping or food access support (3/3, 0/2 and 1/3 respectively), with the reverse pattern seen for the use of a needs-assessment approach (1/3, 2/2 and 2/3 respectively).

Consumer testing

Consumer testing of the app prior to intervention delivery was carried out in seven of the 13 nutrition improvement trials (36,48,50,52,53,62,63) and 17 of the 21 discreet app development projects (65,68,70,72-77,79,80,85,86,88-90,92). No description of consumer testing prior to trial delivery was provided in any of the reports of dietary self-monitoring trials, or qualitative app development papers. One study extensively elicited feedback about app experience and released software updates during the trial (52), and evaluation of the app to a lesser extent after trial completion was a common approach. App development project reports generally provided a more comprehensive description of consumer testing methods.

Testing design

Field deployment (real time use of the app by consumers in the intended setting), with or without participant observation, was the most common testing design used. This approach was taken in three nutrition improvement trials (36,48,50) and 13 app development projects (65,68,70,72,74,76,79,80,85,88-90,92). Other common approaches were testing of app components (36,52,75,85) and focus groups (73,85,86). Less common approaches were online app demonstrations (92), weekly design, development and testing sprints (68), cognitive walkthrough iterations (77), modified think-aloud protocols (90), acceptability testing (53) and two papers reported 'testing' with no elaboration on method (62,63). Thirteen studies reported one round of testing

(48,50,62,63,65,70,72-74,79,80,88,89), seven reported two (36,52,53,75,76,90,92), one reported three (86), and three reported multiple (68,77,85).

Testing duration

Of the trials using a field deployment design and reporting the duration of user testing, one trialled the app for less than a week (88), five for two to four weeks (50,72,74,79,80), three for six to 10 weeks (48,65,76), and two for between six and 10 months (70,90).

Population sampled

The most common population sampled for consumer testing was the target user group of the app, with five nutrition improvement trials (36,48,52,53,62) and all 17 of the app development projects (65,68,70,72-77,79,80,85,86,88-90,92) using this approach. Initial app testing was also conducted by people within or close to the development team (50,52) and project stakeholders (68). One nutrition improvement trial research team tested their app with nutritionists and nurses rather than target users (63).

Sample size

The size of the testing sample varied greatly. The most common size was between 11 and 20 testers (nine studies) (48,72,79,85,86,88-90,92), followed by ten or less testers (four studies) (73,76,85,90), 21 to 50 testers (three studies) (36,74,77), 51 to 100 testers (two studies) (70,80), 101 to 200 testers (two studies) (75,92) and least commonly more than 200 testers (one study) (65).

Instruments used

The instruments used for evaluating apps also varied greatly, with many studies using multiple instruments. The most common evaluative tools used were online surveys, interviews and/or focus groups about accessibility, usability, satisfaction, integration into daily routine, and user experience (36,48,65,70,72-77,79,80,85,86,88-90,92) (18 studies). During field deployment testing, four studies incorporated a pre/post-test of nutrition improvement (48,65,79,88), three logging of app use (links

followed, button pressing, messages responded to) (48,70,72), two analytics for data uptake and usage metrics (65,85) and in one study testers kept a diary of when and where the app was used, progress, enjoyment and thoughts related to nutrition content (79). When testing was not completed through a field deployment design, paper or interactive app mock-ups on a device were always used (52,73,77,85,86) (5 studies). Other instruments used were the System Usability Scale (48,90), the Questionnaire for User Interaction Satisfaction (92), the Paper Prototyping Method (90), and a ranking questionnaire with tester rating of the importance of app features (77,90).

Table 4 synthesises the results of this review into a summary checklist outlining the key development, feature, content and evaluation strategies for development teams to consider when designing an app development project.

Conclusions

The number of studies identified in this review, and specifically the large number completed in the last five years, suggests researcher and practitioner interest in the use of smartphone apps to support nutrition improvement in community settings. While the results themselves provide a useful map of app characteristics for app development teams and practitioners to consider, herein we shall highlight some broader implications of the findings from this systematic scoping review for these groups and the research area in general. A discussion of the importance of app tailoring and consumer testing is followed by suggestions for how to incorporate behavior change theory.

The strongest evaluation theme to come through in this review is the desire for and the success of tailoring in app design. This finding is consistent with findings from others (3,9,100). In their review, Hermawati and Lawson (9) suggest that when apps do not target a very specific user group this may result in a mismatch of potential user needs and app characteristics and therefore poor app engagement. They suggest app developers more specifically define their target groups, and include these target users in all stages of app development to ensure full tailoring of app features and content. Certainly this approach would achieve the specified aim; however it may also result in a proliferation

of highly specific apps targeted towards very small population groups. Additionally, this may make promotion and dissemination of apps more challenging. Another approach may be to keep target user groups relatively broad, but provide opportunity for within app customization (of the type described by Helf and Hlavacs (3)) such that the specific needs of different users can be served. Characteristics described here which can be incorporated into app design to achieve this include a choice between simple and detailed food logging, customizable goals and challenges, time and location customizable reminders and prompts, multiple options for display of progress/food healthiness, and customizable avatars. This approach is likely to meet a diversity of consumer needs within user groups, and meet individual users' needs as they change over time and their interaction with the app matures (49,60).

To be successful in tailoring apps in the manner described above, consumer testing *with target users prior to app release* is essential. However, our findings show this was carried out in just over half of the trials and development projects. This finding was also identified in a systematic review of apps for obesity prevention and focussing on user-centred design (9). Bugs and app functionality problems (such as requiring an internet connection) that would undoubtedly have been illuminated in consumer testing reportedly needlessly influenced app engagement in a number of trials (39,42,51,57,60). Reasons provided for not conducting user testing included practical timing, resource and funding constraints of studies (57), however most reports provided no reasoning. Studies, especially costly RCTs, incorporating made to order apps must consider testing with target users prior to app deployment an essential intervention design step, and allocate resources accordingly (9).

Similarly, the use of a strategic approach for app design, whether it be an interactive user-centred approach or mapping features to behavioral change theory, is known to be a critical step towards ensuring app effectiveness, engagement (21,27) and quality (22). Behaviour change theories are an integral component of successful interventions to improve dietary intake (101). Although providing a detailed summary of the behaviour change theories that were utilised in the cited studies was beyond the scope of this review. A number of papers (27,102,103) have assessed the prevalence and/or role of health behaviour theory in diet apps. The opportunity to theoretically tailor app characteristics is a

major advantage of making an app to order instead of using one that is commercially available. Yet, we found just over half of the studies reviewed here described any type of strategic approach. This may partially be a feature of study reporting, but for the purposes of this review our classification of strategic approach and theory use was broad and inclusive, as can be seen in the results. Commercial app content reviews focussing on incorporation of behavior change techniques offer many useful suggestions for mapping features to behavior change theories for future app developers (21,22,25,27-29). Additionally, our map of the approaches that have been used may serve as a starting point, and the feature domains reported in the findings generally correspond to different behavior change support strategies common to many classical behavioral change models (21,28), thus inclusion of a feature from each domain could be a useful initial approach.

In the same way, incorporating multiple domain features and nutrition content delivery strategies can assist in impacting multiple factors influencing food choices, and therefore provide a more supportive environment for behavior change. For example, following the levels of food choice influence found in the ecological framework from Story et al. (2), providing general information and feedback on food logging may influence cognitions, therefore impact at the individual level (2). Adding social and team related features may contribute to social support, changes in social norms and role modelling at the level of the social environment (2). Similarly, while apps themselves cannot change the physical and macro-level environments as such (although there is a case for reformulation and data collection that can be used for lobbying stimulated by some types of apps (81)), they can provide information about access to local foods or grocery shopping and menu selection assistance that can provide support for consumers to better manipulate these environments for their own health benefit. Our review shows the majority of trials conducted have focused on generalised nutrition improvement and weight loss, and as such typically do not incorporate supports for these higher levels of food choice influence. However, it is encouraging to see a variety of well designed, theoretically based apps that have been developed to incorporate these features within the app description studies that could be used in community nutrition improvement programs.

Poor quality, vague and inconsistent reporting hinders this evidence base in general. Likely due to strict journal word limits and competing priorities, often reports of trials were lacking comprehensive descriptions of apps, their development, testing and evaluation. As such, our review is limited by the detail about apps provided in the reports, and this has previously been identified as an issue with this body of literature (5). In this study we did not specifically abstract information about the resources that developers used to inform the nutrition information disseminated in their apps, hence, whether the information they provide is accurate requires further evaluation. Some apps may have had additional characteristics that are not reported here but due to practical constraints we could not individually download and try all the apps available commercially, nor request access to made to order apps from authors. Additionally, due to inconsistencies in terminology used between studies there was a level of unavoidable subjective interpretation within data extraction. However, all outcomes of interest to the review were extracted from available reports, so it is as thorough as the quality of reporting in the literature allows. Similarly, critical definitions were discussed at regular author meetings, and all data extraction was completed by one author, therefore consistency in data extraction and analysis was high. In moving the reporting of this area of research forward, we suggest authors take advantage of the option to include online only supplementary material with their manuscripts to provide detailed information about made to order apps. Screenshots of the design of app interfaces and flow would be especially useful.

It is possible that heterogeneity within target group demographics can impact the success of the apps to enhance nutritional impact and limit the generalisability of results. Hence, careful consideration of how target population demographics may modify or confound the effectiveness of nutrition apps is an important component of the design process. A further limitation of the research area is the scarcity of information regarding length of use, impact on health outcomes and sustained change achieved specifically through the use of apps. As this evidence base matures this will be an important area for future research to systematically review and consequently provide concrete data on efficacy for future app projects. We originally intended to examine strategies for promoting and disseminating apps, but

only one study reported on this (95), and they reported using media coverage, mail-outs, clinic posters and patient leaflets in service settings, service provider support and promotion through target user networks and newsletters. Again, this issue with the evidence base has been reported previously as an issue with using traditional research designs, such as RCTs, to test the efficacy of apps (5). Finally, Children and adolescents are at increased risk of developing unhealthy weight control behaviors and as such it is important that caution is taken to ensure that no harm is caused when promoting changes in eating behaviour for this population group (104).

Despite these limitations, to our knowledge this is the first research to comprehensively and inclusively map the characteristics, development and consumer testing of apps for nutrition improvement in community settings.

Collaboration between academics and app developers promotes an appropriate balance of evidence based content and functionality (3-5). This review can be used as a starting point and foundation for these collaborations in designing apps for nutrition improvement projects.

Acknowledgements: All authors have read and approved the final manuscript

References

1. World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013-2020. Geneva, Switzerland: World Health Organization; 2013.
2. Story M, Kaphingst KM, Robinson-O'brien R, Glanz K. Creating healthy food and eating environments: policy and environmental approaches. Ann Rev Public Heal. 2008;29:253-72.
3. Helf C, Hlavacs H. Apps for life change: Critical review and solution directions. Entertainment Comput. 2016;14:17-22.
4. Hingle MPMPHRD, Patrick HP. There Are Thousands of Apps for That: Navigating Mobile Technology for Nutrition Education and Behavior. J Nutr Educ Behav. 2016;48(3):213.
5. Vandelanotte CP, Müller AMMA, Short CEP, Hingle MP, Nathan NMaB, Williams SLP, Lopez MLMUP, Parekh SP, Maher CaP. Past, Present, and Future of eHealth and mHealth Research to Improve Physical Activity and Dietary Behaviors. J Nutr Educ Behav. 2016;48(3):219.
6. Kim Y, Briley DA, Ocepek MG. Differential innovation of smartphone and application use by sociodemographics and personality. Comput Hum Behav. 2015;44:141-147.
7. Poushter J. Smartphone Ownership and Internet Usage Continues to Climb in Emerging Economies. Pew Research Center: Washington DC; 2016.
8. Klasnja P, Pratt W. Healthcare in the Pocket: Mapping the Space of Mobile-Phone Health Interventions. J Biomed Inform. 2012;45(1):184-198.
9. Hermawati S, Lawson G. Managing obesity through mobile phone applications: a state-of-the-art review from a user-centred design perspective. Pers Ubiquit Comput. 2014;18(8):2003-2023.
10. Aguilar-Martínez A, Solé-Sedeño JM, Mancebo-Moreno G, Xavier Medina F, Carreras-Collado R, Saigí-Rubió F. Use of mobile phones as a tool for weight loss: A systematic review. J Telemed Telecare. 2014;20(6):339-349.

11. Bacigalupo R, Cudd P, Littlewood C, Bissell P, Hawley MS, Buckley Woods H. Interventions employing mobile technology for overweight and obesity: An early systematic review of randomized controlled trials. Obes Rev. 2013;14(4):279-291.
12. Wickham CA, Carbone ET. Who's calling for weight loss? A systematic review of mobile phone weight loss programs for adolescents. Nutr Rev. 2015;73(6):386-398 13p.
13. Stephens J, Allen J. Mobile phone interventions to increase physical activity and reduce weight: A systematic review. J Cardiovasc Nurs. 2013;28(4):320-329.
14. Riaz S, Sykes C. Are smartphone health applications effective in modifying obesity and smoking behaviours? A systematic review. Heal Tech. 2015;5(2):73-81.
15. Difilippo KN, Huang WH, Andrade JE, Chapman-Novakofski KM. The use of mobile apps to improve nutrition outcomes: A systematic literature review. J Telemed Telecare. 2015;21(5):243-253.
16. Nour M, Chen J, Allman-Farinelli M. Efficacy and External Validity of Electronic and Mobile Phone-Based Interventions Promoting Vegetable Intake in Young Adults: Systematic Review and Meta-Analysis. J Med Internet Res. 2016;18(4):e58.
17. Buhi ER, Trudnak TE, Martinasek MP, Oberne AB, Fuhrmann HJ, Mcdermott RJ. Mobile phone-based behavioural interventions for health: a systematic review. Health Educ J. 2013;72(5):564-583.
18. Liu F, Kong X, Cao J, Chen S, Li C, Huang J, Gu D, Kelly TN. Mobile phone intervention and weight loss among overweight and obese adults: a meta-analysis of randomized controlled trials. Am J Epidemiol. 2015;181(5):337-48.
19. Bardus M, Smith JR, Samaha L, Abraham C. Mobile phone and web 2.0 technologies for weight management: A systematic scoping review. J Med Internet Res. 2015;17(11).
20. Fiordelli M, Diviani N, Schulz PJ. Mapping mHealth Research: A Decade of Evolution. J Med Internet Res. 2013;15(5):e95.

21. Azar KMJ, Lesser LI, Laing BY, Stephens J, Aurora MS, Burke LE, Palaniappan LP. Mobile Applications for Weight Management: Theory-Based Content Analysis. Am J Prev Med. 2013;45(5):583-589.

22. Bardus M, Van Beurden SB, Smith JR, Abraham C. A review and content analysis of engagement, functionality, aesthetics, information quality, and change techniques in the most popular commercial apps for weight management. Int J Behav Nutr Phy. 2016;13(1).

23. Breton ER, Fuemmeler BF, Abroms LC. Weight loss-there is an app for that! But does it adhere to evidence-informed practices? Translational Behav Med. 2011;1(4):523-529.

24. Burrows TL, Khambalia AZ, Perry R, Carty D, Hendrie GA, Allman-Farinelli MA, Garnett SP, Mcnaughton SA, Rangan AM, Truby H, et al. Great 'app-eal' but not there yet: A review of iPhone nutrition applications relevant to child weight management. Nutr Diet. 2015;72(4):363.

25. Direito A, Pfaeffli Dale L, Shields E, Dobson R, Whittaker R, Maddison R. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? BMC Public Health. 2014;14:646.

26. Lister C, West JH, Cannon B, Sax T, Brodegard D. Just a fad? Gamification in health and fitness apps. J Med Internet Res. 2014;16(8):e9.

27. West JH, Hall PC, Arredondo V, Berrett B, Guerra B, Farrell J. Health Behavior Theories in Diet Apps. Journal of Consumer Health on the Internet. 2013;17(1):10-24.

28. Zahry NR, Cheng Y, Peng W. Content Analysis of Diet-Related Mobile Apps: A Self-Regulation Perspective. Health Commun. 2016:1-10.

29. West JH, Hall PC, Hanson CL, Barnes MD, Giraud-Carrier C, Barrett J. There's an app for that: Content analysis of paid health and fitness apps. J Med Internet Res. 2012;14(3).

30. Levac D, Colquhoun H, O'brien KK. Scoping studies: Advancing the methodology. Implement Sci. 2010;5(1).

31. Armstrong R, Hall BJ, Doyle J, Waters E. Cochrane Update. 'Scoping the scope' of a cochrane review. J Public Health. 2011;33(1):147-150.

32. Arksey H, O'malley L. Scoping studies: Towards a methodological framework. International Journal of Social Research Methodology: Theory and Practice. 2005;8(1):19-32.

33. Khalil H, Peters M, Godfrey CM, Mcinerney P, Soares CB, Parker D. An Evidence-Based Approach to Scoping Reviews. Worldv Evid-Based Nu. 2016;13(2):118-123.

34. Bert F, Giacometti M, Gualano MR, Siliquini R. Smartphones and Health Promotion: A Review of the Evidence. J Med Syst. 2014;38(1):1-9995.

35. Ozdalga E, Ozdalga A, Ahuja N. The Smartphone in Medicine: A Review of Current and Potential Use Among Physicians and Students. J Med Internet Res. 2012;14(5):e128.

36. Hebden L, Cook A, Ploeg HP, King L, Bauman A, Allman-Farinelli M. A mobile health intervention for weight management among young adults: a pilot randomised controlled trial. J Hum Nutr Diet. 2014;27(4):322-332 11p.

37. Hebden L, Cook A, Van Der Ploeg HP, Allman-Farinelli M. Development of Smartphone Applications for Nutrition and Physical Activity Behavior Change. J Med Internet Res. 2012;14(4).

38. Wharton CM, Johnston CS, Cunningham BK, Sterner D. Dietary self-monitoring, but not dietary quality, improves with use of smartphone app technology in an 8-week weight loss trial. J Nutr Educ Behav. 2014;46(5):440-4.

39. Duncan M, Vandelanotte C, Kolt GS, Rosenkranz RR, Caperchione CM, George ES, Ding H, Hooker C, Karunanithi M, Maeder AJ, et al. Effectiveness of a Web- and mobile phone-based intervention to promote physical activity and healthy eating in middle-aged males: Randomized controlled trial of the ManUp study. J Med Internet Res. 2014;16(6):40-60.

40. Appel HB, Huang B, Cole A, James R, Ai AL. Starting the Conversation – A Childhood Obesity Knowledge Project Using an App. British Journal of Medicine and Medical Research. 2014;4(7):1526-1538.

41. Turner-Mcgrievy GM, Beets MW, Moore JB, Kaczynski AT, Barr-Anderson DJ, Tate DF. Comparison of traditional versus mobile app self-monitoring of physical activity and dietary

intake among overweight adults participating in an mHealth weight loss program. J Am Med Inform Assn. 2013;20(3):513-518.

42. Carter MC, Burley VJ, Nykjaer C, Cade JE. Adherence to a smartphone application for weight loss compared to website and paper diary: pilot randomized controlled trial. J Med Internet Res. 2013;15(4).

43. Allen JK, Stephens J, Dennison Himmelfarb CR, Stewart KJ, Hauck S. Randomized controlled pilot study testing use of smartphone technology for obesity treatment. Journal of Obesity, 2013:1-7.

44. Pellegrini CA, Duncan JM, Moller AC, Buscemi J, Sularz A, Demott A, Pictor A, Pagoto S, Siddique J, Spring B. A smartphone-supported weight loss program: design of the ENGAGED randomized controlled trial. BMC Public Health. 2012;12:1041.

45. Duncan MJ, Vandelanotte C, Rosenkranz RR, Caperchione CM, Ding H, Ellison M, George ES, Hooker C, Karunanithi M, Kolt GS, et al. Effectiveness of a website and mobile phone based physical activity and nutrition intervention for middle-aged males: Trial protocol and baseline findings of the ManUp Study. BMC Public Health. 2012;12:656.

46. Turner-Mcgrievy G, Tate D. Tweets, Apps, and Pods: Results of the 6-Month Mobile Pounds Off Digitally (Mobile POD) Randomized Weight-Loss Intervention Among Adults. J Med Internet Res. 2011;13(4).

47. Skau JK, Nordin AB, Cheah JC, Ali R, Zainal R, Aris T, Ali ZM, Matzen P, Biesma R, Aagaard-Hansen J, et al. A complex behavioural change intervention to reduce the risk of diabetes and prediabetes in the pre-conception period in Malaysia: study protocol for a randomised controlled trial. Trials. 2016;17(1):215.

48. Du H, Venkatakrishnan A, Youngblood GM, Ram A, Pirolli P. A Group-Based Mobile Application to Increase Adherence in Exercise and Nutrition Programs: A Factorial Design Feasibility Study. J Med Internet Res. 2016;4(1):e4.

49. Svetkey LP, Batch BC, Lin PH, Intille SS, Corsino L, Tyson CC, Bosworth HB, Grambow SC, Voils C, Loria C, et al. Cell phone intervention for you (CITY): A randomized, controlled trial of behavioral weight loss intervention for young adults using mobile technology. Obesity. 2015;23(11):2133-2141.

50. Schaefbauer C, Kahn D, Le A, Sczechowski G, Siek K, Acm. Snack Buddy: Supporting Healthy Snacking in Low Socioeconomic Status Families. Proceedings of the 2015 Acm International Conference on Computer-Supported Cooperative Work and Social Computing. 2015:1045-1057.

51. Rabbi M, Pfammatter A, Zhang M, Spring B, Choudhury T. Automated Personalized Feedback for Physical Activity and Dietary Behavior Change With Mobile Phones: A Randomized Controlled Trial on Adults. J Med Internet Res. 2015;3(2).

52. Lin PH, Intille S, Bennett G, Bosworth HB, Corsino L, Voils C, Grambow S, Lazenka T, Batch BC, Tyson C, et al. Adaptive intervention design in mobile health: Intervention design and development in the Cell Phone Intervention for You trial. Clinical Trials. 2015;12(6):634-645.

53. Volkova E, Neal B, Rayner M, Swinburn B, Eyles H, Jiang YN, Michie J, Mhurchu CN. Effects of interpretive front-of-pack nutrition labels on food purchases: protocol for the Starlight randomised controlled trial. BMC Public Health. 2014;14.

54. Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Lubans DR. Smart-phone obesity prevention trial for adolescent boys in low-income communities: the ATLAS RCT. Pediatrics. 2014;134(3):e723-31.

55. Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely AD, Finn TL, Babic MJ, Skinner G, Lubans DR. Rationale and study protocol for the 'active teen leaders avoiding screen-time' (ATLAS) group randomized controlled trial: an obesity prevention intervention for adolescent boys from schools in low-income communities. Contemp Clin Trials. 2014;37(1):106-19.

56. Morrison LG, Hargood C, Lin SX, Dennison L, Joseph J, Hughes S, Michaelides DT, Johnston D, Johnston M, Michie S, et al. Understanding usage of a hybrid website and smartphone app for weight management: a mixed-methods study. J Med Internet Res. 2014;16(10)e201-e221.

57. Lubans DR, Smith JJ, Skinner G, Morgan PJ. Development and implementation of a smartphone application to promote physical activity and reduce screen-time in adolescent boys. Frontiers in Public Health. 2014;2:42.

58. Eyles H, Mclean R, Neal B, Doughty RN, Jiang Y, Mhurchu CN. Using mobile technology to support lower-salt food choices for people with cardiovascular disease: protocol for the SaltSwitch randomized controlled trial. BMC Public Health. 2014;14:950.

59. Batch BC, Tyson C, Bagwell J, Corsino L, Intille S, Lin PH, Lazenka T, Bennett G, Bosworth HB, Voils C, et al. Weight loss intervention for young adults using mobile technology: Design and rationale of a randomized controlled trial - Cell Phone Intervention for You (CITY). Contemp Clin Trials. 2014;37(2):333-341.

60. Brindal E, Hendrie G, Freyne J, Coombe M, Berkovsky S, Noakes M. Design and pilot results of a mobile phone weight-loss application for women starting a meal replacement programme. J Telemed Telecare. 2013;19(3):166-174.

61. Freyne J, Brindal E, Hendrie G, Berkovsky S, Coombe M, Mobile applications to support dietary change: highlighting the importance of evaluation context, in CHI '12 Extended Abstracts on Human Factors in Computing Systems. 2012, ACM: Austin, Texas, USA. p. 1781-1786.

62. Pollak J, Gay G, Byrne S, Wagner E, Retelny D, Humphreys L. It's Time to Eat! Using Mobile Games to Promote Healthy Eating. IEEE Pervas Comput. 2010;9(3):21-27.

63. Lee W, Chae YM, Kim S, Ho SH, Choi I. Evaluation of a mobile phone-based diet game for weight control. J Telemed Telecare. 2010;16(5):270-275.

64. Waltner G, Schwarz M, Ladstatter S, Weber A, Luley P, Bischof H, Lindschinger M, Schmid I, Paletta L. MANGO - Mobile Augmented Reality with Functional Eating Guidance and Food

Awareness. In: Murino V, et al., editors. New Trends in Image Analysis and Processing - Iciap 2015 Workshops. 2015. p. 425-432.

65. Gilliland J, Sadler R, Clark A, O'connor C, Milczarek M, Doherty S. Using a Smartphone Application to Promote Healthy Dietary Behaviours and Local Food Consumption. BioMed Research International. 2015.

66. Freyne J, Bhandari D, Berkovsky S, Borlyse L, Campbell C, Chau S, Mobile mentor: weight management platform, in Proceedings of the 15th international conference on Intelligent user interfaces. 2010, ACM: Hong Kong, China. p. 409-410.

67. Arsand E, Tufano JT, Ralston JD, Hjortdahl P. Designing mobile dietary management support technologies for people with diabetes. J Telemed Telecare. 2008;14(7):329-332.

68. Vylegzhanina V, Schmidt DC, Hull P, Emerson JS, Quirk ME, Mulvaney S, Helping Children Eat Well via Mobile Software Technologies, in Proceedings of the 2nd International Workshop on Mobile Development Lifecycle. 2014, ACM: Portland, Oregon, USA. p. 9-16.

69. Volkova E, Li N, Dunford E, Eyles H, Crino M, Michie J, Ni Mhurchu C. "Smart" RCTs: Development of a Smartphone App for Fully Automated Nutrition-Labeling Intervention Trials. J Med Internet Res. 2016;4(1):e23.

70. Simons LPA, Foerster F, Bruck PA, Motiwalla L, Jonker CM. Microlearning mApp raises health competence: hybrid service design. Health and Technology. 2015;5(1):35-43.

71. Silva BM, Lopes IM, Rodrigues JJPC, Ray P. SapoFitness: A mobile health application for dietary evaluation, in IEEE 13th International Conference on e-Health Networking, Applications and Services, HEALTHCOM 2011, 2011: p. 375-380.

72. Robinson E, Higgs S, Daley AJ, Jolly K, Lycett D, Lewis A, Aveyard P. Development and feasibility testing of a smart phone based attentive eating intervention. BMC Public Health. 2013;13:639.

73. Miller T, Chandler L, Mouttapa M. A Needs Assessment, Development, and Formative Evaluation of a Health Promotion Smartphone Application for College Students. American Journal of Health Education. 2015;46(4):207-215.

74. Mann D, Riddell L, Lim K, Byrne LK, Nowson C, Rigo M, Szymlek-Gay EA, Booth AO. Mobile Phone App Aimed at Improving Iron Intake and Bioavailability in Premenopausal Women: A Qualitative Evaluation. J Med Internet Res. 2015;3(3).

75. Lopes IM, Silva BM, Rodrigues JJPC, Lloret J, Proen ML, X00e. A mobile health monitoring solution for weight control, in Wireless Communications and Signal Processing (WCSP), 2011 International Conference; 2011: p. 1-5.

76. Knight-Agarwal C, Davis DL, Williams L, Davey R, Cox R, Clarke A. Development and Pilot Testing of the Eating4two Mobile Phone App to Monitor Gestational Weight Gain. J Med Internet Res. 2015;3(2).

77. Khan DU. Designing mobile snack application for low socioeconomic status families. Proceedings of the 6th international conference on pervasive computing technologies for health care; 2012:57-64.

78. Helander E, Kaipainen K, Korhonen I, Wansink B. Factors Related to Sustained Use of a Free Mobile App for Dietary Self-Monitoring With Photography and Peer Feedback: Retrospective Cohort Study. J Med Internet Res. 2014;16(4).

79. Grimes A, Kantroo V, Grinter RE, Acm. Let's Play! Mobile Health Games for Adults, in Ubicomp 2010: Proceedings of the 2010 Acm Conference on Ubiquitous Computing, 2010.

80. Epstein DA, Cordeiro F, Fogarty J, Hsieh G, Munson SA, Crumbs: Lightweight Daily Food Challenges to Promote Engagement and Mindfulness, in Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems. 2016, ACM: Santa Clara, California, USA. p. 5632-5644.

81. Dunford E, Trevena H, Goodsell C, Ng KH, Webster J, Millis A, Goldstein S, Hugueniot O, Neal B. FoodSwitch: A mobile phone app to enable consumers to make healthier food choices and crowdsourcing of national food composition data. J Med Internet Res. 2014;16(8):e37.

82. Du H, Youngblood GM, Pirolli P. Efficacy of a smartphone system to support groups in behavior change programs, in Proceedings - Wireless Health 2014; 2014.

83. Dorman K, Yahyanejad M, Nahapetian A, Suh MK, Sarrafzadeh M, Mccarthy W, Kaiser W. Nutrition Monitor: A Food Purchase and Consumption Monitoring Mobile System. In: Phan T, Montanari R, and Zerfos P, editors. Mobile Computing, Applications and Services. 2010. p. 1-11.

84. Ding H, Karunanithi M, Duncan M, Ireland D, Noakes M, Hooker C. A mobile phone enabled health promotion program for middle-aged males, in Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS; 2013: p. 1173-1176.

85. Deshazo J, Harris L, Turner A, Pratt W. Designing and remotely testing mobile diabetes video games. J Telemed Telecare. 2010;16(7):378-382.

86. Curtis KE, Lahiri S, Brown KE. Targeting Parents for Childhood Weight Management: Development of a Theory-Driven and User-Centered Healthy Eating App. J Med Internet Res. 2015;3(2).

87. Carter MC, Burley VJ, Cade JE. Development of 'My Meal Mate' - A smartphone intervention for weight loss. Nutrition Bulletin. 2013;38(1):80-84.

88. Carroll EA, Czerwinski M, Roseway A, Kapoor A, Johns P, Rowan K, Schraefel MC, Ieee. Food and Mood: Just-in-Time Support for Emotional Eating, in 2013 Humaine Association Conference on Affective Computing and Intelligent Interaction; 2013: p. 252-257.

89. Brand L, Beltran A, Buday R, Hughes S, O'connor T, Baranowski J, Dadabhoy HR, Diep CS, Baranowski T. Training Vegetable Parenting Practices Through a Mobile Game: Iterative Qualitative Alpha Test. J Med Internet Res. 2015;3(2):e6.

90. Arsand E, Tatara N, Ostengen G, Hartvigsen G. Mobile phone-based self-management tools for type 2 diabetes: the few touch application. Journal of Diabetes Science & Technology. 2010;4(2):328-36.

91. Anwar M, Hill E, Skujins J, Huynh K, Doss C, Kalico: a smartphone application for health-smart menu selection within a budget, in Proceedings of the 2013 international conference on Smart Health. 2013, Springer-Verlag: Beijing, China. p. 113-121.

92. Ahn J, Williamson J, Gartrell M, Han R, Lv Q, Mishra S. Supporting Healthy Grocery Shopping via Mobile Augmented Reality. ACM T Multim Comput. 2015;12(1).

93. Dennison L, Morrison L, Conway G, Yardley L. Opportunities and challenges for smartphone applications in supporting health behavior change: Qualitative study. J Med Internet Res. 2013;15(4):73-84.

94. Hearn L, Miller M, Fletcher A. Online healthy lifestyle support in the perinatal period: what do women want and do they use it? Aust J Prim Health. 2013;19(4):313-8.

95. Hearn L, Miller M, Lester L. Reaching perinatal women online: The healthy you, healthy baby website and app. Journal of Obesity. 2014;2014.

96. Watkins I, Bo X. Older Adults' Perceptions of Using iPads for Improving Fruit and Vegetable Intake: An Exploratory Study. Care Management Journals. 2015;16(1):2-13 12p.

97. Wang Q, Egelandsdal B, Amdam GV, Almli VL, Oostindjer M. Diet and Physical Activity Apps: Perceived Effectiveness by App Users. J Med Internet Res. 2016;4(2):e33.

98. Tang J, Abraham C, Stamp E, Greaves C. How can weight-loss app designers' best engage and support users? A qualitative investigation. Brit J Health Psych. 2015;20(1):151-171.

99. Gowin M, Cheney M, Gwin S, Wann TF. Health and Fitness App Use in College Students: A Qualitative Study. American Journal of Health Education. 2015;46(4):223-230.

100. Turner T, Spruijt-Metz D, Wen CKF, Hingle MD. Prevention and treatment of pediatric obesity using mobile and wireless technologies: a systematic review. Pediatric Obesity. 2015;10(6):403-409.

101. Michie S, Van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6(1):42.

102. Direito A, Pfaeffli Dale L, Shields E, Dobson R, Whittaker R, Maddison R. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? BMC Public Health. 2014;14(1):646.

103. Azar KMJ, Lesser LI, Laing BY, Stephens J, Aurora MS, Burke LE, Palaniappan LP. Mobile Applications for Weight Management. Am J Prev Med..45(5):583-589.

104. Lampard AM, Maclehose RF, Eisenberg ME, Larson NI, Davison KK, Neumark-Sztainer D. Adolescents who engage exclusively in healthy weight control behaviors: Who are they? Int J Behav Nutr Phys Act. 2016;13:5.

Table 1. Review inclusion and exclusion criteria

	Inclusion	Exclusion
All reports		
1	Reports including a smartphone app with a nutrition improvement focus	Reports including an app with no specific nutrition improvement focus (e.g. fitness apps or dietary tracking only with no within-app feedback or nutrition education delivery [controlled self-monitoring trials excluded])
2	Reports providing data regarding a relevant smartphone app characteristic as identified by the sub-objectives	Reports with inadequate description of all app characteristics
3	Participants/target users living independently within a community	Participants/target users that are - pre-school aged children (those <12 years), *or* - clinical populations with dietary treatments that extend beyond national healthy eating guidelines (for example coeliac disease, allergy), but including overweight/obese, hypertensive, cardiovascular disease and diabetic populations
4	Apps intended for use in the community setting	Apps intended for use in a primary, clinical *or* acute care setting
5	Any published peer-reviewed literature	Review articles, commentaries and theses/dissertations
6	Full reports published in English language after 2008, and where data was collected after 2008	Abstracts/brief reports, those not in English, *or* with pre-2008 data collection or publication date
Additional criteria for reports of controlled trials		
7	Reports describing programs using a smartphone app as a primary or complementary program delivery tool	Reports of social media, eHealth, text messaging or other online programs not specifying the use of a smartphone app
8	Reports describing programs with nutrition content delivery via a smartphone app as a primary or complementary component, *or* Studies assessing the impact of dietary self-monitoring using a smartphone app on dietary improvement	Reports of programs - with no nutrition content delivered via the app, *or* - where apps were used to record dietary intake without responsive in-app generated feedback/education, *or* - where apps were used only for research data collection, without an explicit participant self-monitoring objective
9	Reports describing programs delivered in the community setting	Reports describing interventions/programs delivered in a primary, clinical or acute care setting

Table 2. App features used in included studies, organized by study type

Features	Self-monitoring trials *n*=7	Nutrition improvement trials *n*=13	App description papers *n*=21	Qualitative studies *n*=6
Dietary logging and tracking				
Detailed meal/snack/drink logging using database (commercial/custom)	6 (38,40-44)	5 (36,50-52,63)	3 (75,77,83)	3 (93,98,99)
Real-time/daily tracking				
Calorie	5 (38,40-43)	2 (52,63)	2 (75,83)	-
Macro/micro nutrient	1 (41)	-	1 (83)	1 (98)
Real-time/historical graphical report based on food logging	4 (38,40,42,43)	2 (36,60)	6 (77,78,83,86,88,90)	5 (93,95,97-99)
Barcode scanner	4 (38,40,41,43)	2 (53,58)	2 (68,83)	1 (98)
Simple food group/meal type logging	1 (39)	2 (52,60)	3 (86,88,90)	2 (95,96)
Store favorite meal combinations and recently used items	1 (42)	1 (51)	1 (83)	-
Diary of food photographs	1 (42)	2 (51,62)	5 (72,74,78,80,86)	-
Chronological log of all day's dietary events	-	1 (51)	2 (72,91)	-
Snack tracking of family members	-	1 (50)	1 (77)	-
Mood and hunger logging	-	-	2 (72,88)	1 (98)
Visual cues such as 'calories remaining' turning from green to red	-	-	-	2 (98,99)
Social connectivity				
Find and connect with friends	4 (38,40,41,43)	-	-	-
Recipe sharing	4 (38,40,41,43)	-	-	-
Join public groups	3 (38,40,43)	-	-	-
Connecting with social networking sites	3 (38,40,43)	1 (53)	2 (75,80)	2 (97,98)
Interact with a professional of choice	1 (41)	-	-	2 (93,96)
Team/buddy participation	1 (44)	4 (47,48,50,52)	1 (77)	-
View of team members self-monitoring adherence	1 (44)	1 (50)	-	-
Peer-to-peer messaging	1 (44)	3 (48,50,52)	2 (77,86)	-
Interactive team activity feed	-	1 (48)	-	-
Automatic upload of people who met daily challenges to private Facebook group	-	-	1 (80)	-
Option to follow other users, 'like' and comment	-	-	1 (78)	-
Optional forums/chat rooms	-	-	-	2 (93,98)

Reminders, encouragement and prompts				
Non-customizable push notifications (prompts/reminders) (hourly, twice daily, daily)	4 (38,40,42,43)	1 (52)	6 (65,68,70,78,86,88)	1 (98)
Motivational push notifications				
Generic	1 (42)	1 (57)	-	2 (93,98)
Tailored to self-reported behavior	1 (39)	4 (36,52,56,60)	-	1 (96)
Virtual rewards (badges, stars)	-	3 (48,56,60)	1 (86)	1 (98)
Customizable automated reminders				
Time based	-	3 (47,56,60)	2 (72,80)	3 (93,98,99)
Location based	-	1 (47)	-	
Prompting to resume engagement after periods of inactivity				
Full-app-interruption	-	1 (52)	-	-
Peripheral	-	2 (52,60)	-	-
Real rewards (cartoons, games, blogs)	-	1 (52)	-	-
Goal setting and challenges				
Join public challenges	4 (38-40,43)	-	-	-
Automated graphical and text-based reports of progress towards challenges/goals	3 (39,41,44)	4 (47,48,52,56)	1 (74)	-
Dietary goal setting	2 (41,44)	2 (52,56)	3 (74,86,90)	2 (93,98)
Start a dietary challenge				
Pre-defined challenges	1 (39)	2 (47,48)	1 (80)	-
Customizable challenges	-	1 (48)	1 (80)	-
Historical record of completed challenges	-	-	1 (80)	-
Game elements				
Use of avatar or virtual pet	-	3 (50,62,63)	1 (89)	-
Narrative based game using points	-	2 (50,62)	1 (77)	-
Food games				
Quiz	-	2 (52,63)	4 (70,79,85,86)	1 (95)
Word search/jumble	-	-	1 (74)	-

Competition aspect	-	2 (47,50)	1 (77)	1 (93)
Virtual reality short game	-	-	2 (79,89)	-
General gamification	-	-	-	1 (98)
Environmental supports				
Food/menu and recipe suggestions	-	2 (36,60)	7 (65,68,73,76,86,89,91)	2 (95,96)
Detailed food product information (price, nutritional, health claims, rating)	-	2 (53,58)	4 (64,73,83,92)	-
Budgeting supports (simple fresh produce cost calculator/shopping list)	-	-	3 (68,77,91)	-
Locate inexpensive and fresh local produce	-	-	2 (65,73)	1 (96)
Augmented reality colored tagging of food products in shopping aisles	-	-	1 (92)	-
Video based food recognition	-	-	1 (64)	-
Customizable nutritional combinations used for product information/tagging	-	-	1 (92)	-
Tailoring to local cuisine	-	-	1 (79)	1 (97)
App development				
Crowdsourcing function enabling users to assist with improving breadth of back-end database	-	2 (53,58)	-	-
Multiple interfaces/modes (e.g. carer, child or shopping, logging)	-	1 (50)	2 (77,83)	-

Table 3. Nutrition content delivered through apps in included studies, organized by study type

Nutrition content	Nutrition improvement trials *n*=13	App description papers *n*=21	Qualitative studies *n*=4
Content areas			
Food composition			
Decreasing undesirable nutrients (sugar, saturated fat, sodium)	7 (36,50,53,56-58,62)	4 (77,80,83,92)	-
Specific macro/micronutrients	4 (36,51,53,58)	7 (74,76,80,83,85,91,92)	-
General healthy eating/nutritional knowledge	4 (47,52,60,63)	6 (68,70,73,78,85,90)	1 (93)
Food groups general	2 (36,48)	2 (80,89)	-
Food group balance	-	2 (85,86)	1 (97)
Portion sizing	-	2 (68,86)	-
Glycemic index	-	1 (80)	-
Relative healthiness of meals (ingredients, preparation)	-	1 (79)	-
Diet-health links			
Diet-disease link	2 (47,57)	4 (65,74,75,80)	1 (98)
Eating for life-stage	-	2 (68,76)	1 (95)
Information about specific diets (e.g. Mediterranean)	-	2 (64,72)	-
Consequences (negative/positive) of dietary choices	-	1 (65)	-
Dietary strategies for enhancing nutrient absorption	-	1 (74)	-
General importance of healthy eating	-	1 (73)	-
Feeding practices			
Meal planning	1 (48)	1 (75)	-
Eating slowly/mindfully	1 (48)	1 (88)	-
Eating breakfast	1 (62)	-	-
Time management tips	-	1 (65)	-
Feedback			
Tailored feedback (healthiness [e.g. star rating]/hints/tips/strategies) based on food logging/scanning ± anthropometrics/life-stage	7 (36,50-53,58,62)	5 (75,77,83,86,88)	4 (93,95,97,98)
Alternative, healthier food suggestions based on logging/scanning	5 (50,51,53,58,62)	1 (77)	-
Poses questions based on food logging	2 (56,60)	-	-
Within game feedback/education on answers	1 (63)	4 (70,79,85,86)	-
Comparison of healthiness of food logging with other users	1 (50)	1 (78)	-

Information about affective and/or physiological consequences of dietary choices based on food logging	-	1 (77)	1 (98)
Crowdsourced feedback on healthiness of food logging	-	1 (78)	-
Game characters react to food logging	-	1 (77)	-
General nutritional information			
Links to additional information	2 (48,60)	1 (65)	1 (95)
Answers to frequently asked nutritional questions	1 (60)	-	1 (95)
Dietary guidelines (tailored to life-stage)	1 (36)	-	1 (95)
Nutritional tools			
Practical dietary examples of nutrients	2 (48,56)	3 (74,76,85)	-
Portion sizing guide with photographs	-	2 (76,86)	-
Meal balance wheel	-	1 (86)	-
Environmental supports			
Food product recommendations based on dietary guidelines/user-defined criteria	2 (53,58)	4 (64,65,91,92)	-
Strategies/plans/tips for helping children eat more vegetables	-	2 (68,89)	-
Information about local dietitians, weight loss programs	-	1 (86)	-
Warnings about high-level energy or fat of scanned foods	-	1 (83)	-
Context triggered advice/intervention (e.g. based on location)	-	-	1 (93)

Table 4. Checklist for app development projects targeting nutrition improvement in community settings

Development
☐ Work in development teams including researchers, practitioners, target users and app developers
☐ Utilize branding from a credible/familiar source within the app (for example, academic branding)
☐ Conduct pre-development qualitative needs assessment of the target user population
☐ Use a behavior change theory as a broad base for app design
☐ Include target users through all key stages of app development/design
☐ Allocate resources to and conduct pre-deployment field testing with the target user group
Features
☐ Incorporate interactive features, an attractive interface and non-repetitive images and colors
☐ Include a feature from each feature domain identified in this review
☐ Tailor features broadly to those most suited to the target user group
☐ Enable individual user customization of app features
☐ Allow for changes in individual user customization over time
Nutrition content
☐ Tailor information and environmental supports to sub-populations
☐ Consider including more than one of the content areas identified in this review
☐ Consider including more than one of the feedback strategies identified in this review
☐ Include both positive and negative reinforcement of eating behaviors
☐ Use graphical presentations such as colors, traffic light and star representations
Evaluation and reporting
☐ Allocate resources to, conduct and report on app usability and consumer satisfaction evaluation
☐ Utilize existing tools, such as those identified in this review, in usability and satisfaction evaluation
☐ Clearly define and evaluate health outcomes to be influenced by the app
☐ Design studies to identify the contribution of the app to outcomes in multi-component program trials
☐ Describe the app and its development in detail in publications, including pictures of the interface and app flow
☐ Utilize the technical terminology of the area (that used in this review) when writing reports

Figure Legend:

Fig 1. Search process and results

Abbreviations: PDA, personal digital assistant

Supplemental Table 1. Controlled trials assessing the effect of dietary self-monitoring using an app on nutritional improvement or weight loss (no nutrition education content delivered via app, dietary tracking only). Seven discreet trials are included.

Study	Population	Intervention/Program	Aim of app for program	Nutrition relevant app features	Strategic approach/theory	Study conclusions and app evaluation
Appel et al. 2014 (40) USA Controlled trial	421 adolescents (14-19 y) 118/421 completed	App: *LoseIt! (free version)* Intervention: 20 daily diet entries on app Control: paper entries Duration: 20 d Single-component	Support self-monitoring of dietary intake	Detailed food logging Real-time calorie tracking Weight goal setting My Plate report based on calorie tracking Barcode scanner iOS/android reminders Find and connect with friends Join public groups Join public challenges Recipe sharing Share on Facebook and Twitter	Commercial app	Participants noted that using the app motivated them to eat more responsibly Some adolescents preferred handwriting to app Access to smart phones with data access was problematic for some adolescents
Duncan et al. 2014 (39) Duncan et al. 2012 (45) Ding et al. 2013 (84) Australia RCT	317 males (35-54 y) 125/317 completed	App: *ManUp* Intervention: program delivery (nutrition and PA education + self-monitoring challenges) via IT platforms (web and app) + automated feedback + social networking Control: program delivery via print-based materials Duration: 9 mo Multi-component	Support recording of progress towards web-based dietary challenges (for example fast food, SSB or fruit consumption challenges)	Simple food group logging Begin structured dietary challenges Automated graphical and text-based reports of progress towards achievement of dietary challenges Motivational push notifications based on challenge progress Join public challenges	Not specifically described for app	No difference in dietary outcomes between groups Only 22% of IT group accessed the app, limited functionality potentially contributing Desired app to be functional without an internet connection Desired tailored feedback on progress Desired personalised challenges
Wharton et al. 2014 (38) USA Controlled trial	57 weight-stable adults (18-65 y) BMI 25-40kg/m^2 47/57 completed	App: *LoseIt! (assume free version)* App group: diet entries on app Memo group: diet entries on memo function of phone + nutrition counselling + weekly emails Paper group: diet tracking with paper diary + nutrition counselling + weekly emails Duration: 8 wk Multi-component	Support self-monitoring of dietary intake	Detailed food logging Real-time calorie tracking Weight goal setting My Plate report based on calorie tracking Barcode scanner iOS/android reminders Find and connect with friends Join public groups Join public challenges Recipe sharing	Commercial app	App group more consistently entered complete days of dietary data compared to paper group App users withdrew from the study less often Apps only providing calorie information fail to also improve diet quality

				Share on Facebook and Twitter		
Allen et al. 2013 (43) USA Pilot RCT	68 adults (21-65 y) with BMI 28-42kg/m^2 43/68 completed	App: *LoseIt! (assume free version)* Intervention 1: intensive diet and exercise counselling Intervention 2: intensive diet and exercise counselling + self-monitoring app Intervention 3: less intensive diet and exercise counselling + self-monitoring app Intervention 4: self-monitoring app only Duration: 6 mo Multi-component	Support self-monitoring of dietary intake	Detailed food logging Real-time calorie tracking Weight goal setting My Plate report based on calorie tracking Barcode scanner iOS/android reminders Find and connect with friends Join public groups Join public challenges Recipe sharing Share on Facebook and Twitter	Commercial app	All groups decreased total calorie, calories from fat and sodium intake. Double the engagement with the app in groups also getting counselling F&V intake increased in all but app only group
Carter et al. 2013 (42) Carter et al. 2013 (87) UK Pilot RCT	128 overweight adults (18-65 y) BMI ≥27kg/m^2 79/128 completed	App: *My Meal Mate* Intervention: app Control 1: web-based weight loss support and self-monitoring Control 2: paper diaries with calorie counting book Duration: 6 mo Single-component	Support self-monitoring of dietary intake	Food logging using commercial database Calorie tracking Weight goal setting Graphical report of tracking (instant and longer term) Push notifications triggered by progress towards calorie targets based on enhancing confidence, competence, and mastery Ability to take food photographs Store favorite meal combinations and recently used items Weekly push notification prompts to self-monitor	Self-regulation strategies of goal setting, self-monitoring and feedback Potential users contributed to app development App benchmarked against commercial apps	Similar weight loss at 6 mo between completers Dietary self-monitoring highest in app group (almost triple the days of engagement) Convenience of use highest for app group Participants were more comfortable recording diet in social settings in app group
Turner-McGrievy et al. 2013 (41) Turner-McGrievy et al. 2011 (46) USA RCT	96 overweight adults 86/96 completed	App: *FatSecret's Calorie Counter* Intervention: podcasts with lifestyle education material + app for self-monitoring Control: podcasts + printed nutritional information (could use their own app or paper/web self-monitoring methods) Duration: 6 mo Multi-component	Support self-monitoring of dietary intake	Food logging Dietary tracking including calories and macronutrients Diet calendar to see calories consumed Goal setting and reporting Find and connect with friends Interaction with a professional of choice Barcode scanner and auto-complete functions	Commercial app	No differences in weight loss or calorie intake between groups Mobile tracking of diet is associated with decreased energy intake Mobile logging (collapsed groups) led to more consistent food logging Auto-complete functions for food logging useful Addition of app to intervention did not increase cognitive burden

				Recipes ideas		Tailoring of feedback desirable
Pellegrini et al. 2012 (44) USA RCT protocol	96 obese adults (18-60 y) BMI 30-40kg/m^2	App: *ENGAGED app* Intervention 1: standard behavioral weight loss + paper diary Intervention 2: technology supported behavioral weight loss Control: self-guided behavioral weight loss + paper diary Duration: 12 mo Multi-component	Support self-monitoring of dietary intake	Food logging using CalorieKing food database Goal thermometers showing goal and actual calories and fat grams consumed Team participation View of team members adherence to self-monitoring Peer-to-peer messaging within teams	Control systems theory of self-regulation	Protocol only

Abbreviations: BMI, body mass index; F&V, fruit and vegetable; IT, information technology; RCT, randomized controlled trial; SSB, sugar-sweetened beverage

Supplemental Table 2. Controlled trials assessing programs/interventions for nutritional improvement or weight loss with nutrition education content delivered via an app. Thirteen discreet trials are included.

Study	Intervention/Program	Consumer testing of app (prior to trial)	Aim of app for program	Nutrition relevant app features	Nutrition relevant app content	Strategic approach/theory	Study conclusions and app evaluation
Du et al. 2016 (48) Du et al. 2014 (82) USA RCT Single-component trial to assess the efficacy of an app for helping people progressively master healthy habits	App: *Fittle* Population: 124 adults (>18 y) ePaper Solo: PDF wellness program ePaper Team: PDF wellness program + team emails Mobile Solo: app with 1-person team Mobile Team: full app Duration: 8 wk	19 users completed 8 wk field study Pre- and post-test instruments to assess healthy eating, PA and stress levels, behavior change intentions and the System Usability Scale App usage logs were collected Interviews to explore group interaction effects	To provide ecological momentary interventions and group support	Structured 8 wk challenges involve multiple goals to be achieved during a day Users select predefined challenges Team participation Progress (individual and team) towards goals is graphically displayed in traffic-light format Ability to substitute goals within challenges Interactive team activity feed, accessible through always-present dashboard multimedia posting bar Share information, give high-fives and comment on team posts Peer-to-peer messaging system Virtual badge rewards	Detailed information about goals that can include images, background information, external links Nutrition messages include eating slowly, adding a serving of vegetables, add a small healthy meal while reducing the others and keep a food diary	Theory of planned behavior, goal setting theory and ecological momentary intervention	All participants in consumer testing and trial reported positive changes in healthy eating Having people work in teams led to higher adherence and engagement over time Participants in Paper groups reported more improvements in healthy eating than mobile groups, however attrition was higher in Paper
Skau et al. 2016 (47) Malaysia RCT protocol Multi-component trial to assess the efficacy of a complex behavioral change intervention to enhance women's health prior to pregnancy	App: unnamed Population: Young women (20-39 y) prior to pregnancy Intervention: meetings + phone calls + Whatsapp group chat with community health promoter + app Control: no intervention Duration: 8 mo	ND	To support healthy habit formation	Participants and spouses can select monthly challenges for obtaining a healthy diet (e.g. 'avoid soft drinks 3 d/wk challenge') Challenges include making healthy choices and healthy food preparation Progress tracking Competition between spouses Customizable reminders (time or location based)	Challenge descriptions provide instructions for each challenge, and education on why this is a healthy approach including diet-disease links General information about healthy lifestyles (including diet)	ND	Protocol only

Volkova et al. 2016 (69) Volkova et al. 2014 (53) Dunford et al. 2014 (81) Australia and New Zealand RCT protocol Single-component trial to assess the effects of two interpretive front-of-pack nutrition labels on healthiness of consumer food purchases	App: *Food Labelling Trial (FLT) app* with intervention component based on *FoodSwitch* Population: 1500 adults (>18 y) Intervention 1: Traffic-light labels Intervention 2: Health-Star-Rating labels Control: standard, non-interpretive labels Duration: 5 wk	An initial test version of *FoodSwitch* was built and deployed for acceptability testing with a limited group of users associated with the development team Feedback was incorporated and then a second prototype deployed to a broader group of external stakeholders	*FLT:* fully automated delivery of the RCT from obtaining consent, through intervention delivery and outcome assessment *FoodSwitch:* To provide Australian consumers with access to easy-to-understand nutritional information about packaged and processed foods	*FoodSwitch:* Barcode scanner Detailed food product information (nutritional traffic light display) Uses branded food composition database from The George Institute for Global Health Share observations via social media Crowdsourcing function incorporated where users can provide images of products to send to data management centre for updating database	*FoodSwitch:* Immediate Traffic-light, or Health-Star-Rating style display of total fat, saturated fat, sugar, salt and energy density of scanned products Immediate suggestion of alternative, healthier, products, also showing their traffic-light or star-rating profile Food product comparison based on FSANZ Nutrient Profiling Scoring Calculator enabling ranking of foods For specific food categories such as SSB a standard message about making healthier choices is provided instead of alternative product suggestions	ND	FoodSwitch has over 600,000 users and maintains a 4+ star rating in iTunes Crowdsourcing function extremely successful for maintaining an updated and useful database of products
Lin et al. 2015 (52) Svetkey et al. 2015 (49) Batch et al. 2014 (59) USA RCT Multi-component weight-loss trial	App: *Cell Phone Intervention for You (CITY)* Population: 365 young adults (18-35 y) BMI >25kg/m^2 Intervention 1: program delivery via app Intervention 2: program delivery via personal coaching calls + group sessions + app for self -monitoring Control: advice only	Paper prototypes used in testing with target users The research team (mainly young adults) tested the prototype app components	Program delivery in Intervention 1, self-monitoring of dietary intake in Intervention 2	Detailed food logging Simple food groups logging Real-time view of daily calories consumed and available Buddy system with random pairing every 4 wk Dietary and weight goal setting with feedback towards goal Rewards in the form of cartoons, video links, blog entries when they achieve a certain tracking level Within app alerts to resume use after periods of inactivity including audio, vibration and turning screen on/off	3-8 min coaching tutorials on lifestyle change topics Live wallpaper including tips for healthy living, jokes and motivational quotes	Social cognitive theory, behavioural self-management, transtheoretical model and motivational enhancement approaches Iterative participatory design	No difference in weight loss at 24 mo between groups Some notifications and live wallpaper considered too obvious/personal if someone else were to use their phone, so sent through text message instead Deploying content periodically was useful for maintaining app engagement

	Duration: 24 mo			(full-application-interruption prompting and peripheral prompting) Peer-to-peer messaging Food quiz Motivational push notification tailored to self-reported behavior			
Rabbi et al. 2015 (51) USA RCT Single-component trial to determine the effect of personalised feedback on PA and eating behavior	App: *MyBehavior* Population: 18 adults (17/18 completed) Intervention: personalised suggestions through app Control: non-personalised suggestions through app Duration: 3 wk	ND	To support users to make positive PA and eating behavior changes	Food logging using a USDA database of 8000 foods, entering customized quantities for calorie intake Can photograph foods as a memory aid Option to reuse prior meals Direct entry of calorie information if available Life-Log of all the day's events including PA and food logging	Clustering of food types based on similar ingredients Suggestions to improve food intake based on clustering Suggestions are based on frequently occurring low-calorie food the user already logs, or infrequently occurring but previously completed extremely low-calorie meals/snacks App suggests 10 suggestions (9 frequent, 1 infrequent) every morning	Learning theory, social cognitive theory and Fogg behavioral model	Users rated personalised suggestions more positively than non-personalised Intervention groups showed superior behavior changes compared to control Manual logging was considered time consuming, but made users more aware of their foods Crowdsourcing based semi-automated approaches to food logging desirable
Schaefbauer et al. 2015 (50) USA Controlled trial Single-component trial to determine the effect of *Snack Buddy* on family snacking behaviors	App: *Snack Buddy* Population: 10 low SES families including 1 primary and 1 secondary carer Intervention: app Control: no app Duration: 12 wk	Lab members used *Snack Buddy* for one mo	To assist users to track snacking, receive feedback on healthiness of snacks, and review snack healthiness of family members	*Both interfaces:* Snack logging *Informational interface for primary carers:* Detailed snacking history for all family members Access to gaming interface *Gaming interface for secondary carers:* Average snacking history for family members Narrative based game where an avatar is selected and life-goals met through earning points for snacking healthiness. Healthiness points (1-10) awarded based on snack healthiness	Feedback on snack healthiness based on Fooducate database using a 0.5-5 star rating scale App provides healthier snack suggestions based on same type of food but 1 star improvement Comparison of snacking history with other family members	Social cognitive theory and transportation theory Needs assessment approach	*Snack Buddy* increased family members' snacking awareness individually and at the family level Separate interfaces useful – ability to switch undesired Teenagers found gaming interface 'fun' and 'cool', primary carers found it complicated Messaging feature not perceived as useful Within family competition motivated engagement with app,

				Peer-to-peer messaging			healthier snacking and dialogue about snacking Ability to track family snacking assisted in primary carers suggesting alternatives Social comparison facilitated healthier choices Missing cultural foods was a problem
Eyles et al. 2014 (58) New Zealand RCT protocol Single-component trial to determine the effect of *SaltSwitch* on the salt content of foods purchased	App: *SaltSwitch* Population: 300 adults (>40 y) with a CVD diagnosis Intervention: app Control: no intervention Duration: 6 wk	ND	To support users to make lower-salt food choices	Barcode scanner Detailed food product information (nutritional traffic light display) Crowdsourcing function incorporated where users can provide images of products to send to data management centre for updating database	Immediate Traffic-light style display of total fat, saturated fat, sugar, salt and energy density of scanned products Immediate suggestion of alternative, healthier, products, also showing their traffic-light or star-rating profile Healthier alternatives are always lower in salt than the product scanned Food product comparison based on FSANZ Nutrient Profiling Scoring Calculator enabling ranking of foods	ND	Protocol only
Hebden et al. 2014 (36) Hebden et al. 2012 (37) Australia RCT Multi-component mHealth intervention to	App: *eVIP* (F&V), *eSIYP* (SSB), *eTIYP* (fast food) Population: 51 university students and staff (18-35 y) BMI 24-32kg/m^2 Intervention: Diet booklet + SMS + emails + apps + internet forums Control: diet booklet Duration: 12 wk	2 authors entered data at random in each app checking data output was correct 21 adults participating in a weight-loss trial were provided with the apps Post-test online survey regarding ease of download,	Support change in excessive intake of high-fat fast food, over consumption of SSBs, inadequate consumption of F&V	Food and drink logging via search of foods/drinks in database Daily or weekly summaries of intake with reference to ADG Motivational tips tailored to self-reported behavior Recipe ideas	Images of young adults with normal healthy appearance performing target behaviors and healthier food and drinks Information on relevant ADG targets *eVIP*: graphical display of F&V serving compared to ADG *eSIYP*	Transtheoretical model strategies of self-regulation, self-monitoring, planning, self-efficacy and self-reevaluation	Both groups lost weight, increased F&V intake and decreased SSB intake Log-ins undesirable Slow running speed as app required internet connection undesirable

improve body weight, BMI and lifestyle behaviors		potential improvements and other comments			color display of total energy, sugar and alcohol from drinks compared to ADG *eTIYP* color display of average energy and fat of fast food meals compared to ADG		
Lubans et al. 2014 (57) Smith et al. 2014 (55) Smith et al. 2014 (54) Australia Cluster RCT Multi-component Active Teen Leaders Avoiding Screen-Time (ATLAS) intervention, primarily aiming to reduce screen time, increase PA and reduce SSB consumption	App: *ATLAS app* Population: 361 adolescent males at risk of obesity Intervention: ATLAS program Control: no program Duration: 20 wk	ND	Enhance participants' outcome expectations regarding the consequences of excessive SSB consumption	Push notifications	Informational (consequences, behavior-health link) and motivational (encouragement) push notifications sent twice weekly through app, some relating to SSB consumption	Self-determination theory and social cognitive theory	Intervention group significantly reduced SSB consumption Push notifications reminded participants to drink less sugary drink Participants found push notifications to be a nuisance due to frequency, repetitiveness and inappropriate timing (midnight) Simple messages written in vernacular 'text speak' desirable
Morrison et al. 2014 (56) UK Clinical trial Multi-component,	App: *POWeR Tracker* Population: 13 university students and staff (18-52 y) BMI ≥23kg/m^2	ND	Enhance participants' self-reported goal engagement (motivation for goal pursuit,	Dietary goal setting Daily goal progress tracking User-controlled automated reminders Motivational tips tailored to self-reported behavior POWeR stars awarded for goal tracking, max 7 per wk	Selected POWeR content such as color coded food lists (low/med/high calorie and carbohydrate foods) with guidelines on frequency of consumption	Health action process approach	Hybrid web- and app-based intervention encourages greater goal engagement than web- or app-based interventions alone App use was positively correlated with effect on

web based weight management program Positive Online Weight Reduction (POWeR). Included diet and PA goals	Group 1: access POWeR content on wk 1 and 3 Group 2: access POWeR content on wk 2 and 4) Duration: 4 wk		coping self-efficacy, action control and achievement of goals)	Manual food logging	Question prompts to aid in evaluation of food tracking		awareness and achievement of eating goals Regular use of tracking tools enables critical self-reflection prompting further goal-directed behavior App perceived as more conveniently accessed than web platform Would have preferred barcode scanners and drop-down menus for food intake tracking App valued for short bursts of activity in moments of free time and when shopping/cooking Number of reminders received did not impact eating goal engagement, and were only acted on if received at a relevant time
Brindal et al. 2013 (60) Freyne et al. 2012 (61) Freyne et al. 2010 (66) Australia RCT Multi-component trial	App: *Weight Management Mentor* Population: 58 females (19-63 y) BMI ≥25kg/m^2 Intervention: fully interactive app Control: baseline app with no interactive features or prompting Duration: 8 wk	ND	Support tool for individuals engaged in a weight loss program	Simple food logging with drag and drop interface Pop-up notifications on phone home screen prompting data entry upon failed expected entry (initiates data entry tasks) Customizable push notification reminders for food logging at meal times Creates graphs of real time progress for dietary intake and compliance with diet Calendar showing previous compliance	Poses questions leading to reflection on eating behaviours with feedback based on responses Questions based on time of day, previous information entered, stage in diet program Featured articles about general wellness including nutrition Links to additional information, ie. websites Answers FAQs	Health Action Process Approach	No difference in weight loss between the groups Interactive app resulted in more days of and greater amount of interaction with app – accessed app >10 times more Self-monitoring and prompting were the most beneficial aspects of the app Gamification aspect (trophy room) not

for compliance with Celebrity Slim meal replacement program				Virtual rewards in trophy room, with progress towards next trophy Motivational messages tailored to self-reported behavior Recipe ideas			embraced with this group
Lee et al. 2010 (63) Korea Case-control study Single-component trial of the efficacy of the app	App: *SmartDiet* Population: 36 obese adults Intervention: app Control: ND Duration: 6 wk	Pre-tested by nutritionists and nurses at the obesity clinic	To track obese patient's daily nutrition intake for weight control	Avatar showing the user as 'skinny', 'normal' or 'fat' which was altered based on weight changes Records of daily calorie intake (app calculated based on anthropometrics/demographics) and consumption tracking Food database for meal logging Quiz based diet game with questions about lifestyle, calories consumed and calories digested	Diet game provides feedback about correct answers with additional nutritional information	ND	Mobile phones have the potential to contribute dietary management and users find *SmartDiet* useful and effective in controlling weight
Pollak et al. 2010 (62) USA Pilot controlled trial Single-component trial of the efficacy of the app	App: *Time to Eat* Population: 53 adolescents Intervention: app Control: no app Duration: ND	Testing of prototypes with target demographic prior to deployment	To support and encourage healthy eating habits in seventh and eighth graders	Virtual pet game mimicking other successful virtual pet games (e.g. Tamagotchi) User adopts and names a pet User photographs meals/snacks which score a rating from -2 to +2 depending on healthiness User's overall score determines pet's emotional state when player logs in (sad-happy), and pet's appearance changes based on scores	Pets send users healthy-eating reminders (e.g. 'Remember to eat breakfast today') Feedback on healthiness of photographed foods provided, also feedback if no foods were consumed Suggestions of healthier alternatives provided in feedback	Fogg's behavioral model	App users ate a healthy breakfast more frequently than non-users Emotional and social realism of the game were important for motivation The game would benefit from incorporating social features like chat, competitions between peers and ability to view and comment on other player's pets Enabling crowdsourced feedback/image recognition of foods would enable increased scale

Abbreviations: ADG, Australian dietary guidelines; BMI, body mass index; CVD, cardiovascular disease; FAQs, frequently asked questions; FSANZ, Food Standards Australia New Zealand; F&V, fruit and vegetables; ND, not described; PA, physical activity; RCT, randomized controlled trial; SMS, short message service; SSB, sugar-sweetened beverage; USDA, United States Department of Agriculture

Supplemental Table 3. App description papers with/without uncontrolled consumer usability testing. Twenty-one discreet app development projects are included.

Article	Aim of app	Consumer testing of app	Nutrition relevant app features	Nutrition relevant app content	Strategic approach/theory	App evaluation
Epstein et al. 2016 (80) USA App development with consumer testing	App: *Food4Thought* Support mindfulness and offer opportunities to learn about food Target population: General population	61 participants used app in a 3 wk field deployment Split participants into 4 groups using 2x2 design, nutritional/non-nutritional challenges and social/non-social Facebook group Pre-and post-surveys assessing prior food journaling experiences and app satisfaction/experience Post-study interview about app experience with 19 participants	Daily challenges of consuming one food that meets the challenge Notification of the day's food challenge at customizable time Photograph foods using phone camera Private Facebook group to post challenge photos Previous challenge and photo history can be viewed Automatic daily upload of people who met the challenge to Facebook, with photos Challenges can be personalised to nutritional goals, dietary excesses or deficiencies	Challenges can be nutritional, 'eat something high in fibre' Non-nutritional challenges promote mindful eating, 'eat something yellow' Content areas cover food groups, specific nutrients, reducing undesirable nutrients, diet-health links and glycemic index	Mindful eating, social engagement, low burden, low judgement approaches	Both nutritional and non-nutritional challenges prompted consideration of food choices Increased mindfulness, learning about food and changes in diet can be achieved through eating and recording only one food per day Situational relevance of challenges was important (weekend vs weekday) Social intervention amplified engagement and facilitated learning
Ahn et al. 2015 (92) USA App development with consumer testing	App: unnamed To support healthy grocery shopping Target population: General population	15 users completed preliminary online survey, in-person survey after accompanying researcher using app instore, and satisfaction survey 104 watched online demonstration and completed Questionnaire for User Interaction Satisfaction (QUIS)	Augmented reality tagging of (un)healthy products Aisle based display Product information screen with price, nutritional information and selling rating when clicking on a product's tag User determined nutritional combinations (calorie, sodium, fat, sugar, lactose free, nut free) used for tagging	Nutritional tagging of products as (un)healthy (green and red tags) Recommendations based on dietary guidelines	Needs assessment (through preliminary online surveys)	Most participants found the system was useful for its intended purpose
Brand et al. 2015 (89) USA App development	App: *Mommio* To train mothers of pre-schoolers in effective vegetable parenting practices	20 mothers reporting difficulty getting their child to eat vegetables, (20-40 y) played *Mommio*	Virtual reality game simulating mother and vegetable-hating-child interactions Character appearance customizable	Player selects recipe from kitchen's recipe box (instructions and nutritional information included), then convinces child to eat it	Social cognitive theory and self-determination theory	Knowledge, transferable skills, self-efficacy and intrinsic motivation to support pre-schooler vegetable consumption (aspects of the underpinning theories) were gained through playing *Mommio*

with consumer testing	Target population: Parents of pre-schoolers	Mothers played single quests under observation for 1 hour (1-4 single quests) Semi-structured interview regarding perceptions of game content, features, applicability and usefulness followed game play	Simple recipes for vegetable and non-vegetable side dishes	Strategies for convincing child include statements (modifiable by voice tone, facial expression) and changes to virtual environment Strategies move player closer to child eating vegetable (win), or leaving room (loss) Also provides tailored motivational tips/strategies/plan for increasing vegetable consumption based on identified parenting values		Found customizable child appearance/naming feature motivating Felt tailored within-app feedback should be provided at end of each quest
Curtis et al. 2015 (86) UK App development with consumer testing	App: unnamed To support parents in childhood weight management through portion sizing and frequency Target population: Parents of overweight children	20 parents participated in 3 focus groups Overall usability and experience impressions of app based on interactive mock-ups Laptop, tablet and projector used to present mock-ups Content of app refined after first 2 focus groups, revised app presented to third	Goal setting Food logging using camera Visual feedback on progress towards goals and food groups to target in following wk Points and awards for completing activities, logging food and helping family members Parents receive daily notifications, within app text messages and feedback regarding child's progress Peer-to-peer messaging Daily quiz Healthy recipes	Balance wheel and portion guide tool as reference Quiz questions on portion size and food group balance Parents signposted to local dietitians, groups weight management programs	Behavior Change Wheel and user centred design	ND
Gilliland et al. 2015 (65) Canada App development with consumer testing	App: *SmartAPPetite* To encourage healthy eating by reducing educational, behavioral and economic barriers to accessing healthy, local food	208 users trailed the app for 8-10 wk Users received 2-3 daily notifications Initial survey to asses dietary habits and goals, then message uptake tracking using Google Analytics (frequency of links followed), telephone interviews	Push notifications delivering nutrition and healthy eating tips, recipes and local food vendor information Clicking 'like' on the messages provided additional tips on related topics	Message content included diet-health links, consequences and contingent rewards, prompts for intention formation, instruction and specific goal setting, time management tips, links to	Behavioral economic theory, Atkin's and Michie's principles of individual behavior change, iterative participatory design	Participants who were more engaged with the app experienced more positive dietary changes Information relating to seasonal and local foods most valued; produce storage/prep, recipes and vendor sales the least

	Target population: General population	during study to assess experience and follow-up survey to assess dietary and goal changes	Motivational interviewing principles and follow-up prompts were also used	further information (health behavior, vendor websites) Canadian dietitian and public health websites used to inform messages		Hesitancy to connect the app with social networking sites Timing of messages important
Knight-Agarwal et al. 2015 (76) Australia App development with consumer testing	App: *Eating4Two* To provide women with the tools and motivation to achieve a healthy weight gain during pregnancy Target population: Pregnant women	10 pregnant women (<30 wk gestation) used the app for 6 wk Asked to weigh weekly and view nutritional information as desired Online usability survey at 3 wk assessing if content was helpful and most/least liked features 2 focus groups and 1 interview post-evaluation to assess the above again	Pregnancy relevant food menus	Information about nutrients with practical dietary examples Information about foods and dietary symptoms and behaviors relevant to pregnancy Photographs demonstrating recommended food portions and standard servings for all food groups	ND	App was found to be a support system to help motivate healthy behaviors during pregnancy Images demonstrating portion sizing found helpful and important Nutrition information to have a more user-friendly presentation desirable
Mann et al. 2015 (74) Australia App development with consumer testing	App: *WIZE app* To improve bioavailable iron intake Target population: Premenopausal women	26 women aged 18-36 y used the app for 2 wk Continued use of app encouraged through reminder emails sent through trial period Semi-structured 1-hr focus groups (6-7 participants) assessing dis/likes for each app section and usability	Weekly goals for dietary iron intake introduced incrementally, with goal tracker Iron related word search and word jumble games Photo diary function for dietary tracking	7 fact sheets providing information about rich dietary sources of iron and iron/health relationship Recommendations to increase iron-fortified food intake, consume foods rich in Vitamin C with meals and avoid coffee/tea with meals	Social cognitive theory, health belief model and self-determination theory	Facts were succinct, interesting, easy to understand, informative and best part of the app Participants requested extended information (e.g. link) option Mixed opinions about games, suggested quiz would be better with incentives Goals needed to be clearer Participants wanted pop-up notifications and reminders to complete and enter goals Feedback on strategies for achieving goals desirable Photo diary disliked/pointless Personalisation of interface desirable Colors and pictures desirable

Miller et al. 2015 (73) USA Needs assessment, app development and consumer testing	App: unnamed To provide health behavior information and resources specific to university students Target population: College students at a specific university campus	Focus groups with 9 students assessed first impressions of app, dis/likes and suggestions for improvement iPads used for app prototype navigation during focus groups	Information about campus specific resources (e.g. campus venues, healthy menu items, vegetarian options, nutritional information of selected menu items) Campus map with food venues mapped	'Health tip of the day' including nutritional tips Health promotion information about nutrition and the importance of healthy eating	Needs assessment approach	More interactive features desirable (e.g. calorie tracking)
Simons et al. 2015 (70) The Netherlands App development and consumer testing	App: *Health Quiz app* To support a healthy lifestyle support service mix Target population: General population	86 users tested app in a multiple-case study over 10 mo Design survey at 1 mo to assess the health promotion value of service elements (including app) and the usefulness and ease of use of the app Logging of app use also carried out	Push notification micro learning cards contain questions with multiple choice answers options Course content (focus of learning cards) is structured to address consecutive learning objectives (knowledge and awareness, motivation and plan making, support for daily activities and coping strategies, self-norms and self-identity) Participants can switch between 'courses'	Brief explanation for correct answer after each answering attempt Learning cards educate on basic knowledge of healthy food and daily tactics of healthy food	Micro-learning principles	Health behaviors improved after using the *Health Quiz app* Users reported it was efficient, useful, fun and they learned from the app There were low barriers to use of the app reported

Waltner et al. 2015 (64) Austria App development	App: *MANGO app* To support users to make food choices consistent with CVD risk reduction during everyday grocery shopping Target population: General population	ND	Video based food recognition Browse food database Detailed information about macronutrients and health claims about selected foods	Food recognition shows food and alternatives with ranking bar display of how well the food matches their dietary profile Information about the functional eating concept Dietary questionnaire to tailor dietary profile	ND	ND
Helander et al. 2014 (78) Finland Study of active and less active users of commercial app	App: *The Eatery* To support healthy eating Target population: General population	Commercial app	Photographic food recording using camera Automated historical daily healthiness ratings and overall healthiness rating Prompts to rate other users pictures upon opening app Option to follow other users and 'like' or comment on pictures	Users rate other users pictures also, each picture receiving an average healthiness rating based on crowdsourced feedback Users take a picture of foods pre-consumption and rate the healthiness on a fat (unhealthy) to fit (healthy) scale Automated feedback on weekly healthiness and comparison to other users Automated best and worst meal of the wk and most frequent eating locations	Commercial app	Use was higher in users with strict diets Feedback from peers fostered engagement
Vylegzhanina et al. 2014 (68) USA App development	App: *CHEW app* To simplify the purchase of life-stage appropriate, nutritious foods when shopping Special Supplemental Nutrition Program for Women, Infants and Children (WIC) participants are	Weekly sprints of design, development and testing culminating in meetings with project stakeholders to elicit feedback Conducted several shopping trips with WIC participants in store environments	Barcode scanning of products Push notifications Compares scanned items for voucher eligibility and tracks selections by family or family member Fresh produce cost calculator using a scales widget wheel, and tracking of voucher value used	Push notifications of general healthy tips (e.g. portion sizes for pre-schoolers and distributing healthy snacks throughout the day) Strategies/plans/tips for helping children eat more healthily	User involvement in app development	No internet connection required a desirable feature

	provided with shopping vouchers for individual family members Target population: WIC participants (low income pregnant, or postpartum women and children <5 y at nutritional risk)		Recipes of easy-to-prepare, healthy snacks for children including text and pictures, and some videos of meal preparation Prompts for recipe selection before shopping trip, with automatic upload of ingredients to a within-app shopping list			
Anwar et al. 2013 (91) USA App development	App: *Kalico* To assist users to select a healthy eat-out menu item on a budget Target population: General population	ND	Log of dietary events Searching of available meals within restaurants meeting user-defined criteria on price, calories, macronutrient, sugar and sodium content	Health tips relating to macronutrients Customizable meal profile criteria	ND	ND
Carroll et al. 2013 (88) USA App development with consumer testing	App: *EmoTree* To provide just-in-time support for emotional eating Target population: People who identify as emotional eaters	11 participants used the app for 4 d and completed pre-(participant awareness of eating behaviors and emotions) and post-surveys (success of intervention and possible alternatives)	Users input mood (valence and arousal) data and engagement with current task hourly Reminders to input data sent hourly Food diary including 3 domains of food healthfulness, volume and hunger state at consumption After logging food users again log emotions immediately prior to eating Overall progress can be assessed through 'history' icon on home screen	Home screen includes a tree that grows over time with leaves (representing days) colored based on food intake decisions	Cognitive behavioral therapy Iterative needs assessment approach	Logging eating behaviors with emotions increased awareness of eating behaviors Personalisation of intervention important Options for future interventions: presentation of something funny, gratitude questionnaire, meditation, suggestion of a walk, brain teasers/games, questioning hunger, reading or writing, calling a friend.
Robinson et al. 2013 (72) UK App development with consumer testing	App: unnamed To support attentive eating Target population: Overweight/obese populations	12 overweight/obese participants used the app for 4 wk A log of button pressing was used to track app use Follow up session 2-3 d post app installation for technical issues, and 28 d follow up for semi-structured interview about	'Snap' function enables photographs of food prior to consumption, with push notification to remind users to complete the 'Most Recent' function after eating 'Most Recent' function provides information about recently consumed foods	Information sections about principles of attentive eating, how these principles reduce energy intake and other attentive eating strategies Prompts 'Did you finish it all? How full are you now?'	Behavior Change Wheel framework	Participants felt that using the app raised their awareness about what they had been eating, and think more carefully about it leading to changes in food choice decision making

		impressions and experiences using app, followed by self-report questionnaire measuring ease of use, convenience, integration into daily routine, and future use intentions	'I've been eating' function provides push notification of 'remind themselves what they have been eating' and then is an interactive chronological slide show of food recorded during the day Personalisation of app with automated reminders at usual meal times			
Khan 2012 (77) USA App development with consumer testing	Apps: *Snack Manager* *Snack Educator* *Lifespan* *Health heroes* To improve personal and family snacking behaviors Target population: Low SES primary (parents) and secondary (older teens) caregivers	'Multiple cognitive walkthrough iterations' 26 primary and secondary caregivers presented a task list and scenario. Prototypes presented in random order. Questions related to features they (dis)liked, reasoning for choices and potential improvements Post-testing ranking questionnaire with rating of importance of app features	*All apps:* Food logging of snacks View individual snacking history View family snacking healthiness *Snack Manager:* Peer-to-peer messaging Shopping list *Snack Educator:* *Lifespan:* Game based - Animation-based narration where game character life-progress reflected healthiness of snacks with goal to earn points *Health Heroes:* Game based – character defends city against a villain by gaining superpowers through eating healthier snacks Multi-player for family teams	*Snack Manager:* Feedback on snack healthiness (star rating) Suggestions to replace snack with healthier snack within price threshold *Snack Educator:* Suggestions to replace snack with healthier snack Displayed unhealthy snack's potential negative impact on heart, body, teeth and compared with healthier snack Proportion of (un)healthy snacks represented as colored bars (green = healthy, red = unhealthy) Virtual categorisation of individual long-term snacking consumption into healthy, average or unhealthy *Lifespan:* Game character reactions to snacks	*Snack Manager:* Social-cognitive theory *Snack Educator:* Social-cognitive theory, health belief model and elaboration likelihood model *Lifespan:* social-cognitive theory, transportation theory and precaution adoption process model *Health Heroes:* social-cognitive theory and transportation theory	Primary caregivers preferred *Snack Manager,* while secondary caregivers rated this poorly, preferring *Lifespan* Primary caregivers preferred non-gaming or hybrid apps, while secondary overwhelmingly preferred gaming apps Need to incorporate some snack frequency limit *Snack Manager:* Peer-to-peer messaging desirable Primary caregivers preferred star representation of snack healthiness, but secondary caregivers found it uninteresting Primary caregivers favored views of family health, while secondary favored individual Displaying snack prices was seen as irrelevant and discouraging Secondary caregivers found repetitive images unengaging *Snack Educator:* Liked realistic aspect of (un)healthy snack implications Some wanted additional nutritional details of snacks rather than pictorial representations

						Color representations of snack healthiness easily interpreted, but could not account for snack quantity *Lifespan:* Healthy competition aspect favored by both groups, although negative points were not well understood Relatability of game character motivating *Health Heroes:* Primary caregivers and older teens considered it childish, difficult to understand, not relatable and not motivating Young males preferred it as game action was exciting
Lopes et al. 2011 (75) Silva et al. 2011 (71) Portugal App development with consumer testing	App: *SapoFitness* Obesity prevention Target population: General population/those at risk of obesity	Exhaustive running experiments to test app components 106 users provided feedback about usability and efficacy through Survey Monkey survey	Manual food logging using internal database (provides suggestions based on letters typed) and quantities Calculates estimated caloric requirement based on manually entered anthropometrics Tracking of daily calories consumed/remaining Optional sharing of performance and achievements through existing social networks (Facebook, Twitter, etc)	Suggests meal plans Tailored alerts regarding diet progress based on food logging Information about dangers of obesity/malnutrition and nutritional status	ND	Users found the app helpful for meal control
Arsand et al. 2010 (90) Arsand et al. 2008 (67) Norway App development	App: *Few Touch* To assist users to self-manage lifestyle behavior related to diabetes management (monitoring blood glucose, nutrition habits and PA) Target population: Diabetics	*Early prototype testing* Modified think-aloud protocol 6 test sessions with individual diabetic participants 90 min videorecorded test sessions involving participant observation and interview while using the app prototype under simulated conditions	Manual food logging (high/low carb snack, high/low carb meal, high/low carb drink) Dietary goal setting Graphical display of cumulative totals of consumption within food categories as compared to stated goals	Food related 'tips' provided in the general information function	Iterative participatory design	Act of dietary tracking was inherently motivating Reward (such as education about the meal entered or immediate feedback on progress towards goals) should be incorporated at each meal entry to compensate for work done Ability to tailor and self-configure the app, download info for longitudinal progress view, delete or

with consumer testing		Participants reported on design strengths and weaknesses, ease and contexts of use, potential utility, compared and contrasted preferences for features, functions and overall design concepts *Later testing* 12 diabetics tested the app in their daily lives for approximately 6 mo The paper prototyping method and System Usability Scale were used to assess usability				edit submitted entries were seen as desirable improvements Incorporation of negative as well as positive reinforcement was suggested Simple food logging categories were too broad, but useful for working with F&V habits Participants felt motivated by challenges Must be connected to the internet
DeShazo et al. 2010 (85) USA App development with consumer testing	App: mini-games *Hangman* *QuizShow* *Countdown* To improve nutritional-estimation and food-comparison skills Target population: Diabetics	*Formative testing* 2 focus groups (11 people total) Feedback from first group used to refine prototypes for second focus group Games described to groups and demonstrated with mock-up screens Transcripts analysed for group's thoughts about features, game play, scoring and difficulty level *Remote testing* Initial component testing by internal peers 10 external testers Usage metrics and 11-item online questionnaire assessing enjoyment, nutritional relevance, amount learned, level of challenge, simplicity of game play and confusing elements	*All apps:* Mini-games customizable by diet (vegetarian or not), nutritional goals (carbohydrates, calories or energy density) and skill level (easy, hard)	*All apps:* Nutritional information adapted from USDA Food and Nutrient Database for Dietary Studies *Hangman:* Players have 6 guesses to estimate carbohydrates or calories in a food item Nutritional feedback on guesses *QuizShow:* Multiple choice television show-style nutritional knowledge Players have 3 'lifelines' available for hints *Countdown:* Players choose between 2 foods given a category accruing points for fast correct responses	Health communication and education theory including tailoring, scaffolding, interactive learning technique and linking educational attainment score	All but one tester reported learning about nutrition through games Participants commented games are more for young people Short game play expected (good to use while passing time waiting for something else) QuizShow most preferred by testers (average age 38 y) Tailoring of favorite foods for incorporation into game play desirable
Dorman et al. 2010 (83)	App: *Nutrition Monitor*	ND	Food logging	Feedback regarding whether scanned product is	ND	ND

USA App description paper	Promote healthy eating through dietary monitoring and modification Target population: General population		Manual entry of barcodes or barcode scanning of packaged foods Common list of frequently consumed products Provides ingredient lists and nutritional information Separate 'grocery' and 'meal' modes for tracking purchases and meals Provides running totals of calories and macronutrients, with option to select serving sizes consumed in Meal Mode Report generation of dietary intake between entered dates	consistent with Dietary Guidelines for Americans Prompts such as 'you are 50% over your daily energy limit' Shopping Mode provides warnings about high-level energy or fat content of scanned foods Requires initial web-based profile set up including selection of predefined or personalised diet plan		
Grimes et al. 2010 (79) USA App development with consumer testing	App: *OrderUp!* Support users to make healthier meal choices Target population: African American adults in the Southeastern US	12 participants were asked to play at least once per wk, for 3 wk Pre- and post-surveys and interviews were used to assess impact on nutrition-related attitudes, thinking and actions, and how often they played the game, how relevant the foods were and how entertaining it was Participants kept a diary of when and where they played, final score, entertainment level and if the game caused them to think about eating habits (and how so)	Player assumes role of restaurant server with the goal of making the healthiest meal suggestions to customers, allowing her to keep her job Each customer presents 3 common fast food meal choices for player to select Customers start with a health score of 100, decreasing with all meal choices (smallest decrement with healthiest choice) Customer must be served in 6 seconds Game design tailored to African American cuisine	Flashing stoplight feedback on the healthfulness of the meal chosen for each customer	Transtheoretical Model	Participants reported the game helped them to think about nutrition in their own life Stoplight feedback corrected faulty thinking Choosing between 3 option helped with learning about relative healthiness of foods, and added complexity More feedback on why the choices we/were not the healthiest was desired Playing led participants to have conversations about nutrition in social life Incorporating culturally relevant foods enabled transfer of learning to real life

Abbreviations: F&V, fruit and vegetable; ND, not described; PA, physical activity; SES, socio-economic status; USDA, United States Department of Agriculture

Supplemental Table 4. Qualitative studies informing app development with consumer groups. Six discreet studies are included.

Article	Population	Aim of app	Nutrition relevant app features	Nutrition relevant app content	Strategic approach/theory	App evaluation/additional points for consideration
Wang et al. 2016 (97) Norway Focus group and questionnaire study	15 app users and 8 non-users participated in focus groups 500 questionnaire respondents	Promote healthy eating and PA	Self-assessment tool to track macronutrients and overall diet quality/balance Demonstrate progress over time Databases including locally relevant food products (e.g. products found in Australian marketplace) Connecting to social networking sites	Advice or feedback (hints, tips) based on tracking data Tailoring to match personal/subgroup (e.g. adolescents) requirements	ND	App users find diet apps effective in promoting healthy eating though effects on their actions, health consciousness, self-education App users find diet apps effectively assist them to eat more F&V, less fast food, less SSB and choose healthier food products Diet apps more effective when frequently used and over long time periods Young adults find diet apps fun but time consuming
Gowin et al. 2015 (99) USA Interview study	27 college students (18-30 y)	Support health and fitness	Dietary self-monitoring, with reminders Visual cues to increase awareness of target behaviors such as 'calories remaining' switching from green to red	ND	ND	Excessive data entry in setup, complicated operating procedures or features requiring instructions undesirable Mixed feelings about sharing on social media, but most participants do not use these features Competitive elements desirable Positive and negative reinforcement motivating
Tang et al. 2015 (98) UK Interview study	19 young adults (18-40 y)	Support weight-loss (including eating and PA)	Dietary goal setting Food logging with comprehensive database Visual cues to prompt actions Visual representations of progress for food intake self-monitoring Gamification Constantly updated statistics for real-time self-monitoring Barcode scanner Notifications and reminders Feedback on calories, macronutrients and other dietary quality indicators Online contact and support/social networking (but *voluntary* sharing) Optional forums/chat rooms Virtual rewards Mood and emotion logging	Feedback following self-monitoring, including affective and/or physiological consequences for dietary choices Personally tailored advice based on data input (e.g. information and strategies for achieving goals) Energy-balance focus	Use both physical appearance and health-related approaches Behavior change techniques including goal setting, self-monitoring, highlighting affective consequences, providing information, rewards and prompting problem solving	Ease of use and setup, attractiveness of user interface, accessibility are important Comprehensive and easy to navigate food database desirable Feedback on energy-balance desirable Personal tailoring of information, strategies and tools important

Watkins and Bo 2015 (96) USA Focus group study	22 older adults (>60 y)	Support improved F&V consumption	Locate inexpensive and fresh F&V from nearby sources (community gardens or farmers markets) Provide tailored (dietary needs and taste preferences) food and recipe suggestions Track and communicate F&V intake records with doctor	Motivational messages tailored to food logging	Social support approach	Tailoring to personal preferences/needs important
Hearn et al. 2014 (95) Hearn et al. 2013 (94) Australia Focus group study	120 perinatal mothers and 76 perinatal health care providers	App: *Ngala Healthy You, Healthy Baby* Support healthy weight gain during and after pregnancy	Self-assessment tool to track nutrition App alerts corresponding to pregnancy stage/child development Quizzes Recipe suggestions	Supportive tailored feedback based on height, weight and stage of pregnancy/postpartum Tips on how to make improvements Answers to FAQs Infant and toddler feeding guidelines Links to website information	Behavior change techniques including self-assessment, information provision, and goal setting	User friendly format desirable Quality of information important Personalisation desirable Promotion via media and health professionals enhanced use
Dennison et al. 2013 (93) UK Focus group study	19 adults from a University campus	Support health behavior change (including diet, PA and alcohol consumption)	Dietary goal setting Food logging Tracking, monitoring and review tools, especially visually (graphs, patterns) Social sharing with users of same app Competition aspect Tips and advice from other users Prompts/reminders Positive motivational messages and encouragement Connecting with a health professional	Tailored advice or feedback (hints, tips) based on logging Context triggered advice/intervention (eg based on location)	Behavior change techniques including self-assessment, information provision, and goal setting	Manual entry of detail perceived as boring/burdensome Automatic reports sent to nominated support person can be embarrassing Unselective broadcasting of goals/progress to social media sites undesirable User-setting of frequency and timing of prompts desirable Information clearly from a credible source (academic branding) desirable Mixed feelings about requiring logins Mixed feelings about context-triggered advice Full explanation on what the app can and cannot do (eg automatic uploads onto Facebook) desirable High level of detail – exact products/brands for food intake data desirable Personalised settings, ability to turn off/silence features desirable Feedback must not feel like 'telling off'

Abbreviations: FAQs, frequently asked questions; F&V, fruit and vegetables; ND, not described; PA, physical activity; SSB, sugar sweetened beverage