Using technology and tailored feedback to improve dietary behaviours

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Doctorate

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Public Health

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Author’s Declaration

I declare that this thesis is my account of my research and contains work which has not previously been submitted for a degree at any tertiary education institution. To the best of my knowledge, this thesis contains no material previously published, except for peer-reviewed publications where due acknowledgment has been made.

Human ethics

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. It comprises data from two randomised controlled trials: The Connecting Health and Technology Study and the ToDAy Study.

The Connecting Health and Technology Study was registered on the Australian and New Zealand Clinical Trials Registry (ACTRN12612000250831) and received human research ethics approval from the Curtin University Human Resources Ethics Committee (HR181/2011) and the Western Australian Department of Health Research Ethics Committee (#2011/90). The ToDAy trial protocol, qualitative studies and all analyses presented in this thesis have been approved by the Curtin University Human Research Ethics Committee (approval number HR61/2016). The protocol of the trial was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12617000554369). Copies of ethical approval can be found in Appendix A and B.

10th December 2020

Abstract

Background: Together, poor diet and obesity are the leading cause of chronic disease in Australia. Digital interventions that can be delivered remotely and up-scaled have the potential to improve diet quality and produce modest weight loss at a population level. This thesis describes the studies undertaken to design and evaluate a theory driven, digital, tailored weight loss intervention. The aim is to (1) Investigate whether using technology and tailored feedback can improve dietary behaviours and (2) Describe the studies undertaken to develop and evaluate a theory driven digital tailored weight loss intervention.

Methods: A four-stage multi-method approach included (1) a systematic review of the dietary assessment methods used in digital, tailored interventions for weight loss. Next, (2) a process evaluation of the Connecting Health and Technology (CHAT) study to determine the mediators of behaviour change and then (3) six interviews and six focus groups with 56 potential users and health professionals to inform the design and development of Tailored Diet and Activity (ToDAy). Finally, (4) conduct a three armed randomised controlled trial to perform quantitative and qualitative evaluation of ToDAy. Weight and dietary intake data collected at baseline and 6-months were analysed. (5) Telephone interviews with 19 participants who either gained, lost or maintained weight, were conducted to explore their experience of the intervention features.

Results: (1) Systematic review: Out of 222 studies screened at the full text, 13 met the inclusion criteria. Diet records where participants select food and beverage items from an existing database were most commonly used. There was little homogeneity for how the dietary assessment was used to inform tailored feedback, and quality of dietary assessment ranged from brief and inadequate to comprehensive and validated. (2) Process evaluation: Participants who agreed that dietary feedback made them think about vegetables were more likely to increase their intake by at least half a serve than those who disagreed [odds ratio (OR) = 4.28, 95% Confidence Interval (CI): 1.76 to 10.39]. Those who agreed that the text messages made them think about how much 'junk' foods they ate, were twice as likely to decrease their junk food by over half a serve (OR = 2.39, 95% CI: 1.12 to 5.25) than those who disagreed. (3) ToDAy design and development: Thematic analysis of qualitative results revealed dominant themes of misinformation, lack of confidence, and ambivalence hindering weight loss efforts. Participants expressed a preference for image-based dietary feedback with clear, actionable goals to help weight loss and improve diet quality. (4) RCT findings: One-fifth of participants receiving tailored feedback achieved clinically significant weight loss at 6-months (>5%). (5) Exit interviews: Intervention participants attributed the weight loss to increasing knowledge of their diet, self-monitoring of their behaviour, and feedback on their behaviour.

Conclusion: Findings from this body of work present evidence regarding the acceptability and feasibility of using technology to improve dietary intake among adults with overweight and obesity.

Acknowledgements

With a heavy heart, I dedicate this work to my boys who were born sleeping – Daniel, Matthew and Luke. You are always present in my heart. To my husband, Sean, your unconditional love and support has been my rock and my happy place. To our children at home – Jasmine and Christopher, your beautiful faces have given me so much joy and inspired me to be the best version of myself. To my wonderful mother, you inspired my love of food, which has led me to where I am today.

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Acknowledgement of Country

We acknowledge that Curtin University works across hundreds of traditional lands and custodial groups in Australia, and with First Nations people around the globe. We wish to pay our deepest respects to their ancestors and members of their communities, past, present, and to their emerging leaders. Our passion and commitment to work with all Australians and peoples from across the world, including our First Nations peoples are at the core of the work we do, reflective of our institutions' values and commitment to our role as leaders in the Reconciliation space in Australia.

Publications arising from this research

Shoneye, C. L., Mullan, B., Begley, A., Pollard, C. M., Jancey, J., & Kerr, D. A. (2020). Design and Development of a Digital Weight Management Intervention (ToDAy): Qualitative Study. *JMIR mHealth and uHealth*, *8*(9), e17919.

Shoneye, C.L., Dhaliwal, S.S., Pollard, C.M., Boushey, C.J., Delp, E.J., Harray, A.J., Howat, P.A., Hutchesson, M.J., Rollo, M.E., Zhu, F., Wright, J.L., Pratt, I.S., Jancey, J., Halse, R.E., Scott, J.A., Mullan, B., Collins, C.E., Kerr, D.A. *Image-Based Dietary Assessment and Tailored Feedback Using Mobile Technology: Mediating Behaviour Change in Young Adults*. Nutrients *2019;11.*

Halse, R.E., **Shoneye, C.L.,** Pollard, C.M., Jancey, J., Scott, J.A., Pratt, I.S., Dhaliwal, S.S., Norman, R., Straker, L.M., Boushey, C.J., Delp, E.J., Zhu, F., Harray, A.J., Szybiak, M.A., Finch, A., McVeigh, J.A., Mullan, B., Collins, C.E., Mukhtar, S.A., Edwards, K.N., Healy, J.D., Kerr, D.A. *Improving Nutrition and Activity Behaviours Using Digital Technology and Tailored Feedback: Protocol for the LLTailored Diet and Activity (ToDAy) Randomized Controlled Trial.* JMIR Res Protoc *2019*;8(2):e12782

Related publication completed during this PhD

Kerr, D. A., Dhaliwal, S. S., Pollard, C. M., Norman, R., Wright, J. L., Harray, A. J., **Shoneye, C. L.,** Solah, V. A., Hunt, W. J., Zhu, F., Delp, E. J., & Boushey, C. J. (2017). BMI is associated with the willingness to record diet with a mobile food record among adults participating in dietary interventions. *Nutrients, 9*(3).

Conferences and presentations

Shoneye, C.L. Mullan, B., Healy, J., Jancey, J., Pollard, C. and Kerr, D. *Weight change or behaviour change? A qualitative exploration of participants' experience of a 12-month digital weight loss intervention*. UCL Centre for Behaviour Change, Digital Health Conference 'Behaviour Change for Health: new and emerging science and technologies'. London, UK, April 2020. Abstract accepted.

Shoneye, C.L. *"It's not a healthy meal if it's got a potato": a qualitative exploration of overweight adults.* Joint Scientific Meeting of The Australian and New Zealand Obesity Society (ANZOS) and the Obesity Surgery Society of Australia and New Zealand (OSSANZ) in conjunction with Asia Oceania Association of Studies for Obesity (AOASO). Oct 4-5, 2017, Adelaide. Oral presentation, winner of Best Paper Presentation Award, 28th September 2018.

Invited seminars

Shoneye, C. Overview of research conducted for the degree of Doctorate in Public Health. Presentation to the Health Psychology and behavioural medicine research group, Curtin University, 2nd October 2020.

Shoneye, C. *Improving nutrition with technology.* Weekly Research Update Meeting, Diabetes and Endocrinology Service, Royal Perth Hospital, 4Th December 2019.

Shoneye, C. *Using technology to improve diet and physical activity behaviours.* Presentation to the Health Psychology and behavioural medicine research group, Curtin University, 28th June 2017.

Shoneye, C. *Dietitian in your pocket.* Second place in the Curtin 3 Minute Thesis Competition, Curtin University, 5th September 2017.

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List of Abbreviations

ABS	Australian Bureau of Statistics
AC	Active control
ADG	The Australian Dietary Guidelines
App	Application on a mobile device
BMI	Body Mass Index
CHAT	Connecting Health and Technology
EDNP	Energy-dense nutrient-poor
FFQ	Food Frequency Questionnaire
ToDAy	Tailored Online Diet Activity
mFR	Mobile Food Record
MRC	Medical Research Council
NHMRC	National Health and Medical Research Council
NRV	Nutrient Reference Values
RCT	Randomised controlled trial
SSB	Sugar-sweetened beverage
WHO	World Health Organization

Chapter 1 Introduction

Statement of the problem

Poor diet is the leading modifiable cause of poor health in Australia (Melaku et al., 2019). The consequences are seen across the population but are most prevalent in those with social disadvantage. Related issues include the increasing prevalence of overweight and obesity (Australian Bureau of Statistics, 2015) and chronic diseases like type 2 diabetes, cardiovascular disease and several types of cancer (Afshin et al., 2019; Australian Institute of Health and Welfare, 2016; World Health Organization, 2005). The Australian Guide to Healthy Eating depicts proportions of the five core food groups to be consumed daily (National Health and Medical Research Council, 2013b). Adherence to these guidelines is poor and Australians are consuming excess amounts of saturated fat, processed meat, sugar-sweetened beverages, and sodium and inadequate amounts of fruits, vegetables, nuts, seeds and wholegrains (Australian Institute of Health and Welfare, 2016). Wide-reaching interventions to improve diet quality and reduce the trends in weight gain are needed urgently, but there is limited evidence regarding strategies that are effective and scalable.

Existing evidence suggests population-level interventions have the potential to produce wide-reaching awareness of the link between poor diet and health, but the messages need to be personalised to resonate with individuals and change behaviour (Croker et al., 2012; King et al., 2013; Kite et al., 2018). Tailored interventions can take generic messages and personalise them to reflect the unique characteristics of the individual. For example, a generic dietary message is to "eat at least 2 serves of fruit and 5 serves of vegetables every day". A personalised message adapts this advice based on an assessment of the individual, for example "Hello Sam, on average you are eating 1 serve of fruit and 2 serves of vegetables. Almost half-way to achieving the daily goal". The feasibility of a tailored intervention at a population level has not yet been fully explored in Australia.

Clinical interventions are delivered to individuals or small groups, offering personally tailored dietary assessment, feedback on dietary behaviour and behaviour change strategies like self-monitoring and goal setting (National Health and

Medical Research Council, 2013a). There is evidence to show this has some success in achieving sustained and clinically significant weight loss (Cleo et al., 2019; Douketis et al., 2005; Plotnikoff et al., 2015). However, offering this intervention to those at risk would exhaust current health care services. A potential solution is the use of digital, tailored interventions that can replicate the effective features of clinical interventions on a larger scale.

LiveLighter® is a West Australian health education campaign, that aims to prevent obesity. The campaign depicts graphic images of 'toxic' fat followed by messages informing people how to reduce their risk, for example, by avoiding sugar-sweetened beverages (SSB) (LiveLighter, 2019). There is an option to enroll online to access a meal planner, recipes, weight-monitoring tools and newsletters. Cross-sectional surveys with 1,500 adults, shows significant population awareness, with overweight participants more likely to recall the campaign and report the messages as personally relevant (Morley et al., 2013). The evaluation found similar levels of campaign awareness and personal relevance between male and female respondents (over 40% male) and across socio-economic status, (approximately one third of participants reported low socio-economic status). Later campaigns targeting SSB reported increased knowledge on their link with weight and modest decreases in intake (Morley et al., 2019). Despite the successful engagement and awareness raising, the 'LiveLighter' campaign has report limited change in behaviour. This is likely due to the static nature of the information and the lack of tailored content. To have any impact on actual behaviour and subsequently health outcomes, we need more personalised and specific change messages. To date, there is limited evidence about how this should be done at a population level.

Significance of this research

This thesis will examine the use of technology and tailored feedback to improve dietary behaviours. The research will include design, development and evaluation of a digitally tailored weight loss intervention, based on objective measures of diet. Interventions utilising digital technologies have the potential to improve engagement and reach but require further exploration. This body of research has the potential to positively impact dietary behaviours and may inform the early intervention and management of overweight and obesity, the aim of the WA Healthy Weight Action Plan (WA Department of Health, 2019).

Aims

1. This thesis will investigate if using technology and tailored feedback can improve dietary behaviours

2. Describe the studies undertaken to design and evaluate a theory driven digital tailored weight loss intervention.

Objectives

Chapter	Objectives
3	1. Systematically review the protocols for dietary assessment (DA) methods used to inform tailored feedback in digital weight loss interventions, examining the digital platforms used for data collection, type of DA and duration of the assessment
4	2. Report on young adults' experiences of receiving the dietary feedback in the Connecting Health and Technology (CHAT) study and determine whether those experiences were associated with positive improvements in dietary intake.
5	3. Conduct a formative focus group study to inform the development of a digital, tailored weight loss intervention and identify behaviour change techniques for weight loss. 4. Explore preferences for digital intervention features that are proven to be effective in changing dietary behaviours.
6	5. Protocol for ToDAy: one year randomised controlled trial (RCT): Investigate whether a tailored intervention using mobile technology can improve dietary behaviours in adults with overweight or obesity.
7	6. Investigate whether ToDAy can improve dietary behaviours in adults (aged 18-65) with overweight or obesity
8	7. Conduct a qualitative study (exit interviews) to identify intervention features influencing participants' motivation, capability and opportunity to change their dietary and activity behaviours 8. Explore participants' preferences for intervention features and how the intervention might be improved

The study design starts with the mobile food record (mFR), an image-based dietary assessment app (Ahmad et al., 2016). The mFR was used to assess diet in the Connecting Health and Technology Study (CHAT) (Kerr et al., 2012). This six-month randomised controlled trial (RCT) provided participants with tailored dietary feedback that resulted in reductions in junk food, increased intake of vegetables and unintentional weight loss (Kerr et al., 2016). The results indicated the potential for this approach to replicate features of face-to-face dietetic interventions – improving diet quality, increasing nutritional knowledge and achieving moderate weight loss. Further studies were needed to confirm these findings in older adults with overweight or obesity.

At a similar time, LiveLighter® was developed in Western Australia – a public health campaign using mass media to educate Australian adults about the link between excess weight and health (LiveLighter, 2019). The messages focus on encouraging people to eat less discretionary food, increase their physical activity and increase their fruit and vegetable consumption. The Live Lighter website includes healthy eating tips, recipe ideas and online support to maintain healthy weight behaviours. To measure of the impact of the media campaign, a cross-sectional survey with adults aged 25-49 was conducted pre-campaign (N= 2012) and after two media campaigns (N= 2005 and N= 2009) (Morley et al., 2016). Results shows significant population awareness, with overweight adults more likely to recall the campaign and report the messages as personally relevant to them (Morley et al., 2016). A major strength of this evaluation is that it reveals that social marketing is effective in engaging a target group with a clear health message, a prerequisite for behaviour change (Wakefield et al., 2010). Evaluation of LiveLighter® revealed wide-reaching awareness and relevance of the campaign messages (Morley et al., 2013; Morley et al., 2014). The researchers highlighted the need for more intensive and tailored intervention to change behaviour by exposing a gap between clinical weight-loss interventions and public health campaigns.

This thesis describes the research undertaken to develop and evaluate a theory-based and person-centred, tailored weight-loss intervention that can be delivered digitally and up-scaled. The candidate’s role began with a systematic review to explore the dietary assessment methods and protocols used in digital, tailored interventions for weight loss was conducted. The aim of this study was to examine the platform, duration, frequency and method of dietary assessment used to inform tailored, dietary feedback. Chapter 3 is the draft manuscript submitted for publication. Next, was a process evaluation of the connecting health and technology (CHAT) study, using existing data to explore the characteristics and diet of individuals who benefitted most from tailored feedback. This study reported participants' experiences of using the mobile food record, receiving dietary feedback and the factors mediating improvements in dietary intake, following the 6-month RCT (Kerr et al., 2016). The publication that comprises chapter 4 is the published article describing this study (Halse et al., 2019).

Next, I recruited two consumer representatives, 18 health professionals and 56 participants to contribute to the design and development of the ToDAy intervention protocol. Using my previous experience in qualitative research, I conducted 16 focus groups and interviews to explore the acceptability and preferences for intervention features. The results of the user feedback from 56 participants comprise the publication in Chapter 5 (Shoneye et al., 2020). The results of the qualitative study were presented to a research steering committee to guide the development of the intervention; this included representatives from LiveLighter® and researchers with expertise in intervention development, behaviour science, dietetics, public health and physical activity. I worked on the protocol for the intervention, including the selection of assessment tools, recruitment, screening and assessment of participants. Chapter 6 outlines the protocol for the dietary elements of the study, adapted from the published protocol, which the candidate co-authored(Halse et al., 2019). My role also included development of the dietary feedback templates used to provide tailored feedback to participants taking part in the ToDAy intervention and data collection both in person and online.

Chapter 7 provides a quantitative analysis of the results from ToDAy, outlining the participants characteristics and outcomes measured at baseline and six-months. The aim of the final study was to explore the experience of a range of users who completed the ToDAy intervention. I designed the script, protocol, recruited all participants, collected and analysed all the data, and drafted the manuscript. Chapter 8 presents the study design and results. My supervisors, co-authors, and formal

training opportunities afforded by Curtin University guided my research and academic writing throughout the thesis development.

Definitions

The following definitions are used throughout this thesis:

Body mass index – a measure used to indicate adiposity and the risk this poses to chronic disease. The calculation is made by dividing a person's weight in kilograms by the square of the person's height in metres (kg/m^2).

Dietary feedback – an assessment of an individual's food and beverage intake, based on self-reported dietary behaviour.

Digital - electronic technology that generates, stores, and processes data

Food images – an image of food or beverage consumed, collected for the purpose of dietary assessment, dietary analysis or dietary feedback.

Energy-dense nutrient-poor (EDNP) – referred to as 'discretionary foods' in the Australian Dietary Guidelines (ADGs) and 'junk foods' in participant communication. These foods and beverages contain minimal nutritional value and are high in energy (kilojoules), saturated fat, added sugar, salt and/or alcohol.

Mobile food record™ – A mobile dietary assessment application that runs on a mobile device that allows an individual to capture 'before' and 'after eating' images of all foods and beverages consumed for a specified period of time (4-7 days), which are then sent to a server for analysis by either a trained analyst or automated method. Technology Assisted Dietary Assessment System (TADA) consists of two parts: the mobile food record App (mFR™) and a dedicated cloud-based server for storing food and beverage images.

Overweight – a body mass index between 25.0 and 29.9 kg/m^2

Obesity – a body mass index of 30.0 kg/m^2 and above

Self-monitoring - a method used in behavioural management in which individuals keep a record of their behaviour (e.g., type, quantity of food consumed)

Smartphone – a mobile phone with the capacity to install computer functions that typically include internet access, text messaging, an operating system that can run downloadable apps and an integrated camera.

Chapter 2 Literature review

Overview

This literature review will examine the role of diet and dietary behaviour and critique five principal areas of relevance: diet and health, clinical weight loss interventions, population interventions, using technology to improve dietary intake, and tailoring dietary message. This review will identify the limitations of existing literature as well as the gaps which need further research. Finally, the review will explore the potential to merge the effective features from weight loss interventions used in clinical, digital and tailored approaches.

Diet and health

Poor diet is the leading modifiable cause of ill health in Australia (Melaku et al., 2019). Epidemiological data from observational studies provide evidence of the likely causal link between dietary factors associated with a lower risk of disease (fruit, vegetables) and those associated with an increased risk of disease (processed meats, sodium and trans fats) (Micha, 2017;Fund, 2018). Global risk patterns show that inadequate intakes of fruit, vegetables, nuts, seeds and whole grains, and excess intakes of red meat and sodium, underpin the burden of diet-related disease (Forouzanfar et al., 2016; Melaku et al., 2016). This is known as nutrient dilution, when energy dense, nutrient poor food and beverages (EDNP) displaces essential whole foods required for good health (Forshee & Storey, 2004). In Australia, a national survey of over 400 adults found that higher diet quality was associated with lower risk of excess weight for both men and women and higher risk of hypertension for men (Livingstone & McNaughton, 2016). Poor diet quality is also linked to the increased risk of developing type 2 diabetes, cardiovascular disease and cancers of the bowel, uterus, gall bladder, cervix and liver on a global scale (Afshin et al., 2019; Australian Institute of Health and Welfare, 2016; World Health Organization, 2005).

This section will review the background for the dietary targets that form the basis of interventions to improve diet quality and produce clinically significant weight loss.

Australian Dietary Guidelines

The nutrient reference values (NRV) for Australia prescribe intakes for energy, protein, carbohydrates, fibre, fats, vitamins and minerals according to age, gender and life stage (National Health and Medical Research Council 2017). The NRV include intakes recommended to avoid deficiency, and dietary targets that have been set to prevent or reduce the risk of chronic disease. For example, the target for fibre was developed to reduce the risk of coronary heart disease, with suggestions to achieve this by replacing EDNP with fruit, vegetables and wholegrain cereals (National Health and Medical Research Council 2017). The Australian Dietary Guidelines (ADG) provide advice on dietary patterns, types of foods and amounts of food recommended to meet these energy and nutrient requirements. The five guidelines in the 2013 revision of the ADG are listed below in Table 2-1.

Table 2-1The Australian Dietary Guidelines (National Health and Medical Research Council (Australia), 2013)

Guideline 1	To achieve and maintain a healthy weight, be physically active and choose amounts of nutritious food and drinks to meet your energy needs.	Children and adolescents should eat sufficient nutritious foods to grow and develop normally. They should be physically active every day and their growth should be checked regularly Older people should eat nutritious foods and keep physically active to help maintain muscle strength and a healthy weight
Guideline 2	Enjoy a wide variety of nutritious foods from these five food groups every day:	Plenty of vegetables of different types and colours, and legumes/beans Fruit Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties, such as breads, cereals, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley Lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans Milk, yoghurt, cheese and/or their alternatives, mostly reduced fat And drink plenty of water
Guideline 3	Limit intake of foods containing saturated fat, added salt, added sugars and alcohol.	Limit intake of foods high in saturated fat such as many biscuits, cakes, pastries, pies, processed meats, commercial burgers, pizza, fried foods, potato chips, crisps and other savoury snacks • Replace high fat foods that contain predominately saturated fats such as butter, cream,

		cooking margarine, coconut and palm oil with foods, which contain predominately polyunsaturated and monounsaturated fats such as oils, spreads, nut butters/pastes, and avocado
		• Low-fat diets are not suitable for children under the age of 2 years
		Limit intake of foods and drinks containing added salt
		• Read labels to choose lower sodium options among similar foods
		• Do not add salt to foods in cooking or at the table
		Limit intake of foods and drinks containing added sugars such as confectionery, sugar-sweetened soft drinks, and cordials, fruit drinks, vitamin waters, energy and sports drinks
		If you choose to drink alcohol, limit intake. For women who are pregnant, planning a pregnancy or breastfeeding, not drinking alcohol is the safest option
Guideline 4	Encourage, support, promote breastfeeding.	
Guideline 5	Care for your food; prepare and store it safely.	

The guidelines include five core food groups: 1) vegetables, legumes and beans; 2) fruit; 3) grain and cereal foods; 4) lean meat, poultry, fish and alternatives and 5) milk, yoghurt, cheese and alternatives. EDNP or ‘discretionary’ food and beverages and spreads and oils are identified as having a role in the diet but are not included in the core groups. The ADG explicitly describes the importance of energy intake with a dedicated guideline encouraging individuals to ‘limit’ intake of discretionary foods, which are energy dense and nutrient poor (National Health and Medical Research Council, 2013b). However, the ADG acknowledge that people enjoy EDNP food and beverages, and its cultural and celebratory functions. The guideline suggests that those wanting to lose weight will not be able to ‘fit these in’ their energy target while people with a healthy weight can consume these in ‘occasional, small amounts’. This advice is also similar in Canada, the United States and the United Kingdom which all provide qualitative guidance to consume these foods and beverages ‘sometimes’, ‘in small amounts’ and ‘occasionally’ (Bush et al., 2007; Buttriss, 2016; Committee, 2015).

Nonetheless, these guidelines are problematic for several reasons. While the advice is consistent and evidence based, the language is broad and open to interpretation. Secondly, the advice is reliant on people accurately identifying their weight status, but we know that under-perception of weight is widespread (Feng, 2019;Langellier, 2015;Hernan, 2014;Salcedo, 2010). Data from UK surveys found that almost one-third of women and about half of the men with overweight or obesity, identified as being a healthy weight (Johnson et al., 2008; Robinson & Oldham, 2016). Thirdly, while examples of discretionary foods and beverages are provided, there is not a definitive criterion of what constitutes these foods or beverages. A serve of EDNP is defined as the amount providing 600 kJ, and consumers are advised to use the nutrition information panel to calculate this. Low levels of literacy, food insecurity, and health claims on food packaging can make this difficult and confusing (Cowburn, 2016). For example, evidence from Australian data found that terms like 'low fat', 'no added sugar' and 'wholegrains' appear on discretionary foods such as cakes, biscuits and deserts (Pulker et al., 2018).

Surveys with Australian consumers reveal the term 'discretionary food' is not understood, and there is confusion over which foods are considered healthy or unhealthy (Pettigrew et al., 2017). Furthermore, there is a disconnect between what people perceive they are eating and what they are actually eating. One study found that young adults who reported trying to limit their junk food consumed less than their peers but significantly more than recommended – almost three servings of EDNP and SSB per day (Harray et al., 2017). Moving forward, the ADG needs to either develop strategies to educate the public on discretionary foods or amend the language, so the content is more easily understood.

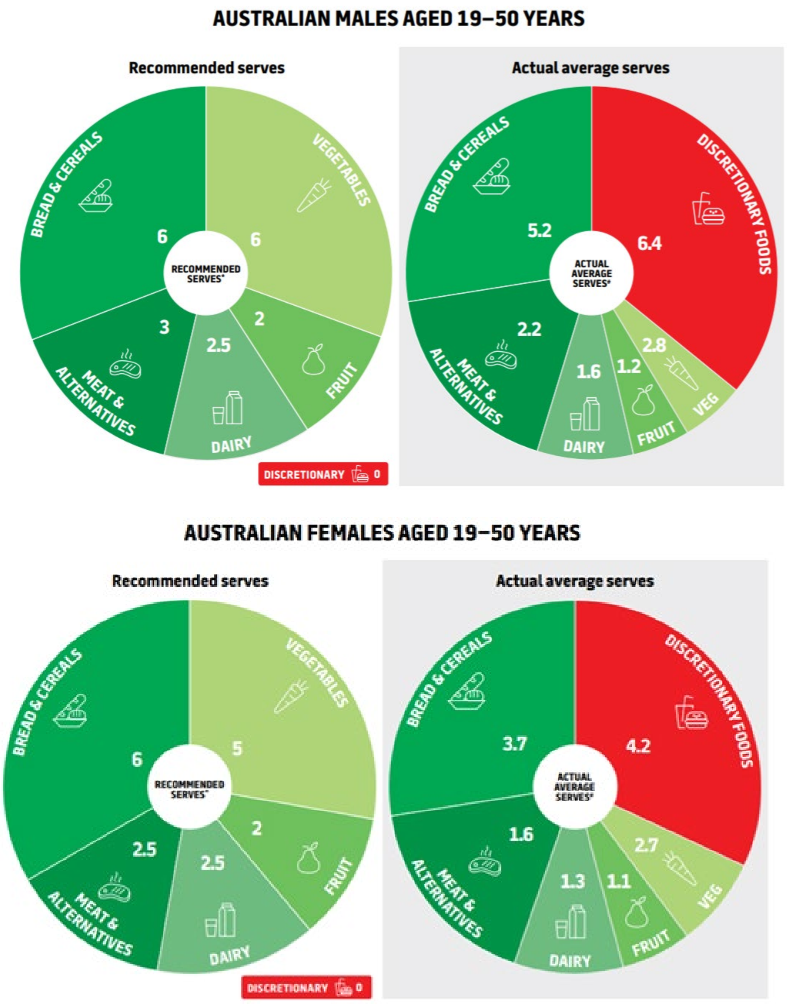
Trends in dietary intake

The intake of EDNP foods and beverages is associated with poor diet quality, increased risk of obesity, and chronic disease (Smith et al., 2012; World Health Organization, 2003). Specifically, consuming takeaway foods is associated with abdominal obesity in Australian young adults (Rangan, Schindeler, Hector, Gill, & Webb, 2009; Smith et al., 2009). EDNP are typically high in energy, saturated fat, added sugar and/or added salt or alcohol but low in nutrients and deemed unnecessary for a healthy diet (National Health and Medical Research Council, 2013a). Since 1995, the portion size of seven popular EDNP foods has increased significantly: pizza, cake, sausages, cereal bars, processed meat, ice cream and wine (Zheng et al., 2017). These foods are consumed frequently, with Australians spending almost 40% of their weekly food budget on takeaways and alcoholic drinks, three times the amount spent on fruit, nuts and vegetables (Australian Institute of Health and Welfare, 2019).

Between 1995 and 2012 data from the National Nutrition and Physical Activity Survey show that energy intake from lean meat and poultry, fish, eggs, nuts and seeds and legumes/beans increased while decreasing for vegetables and legumes/beans, and discretionary foods (Australian Institute of Health and Welfare, 2019). Issues with participants under reporting food intake and the length of time between surveys makes it difficult to quantify this trend accurately so it is not possible to identify the cause. A later study assessing diet quality in over 9,000 adults from the 2011–2012 National Nutrition and Physical Activity Survey used the Healthy Eating Index for Australians with a maximum score of 100(Grech, 2017). Results revealed scores (SD) were lower in men 43.3 (14.7), young-adults 41.6 (14.2) people with obesity 44.1 (14.3), smokers 40.0 (14.2) and low socio-economic status 43.7 (14.9). Inadequate intakes of intakes of vegetables, fruit, grains, dairy and high intakes of added sugar, sodium and discretionary foods were key factors in creating the mean score of 45.5 (Grech, 2017). The study concluded that overall diet quality of the Australian population is poor, recommending interventions specially aimed at engaging young-adults, males and people with obesity.

Figure 2-3 Recommended serves versus actual average serves for male and female adults in Australia shows the recommended serves against the actual serves for men and women in Australia. Australian men are consuming an average of 6.4 serves of discretionary foods per day contributing to over one third of their total energy intake but only eating about half the number of recommended serves of vegetables and fruit. For Australian women the results are slightly better with less discretionary food (4.2 serves per day) but similarly low intakes of fruit and vegetables. As well as environmental concerns about the packaging and processing of these foods, there is evidence of their negative impact on health (Gakidou, 2017). With the growing prevalence of diet-related illness, strategies to both improve diet quality and reduce the consumption of EDNP are urgently needed.

Figure 2-1 Recommended serves versus actual average serves for male and female adults in Australia



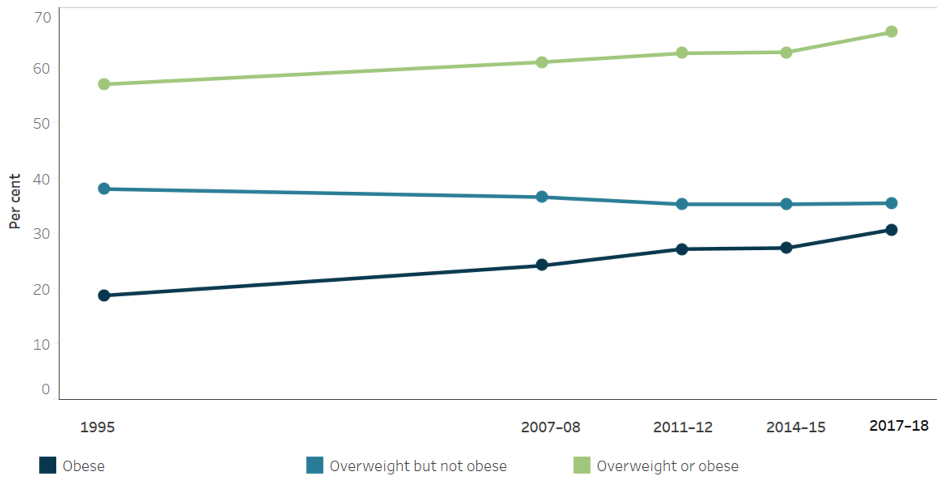
Vic. Health. (2016). Obesity and Healthy Eating in Australia.

While we acknowledge the role of diet, the causes of obesity are complicated and multifaceted with evidence for environmental, biological, social, economic and genetic causes (Mullan et al., 2017). There is clear evidence linking poor diet, social-economic factors and weight gain with the places in which we live and work: the obesogenic environment (Malik, 2013;Lakerveld, 2018). It is also important to note the individual variability in how people respond to the obesogenic environment, with some people more vulnerable to weight gain than others (Whitaker, 2011). A systematic review and meta-analysis on a pooled population of over 200,000 adults found individuals with obesity-associated gene (FTO) had a higher intakes of dietary fat and protein, which may be due to higher intakes of high-fat processed meat products (Livingstone, 2015).However, the issues of dietary mis-reporting is profound and must be considered when interpreted such small effects. The authors call for future studies to invest in and report more accurate methods of dietary assessment to further understand factors influencing individual differences in the dietary intake and health (Livingstone, 2015). While this is a complex area, it is becoming clear that some people are genetically predisposed to weight gain and vulnerable to the impact of the obesogenic environment (Llewellyn, 2015). Efforts to create an environment where the healthy choice is the easy choice include taxation of SSB, smaller packets of confectionery and social marketing strategies (Fisberg, 2016;Looijmans, 2017). Notwithstanding the need to improve the environment, there is also an immediate need to support people who already have obesity to navigate their food environment and reduce their risk of chronic disease.

Achieve and maintain a healthy weight

The effects of poor diet combined with an increasingly sedentary lifestyle have resulted in a positive energy balance and the accumulation of excess body fat, leading to weight gain. Although physical activity has a crucial role in the prevention of weight gain and weight loss, this thesis will focus on the effects of dietary behaviour. In adults, excess weight is assessed using the body mass index (BMI) calculated by dividing a person's weight in kilograms by the square of their height in metres. Although BMI is not an accurate indicator of body fat or body fat distribution, it is a practical and useful measure for identifying overweight and obesity at a population level, and is an internationally accepted measure (Yumuk et al., 2015). Using the BMI, the Australian Institute of Health and Welfare and the World Health Organization report a steady increase in the prevalence of children and adults with obesity and severe obesity both in Australia and internationally (WHO, 2020). As seen in Figure 2-2 Age-standardised proportion of overweight and obese adults aged 18 and over, 1995-2017/18 , the prevalence of obesity increased from 19% in 1995 to 31% in 2017–18.

Figure 2-2 Age-standardised proportion of overweight and obese adults aged 18 and over, 1995-2017/18



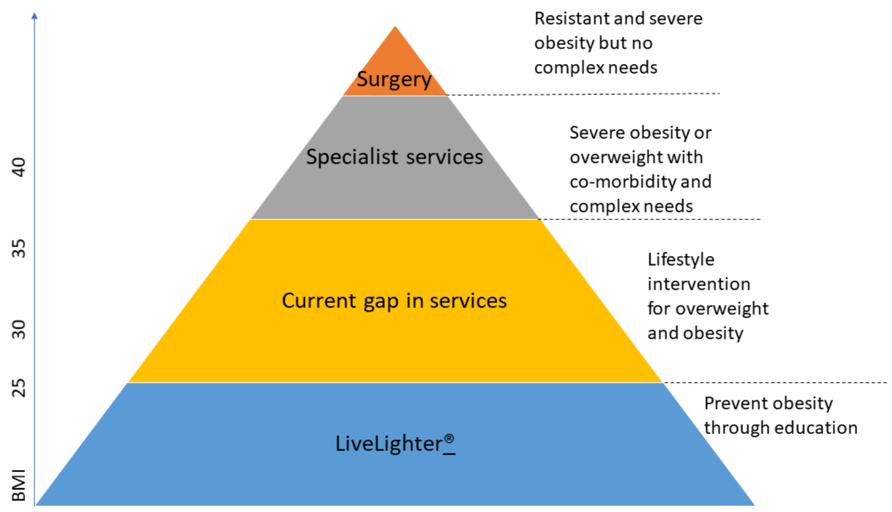
Australian Bureau of Statistics. (2019). National Health Survey: First Results, 2017-18.

Clinical weight loss interventions

In 2013 The National Health and Medical Research Council of Australia released the clinical practice guidelines for the management of overweight and obesity in adults, adolescents and children (NHMRC, 2013). Although these have since been rescinded, the contents align with more recent clinical guidelines from Europe and New Zealand (NZ Ministry of Health, 2016; Yumuk et al., 2015). Designed for health professionals in primary care, they describe the diagnosis, management, risk and medical interventions available to manage excess weight. The guidelines are based on the evidence drawn from the National Institute of Clinical Excellence (NICE., 2006), the Scottish Intercollegiate Guidelines Network (Thompson, 2010) and extensive literature reviews with specific consideration of the Australian population and health system. In brief, they promote the Australian guide to healthy eating, increased physical activity and behaviour change techniques, such as self-monitoring of behaviour and problem solving, as the first line of treatment for adults with overweight and existing comorbidity and those with obesity. More intensive options are recommended if this approach fails and for those with severe or complicated obesity. This includes the use of very low-calorie diets, weight loss medication and bariatric surgery. In practice this requires a multidisciplinary team with expertise in dietetics, psychology, exercise physiology and medical supervision to assess and advise clients to explore these treatment options.

As seen in Figure 2.3 the pathway for treatment is linear with participants encouraged to attempt lifestyle interventions in a community setting, progressing to specialists specialist services only if this is unsuccessful.

Figure 2-3 Australian weight management pathway (NHMRC, 2013)



There are several important limitations to the application of these clinical guidelines for weight management. While the inclusion criteria for the evidence review is rigorous, nearly all of the included studies have been conducted on largely Caucasian, female populations with a BMI of less than 40 (Wadden, 1986 5;Pavlou, 1989 ;Dale, 2009 ;Ilanne-Parikka, 2008). The scientific evidence for achieving a negative energy balance for weight loss is universal, the availability of food, the cultural role of food and access to health care mean the results may not be generalisable. As a result, the small effects sizes referred to in the guidelines are likely to be even smaller in a community sample, who may not be as motivated and supported as research participants (Sturgiss et al., 2018). Digital platforms could make this significant weight loss support more accessible prior to specialist interventions; a gap in the current guidelines and services.

Current clinical treatment of obesity focuses on high-risk individuals: those with a BMI >35 and comorbidities or those with a BMI >40 (National Health and Medical Research Council, 2013a). While this approach aims to ensure treatment is available to the most vulnerable, it offers no support to prevent weight gain among people with overweight (Yumuk, 2015). Another problem is that treatment pathways start with a clinical assessment of those already visiting a health practitioner but men, those on low incomes, and those living in rural areas are less likely to seek help or access health services (Metzgar et al., 2015). Also, effective treatment is intensive, costly and not available at the scale required to address the current demand. Population-based approaches that utilise the effective aspects of clinical interventions may be more economical and sustainable than the current focus on clinical treatments (Murray et al., 2016). Given the benefits of modest weight loss, future interventions need to consider achieving weight loss of lower magnitude but among larger cohorts. Digital interventions have the potential to deliver effective weight management support to with overweight and moderate obesity.

Clinically significant weight loss

In 2013 an expert panel reviewed the literature to determine the amount of weight loss associated with a reduction in risk factors for CVD, mortality and morbidity (Jensen, 2014). The results suggest 2.5% loss of total body weight can have clinically significant benefits for type 2 diabetes, systolic blood pressure, long-term glycaemic control (HbA1 C) and triglyceride levels (Cannon et al., 2016; Pi-Sunyer, 1993; Wing et al., 2011). There is consensus that 5% of baseline weight lost during 12 months is a single valid criterion to determine weight loss as clinically significant, and achievable as an initial target (Ryan & Yockey, 2017; Williamson et al., 2015). Observed benefits include the delay in the development of type 2 diabetes with improved metabolic function of beta-cells of the pancreas and insulin sensitivity; increasing the uptake of glucose by approximately 25% (Magkos, 2016). Other benefits include improved lipid profile and decreased markers of inflammation associated with adverse cardiovascular health (Fayh, 2013 ;Ryan, 2017). Greater weight loss is associated with further benefits with weight loss of at least 10% required for improvements in non-alcoholic fatty liver disease and obstructive sleep apnoea (Cefalu, 2015).

Population health approaches for obesity

This section will describe the strategies used in population health campaigns and explore the available evidence on the effectiveness of these approaches to address overweight and obesity. A population-level intervention has the distinct advantage of a wide scope, which is essential to reach the proportion of the population affected by obesity and poor diet. Strategies can include national, federal and local government organisations to disseminate consistent strategies and messages. The publicly funded campaigns usually raise awareness about health risk and encourage action to reduce that risk.

Mass media campaigns reach a large proportion of the population through a range of media including television, billboards, social media and online. Internationally, several public health campaigns have targeted adults with obesity, using mass media as a strategy (Kornfield, 2014;Grunseit, 2015 ;George, 2016 ;Cismaru, 2007). In these studies, the reporting of the process, implementation and effectiveness is reported infrequently or lacks detail. A recent systematic review assessed 14 mass media campaigns against best practice principles (Kite et al., 2018). The results reveal a lack of formative research with the target audience and varying quality of evaluation methodologies. While 12 campaigns reported improvements in awareness or intention to change behaviour, only one study reported a reduction in BMI, and this was based on self-reported data. Most campaigns (n=12) used a theory base such as the health belief model, theory of planned behaviour or social marketing model. Overall, evaluations focussed on the reach and frequency of television advertising, limiting the available evidence on the other strategies used. Four of the interventions assessed will be reviewed in greater detail to explore features and strategies that are most relevant to this thesis.

The “Change 4 Life” mass media campaign in the United Kingdom combined both upstream and downstream strategies, attempting to influence dietary and physical activity behaviour at a population level. 3, 744 families were recruited via 40 primary schools across England; randomised to control or intervention. Families in intervention schools were mailed “Change 4 Life” questionnaire followed by personalised feedback and follow up questionnaires at 6-months. The evaluation showed a raised awareness of the campaign with a message recall of up to 90% in the target group (n=532). However, no effects on attitudes and behaviour were found with most families reporting no intention to change their family’s diet or activity behaviour (Croker et al., 2012). The researchers conducting the evaluation faced several challenges. Firstly, they were not involved in the development of the intervention so there was limited knowledge of the theory base and the authors suggest this lack of theory was responsible for the unfavourable results. Secondly, the response rate to the follow up evaluation was only 30% (4,419 children out of 16,029) and respondents were predominantly well-educated parents and therefore less likely to need this support, and not representative of the target group.

The study concludes with recommendations that future healthy weight campaigns focus on a small range of target behaviours and conduct formative evaluations using behaviour change theories (Croker et al., 2012).

A similar campaign in the Netherlands aimed to prevent weight gain with a series of television advertisements and supporting online resources to educate young people on the need to prevent weight gain, and the health risks of excess weight (Wammes et al., 2005). “Maak je niet dik” (in English “Do not worry”) was developed systematically using formative evaluation processes and health psychology theory. The evaluation of 1,949 adults aged between 25 and 35 years was conducted via telephone. The results revealed high levels of awareness of strategies to prevent weight gain with small, but statistically significant, increases in motivation, perceived social support and attitudes to weight management (Wammes et al., 2007). The results also indicate the campaign reduced the perceived risk of overweight among the target group. These authors suggest this may be because the mass media messages oversimplified the need to prevent weight gain and portrayed risk factors that the audience did not identify with (Wammes et al., 2007). The authors conclude that future studies should offer a more personally tailored approach to ensure the messages are salient.

In 2008, the Australian Government launched the ‘measure up campaign’, the first nationwide mass media campaign designed to educate the public on the link between waist circumference, physical activity, healthy eating and obesity risk. An evaluation with 1006 adults, pre and post campaign, revealed high awareness (89%) and personal relevance of the link between waist circumference and chronic disease but no significant change in behaviour (King et al., 2013). The authors conclude that mass media campaigns need to be implemented as part of an integrated multifaceted approach, including comprehensive evaluation. Another issue was the focus on imparting declarative knowledge: for example ‘eat 5 vegetables per day’; while this is important for improving the capability for dietary change, it lacks the procedural knowledge that pertains to how to perform the behaviours (Worsley, 2002). In this example, procedures for food budgeting, purchasing and preparing the vegetables are required to eat the recommended 5 vegetables a day (Chapman, 2016). Behaviour change at a population level will likely need long-term investments in public education campaigns, alongside personalised support to help individuals implement the new information.

LiveLighter® social marketing campaign

LiveLighter® is a Western Australian public health education and social marketing campaign that aims to encourage people to eat well, be physically active, and maintain a healthy weight. The campaign engages with the community through paid and unpaid social media, web-based and printed resources, and retailers (http://LiveLighter.com.au/). The website includes healthy eating tips, recipe ideas and online support to maintain healthy weight behaviours. To measure of the impact of the media campaign, a cross-sectional survey with adults aged 25-49 was conducted pre-campaign (N= 2012) and after two media campaigns (N= 2005 and N= 2009) (Morley et al., 2016). Results shows significant population awareness, with overweight adults more likely to recall the campaign and report the messages as personally relevant (Morley et al., 2016). A major strength of this evaluation is that it reveals that social marketing is effective in engaging a target group with a clear health message, a prerequisite for behaviour change (Wakefield et al., 2010). While this is promising, further studies to assess the impact of implementing the message, reducing consumption of SSB, found only small, short-term changes

(Morley et al., 2019). However, in the 2019 study, the pre- and post-campaign intake of SSB was self-reported and hence subject to social desirability bias. As there was no control group it is also possible that the reduced SSB intake reflects national trends in the decline of SSB (Australian Bureau of Statistics, 2015). Approximately 1/3 of adults surveyed consumed 3 or more SSB per week but other surveys report that half of Australia adults never consumer SSB (Miller et al., 2019). A more personalised and specific change-message is needed to help individuals identify sources of EDNP in their diet.

Implications

Few mass media campaigns targeting adults with obesity have been assessed with an evaluation of outcomes, making it challenging to measure the effect of the multiple strategies employed. Although most campaigns cited theories or frameworks, these focused on individual behaviours whereas the process of evaluation was focussed on reach and awareness of the messages. This limits our understanding of how these theories were translated into design and implementation of these campaigns. In conclusion, it appears that mass media campaigns have the potential to change knowledge and beliefs – precursors for behaviour change – but insufficient to change behaviour and halt the trends in weight gain (Wakefield et al., 2010). Robust evaluation of the outcomes and impact are needed to further understand this potential.

Limitation of public health education

Knowledge and education on nutrition is essential but not sufficient for improving dietary behaviours (Wardle, 2000 ;Downs, 2009;Dickson-Spillmann, 2011). Some evidence suggests this is because of other behavioural influences such as motivation and self-efficacy (Anderson, 2015 ;Bogers, 2004;Curtis, 2015;Dove, 2009). In simple terms, declarative knowledge or factual information can form the basis for making every day dietary choices, for example, milk is a good source of calcium or chocolate contains too much sugar. However, this is complicated with we consider the role of procedural knowledge which includes information about how; for example, which type of milk to choose or how much to consume. So, if chocolate milk is advertised as being a good source of calcium, how does one decide if they should purchase this and if so, how often and how much to consume?

A study assessing the nutrition knowledge of people attending an obesity clinic found high levels of nutritional knowledge and strategies for weight loss but this was not reflected in their dietary intake (Kaufer-Horwitz, 2015). Barriers to implementing this knowledge included: lack of routine, time, motivation, money; large portion sizes and temptations when eating outside of the home. With the increasing media attention on the health risks associated with obesity, a lack of knowledge about the health risks is not likely to be the only limiting factor for behaviour change. This thesis aims to explore alternative approaches to providing the skills and support to implement nutritional knowledge.

Using technology to improve dietary intake

Digital tools have the potential to automate aspects of dietary assessment and feedback, making tailored dietary interventions available at a larger scale. If entirely automated, digital interventions can be simultaneously used by millions of people, span any geographic area and allow autonomous participation as seen with mobile apps available for weight loss (Chen et al., 2015). Australian Clinical Practice Guidelines for the Management of Overweight and Obesity made limited references to the use of technology or digital interventions. Still, they did suggest: “Delivery of evidence-based weight management programs via the internet should be considered as part of a range of options for people with overweight and obesity” (National Health and Medical Research Council, 2013a).

Since then, the variety and availability of technology for digital behaviour change interventions has developed rapidly. In 2016, the United States Academy of Nutrition and Dietetics proposed that digital interventions with no face-to-face contact can deliver effective weight loss solutions with greater reach and lower costs (Raynor & Champagne, 2016). Evidence specifically related to digital interventions is now available and should be examined.

Digital interventions

Digital intervention is a broad term that includes the internet, smartphones, apps and emerging technologies to facilitate behaviour change (Hutchesson et al., 2015). The scope of digital interventions is evolving rapidly to utilise new technologies and competing to engage users. The approach can offer intervention options for varying stages of weight management: prevention of weight gain, weight loss and weight loss maintenance. Two systematic reviews of digital weight loss interventions report a sustained weight loss of up to 3.3 kg, compared to controls (Hutchesson et al., 2015; Wieland et al., 2012). While both reviews support the use of digital weight loss interventions using behaviour change techniques, they are not able to identify which features are most effective (i.e. dietary self-monitoring or goal setting) or the optimum dose (i.e. frequency and duration of dietary self-monitoring). Hutchesson et al., (2015) found interventions lasting less than 6-months were more effective compared with longer interventions, which they propose is due to declining engagement. Additional components such as interactive features and games can further increase engagement, retention and weight loss but the improvements are small and not clinically significant (Wieland et al., 2012).

A study exploring motives for taking part in an online nutrition program revealed that being online was a key motivator for most participants; online assessments were viewed as convenient, motivating and preferred by men and participants with severe obesity, groups that are often hard to reach (Mejean et al., 2014). One reason for this could be their anonymous nature, reducing concerns about judgement or feeling awkward. Combining the internet with available technology in smartphones and tablets can also offer dynamic and fun tools for engaging in evidence-based strategies such as self-monitoring, goal setting and social support. From a research perspective, online assessments have several advantages – participants can be recruited from a wide geographic area, and eligibility and consent can be done online so only suitable candidates are selected for further assessment, saving time and money (Khaylis et al., 2010). Further qualitative studies are required to understand the participant's experience of digital interventions, specifically which intervention features led to behaviour change and what mediates this change.

RCTs have reported that, compared to a mean weight loss of about 10 kg achieved through face-to-face delivery (group or individual), online interventions are at best, half as effective, achieving weight loss of approximately 5 kg over 12 months (Johns et al., 2014). Other studies have demonstrated comparable weight loss in face-to-face interventions compared with digital (10.8% vs 7.6%, $P < 0.05$) (Sullivan et al., 2013). Understanding the range of reported effectiveness of digital interventions is made difficult by the variety of study designs and comparators. For example, Chambliss et al. compared daily web-based self-monitoring, weekly email feedback and face-to-face sessions with an enhanced intervention that added monthly telephone counselling and group counselling (Chambliss et al., 2011). The results suggest that digital self-monitoring and tailored dietary feedback were key in achieving significant weight loss after 12 weeks but the additional enhanced behavioural component did not improve the effectiveness of the program

A meta-analysis of 88 digital interventions targeting weight loss or weight maintenance reported modest weight-loss compared with no treatment (mean difference: –2.70 [–3.33, –2.08], $p < 0.001$; nine studies pooled in meta-analysis) or minimal treatment (mean difference: –1.40 [–1.98, –0.82], $p < 0.001$; 16 interventions grouped for meta-analysis) (Hutchesson et al., 2015). This study reported that interventions with digital features to support behaviour change were most effective, for example, self-monitoring of behaviour or goal setting features of the app. Almost a quarter of the studies reviewed used additional digital tools such as activity monitors, podcasts, text messages or mobile applications. This was shown to enhance weight loss further (mean difference: 1.46 [0.80, 2.13], $p < 0.001$). While a total of 88 studies were included, the studies were not homogenous with sample sizes varying from 20 to 2,862 participants and studies using a range of digital tools combined with non-digital features (telephone calls, group meetings). This makes it difficult to make direct comparisons between digital interventions and quantity which features are most effective.

Another meta-analysis of 84 digital weight loss interventions found that a quarter compared a basic digital intervention to the same intervention with extra features or technology (Ryan et al., 2019). This included the addition of personalised weight loss goals, motivational interviewing, online group meetings, reminders to perform a behaviour, or a smart scale that connects to a smartphone via blue tooth (Collins et al., 2012; Steinberg et al., 2013; Webber et al., 2008). Overall, the review found that interventions with a digital component led to greater weight loss at 6-months but digital interventions with a face-to-face component were more effective at 12-months and beyond (Ryan et al., 2019). As these interventions are complex and multifaceted, it is unknown which intervention features contributed to which behaviour change, limiting our understanding of which features were most impactful (Michie et al., 2017).

From the findings to date, it is unclear if digital interventions can achieve clinically significant weight loss on a large scale. Of the studies reviewed, the largest sample size was 2,862 participants in a study comparing weight loss between a tailored, online intervention and an information only intervention (Rothert, 2006). The scale of the study is significant, spanning a large geographical area and population from various minority groups. Results revealed participants receiving tailored content lost a mean of 3 kg ± 0.3% of their baseline weight, compared to 1.2 kg ± 0.4% ($p < 0.0004$) receiving information only. The tailored group reported a more positive experience citing the content as personally relevant, helpful and easy to understand. The scale and reach of this intervention shows the potential for delivering modest but significant weight loss at a population level. While the results are positive, the attrition rate in the intervention group was 70% and in the control 80%. Although the remaining sample is still adequately powered, it highlights the challenge of retention. Similar to results from other studies, male users and young adults were least likely to complete the intervention (Van der Mispel et al., 2017). Another issue across the studies included in these reviews is that the protocols for tailoring dietary content are not fully described, limiting the understanding of the rationale and procedure for how the tailored feedback was developed.

Guidelines and standards for developing digital interventions

The methodology used to develop a digital intervention in this thesis are in line with published reporting standards for tailored interventions (Harrington & Noar, 2012). This 7-item checklist was designed to ensure tailored interventions were consistent in reported methodologies, implementation and evaluation as summarised in Table 2-2. Guidelines include providing a description of the tailored messages, the tailoring algorithm, format and dose of tailored messages, as well as any additional intervention components. A scientific approach to developing a digital program is to develop a prototype based on the theory and content identified as relevant in recent literature. A sample of the target group will test the program to determine if the features are usable and acceptable to the users (Anderson & Wallace, 2015). The intervention development process should include three stages: (1) understanding the problem and user preferences, (2) translating research findings into program features, and (3) pre-testing the features for further refinement.

The UK Medical Research Council (MRC) published important advice detailing the four steps for researchers developing and evaluating interventions with multiple components: development, feasibility/piloting, evaluation and implementation (Craig et al., 2008). The first phase of development includes the review of academic evidence, identification of theoretical frameworks and constructing intervention features that can be explored in the piloting stage. The details on how to conduct this step was brief, leading to extended guidance with specific steps on how to use iterative cycles of development with ongoing input from consumers and stakeholders (Cathain, 2019).

Table 2-2 Reporting standards for studies of tailored interventions: pre-publication checklist (Harrington and Noar 2012)

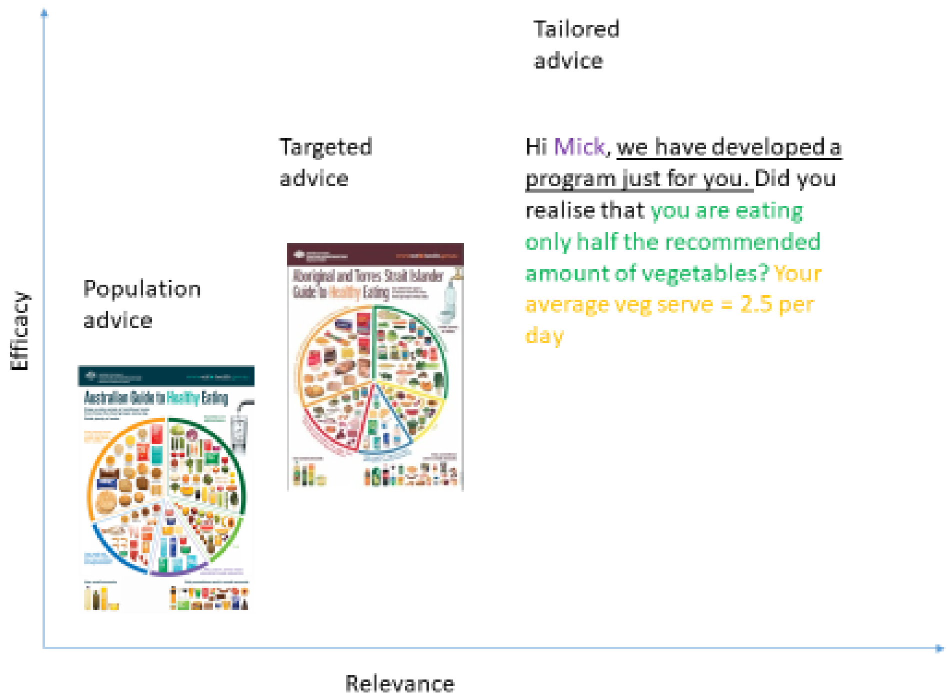
Recommendation	Description
Title, abstract, keywords	Include some variation of 'tailor' in the title, abstract and keywords
Variables/constructs	Specify variables/constructs used for participant assessment in relation to intervention development
Theoretical foundation	Describe how theory guided intervention message design (selection of constructs and intended outcomes)
Tailored messages	Describe the type of the tailored messages participants receive using contemporary terminology
Tailoring system	Describe the tailoring system algorithms
Intervention channel, format, dosage and context	Describe intervention channel, format and 'dosage' of tailoring; describe content (e.g. standard care) that control/comparison group received (if applicable); describe extent to which the tailored intervention was part of a multi-component program (if applicable)
Intervention implementation and assessment	Describe how frequently participants received intervention content and when they received it in relation to assessment

Noar et al. describe tailoring in three steps: 1) assessment of individual-level characteristics, for example, weight, dietary intake; 2) processing of this information by a human or computer; 3) using an algorithm or protocol to select specific content for each participant, for example, text message with tailored feedback on diet (Harrington & Noar, 2012). Few studies have reported on the quality, frequency or duration of data collected during step 1 and hence there is little evidence on the optimum frequency or duration of dietary feedback. The Food 4 Me study is a web-based tailored nutrition intervention, providing tailored dietary feedback developed by nutritionists and dietitians. The published results have been notable in advancing the science of digital tailored dietary intervention. In a RCT with a sample of 1,125, participants were randomised to receive feedback at low frequency or high-frequency (Celis-Morales, 2019). At 3 months, 14.7% in the high frequency group lost >10% body weight, compared to 8.2% for in the low-frequency group. The effects were not sustained at 6-months, falling to 2.8% in the low frequency and 3.6% in the low frequency groups. Importantly, attrition was greater in the high frequency group, but overall retention was comparable with other online interventions (Van der Mispel et al., 2017). The finding from this large and robust tailored digital intervention indicate that the optimum frequency for feedback is likely to be somewhere between 4 and 12 weeks.

Tailoring dietary messages

Targeting messages at segments of the population can increase the engagement with that group, while tailoring the message to the individual enhances the relevance and impact on behaviour even further (Noar et al., 2007; Resnicow et al., 2008). The example in Figure 2-1 shows the Australian dietary guidelines adapted to a visual eating guide for the general population. Acknowledging that Indigenous Australians are more vulnerable to poor diet, a version of the image is *targeted* through consultation with Indigenous communities and health workers. Tailoring goes a step further by assessing the individual, allowing the advice to be personalised with redundant information excluded. This section will explore the published studies on tailored weight loss interventions.

Figure 2-4 Levels of tailoring and intervention efficacy



Developed for this thesis using information from Kreuter, M. W., & Wray, R. J. (2003). Tailored and targeted health communication: strategies for enhancing information relevance. *American journal of health behaviour*, *27*(1), S227-S232.

While evidence for tailoring in weight loss is still emerging, randomised controlled trials comparing a tailored approach with a control have shown sustained improvements in a range of other behaviours. Lustria et al. (2009) conducted a meta-analysis of 40 studies to assess the impact of tailored online interventions for nutrition, smoking, alcohol, PA, medication adherence, stress management and faecal soiling (Lustria et al., 2009). Results revealed that tailored interventions were more effective compared with controls post-treatment, $d = 0.139$ (95% CI = 0.111, 0.166, $p < 0.001$, $k = 40$) and at follow-up, $d = 0.158$ (95% CI = 0.124, 0.192, $p < 0.001$, $k = 21$). The results are positive but the quality of the studies and procedures for tailoring were variable, making it difficult to generalise the impact of this small effect size.

Tailoring for weight loss

In health education tailoring has been defined as "any combination of information or change strategies intended to reach one specific person, based on characteristics that are unique to that person, related to the outcome of interest, and have been derived from an individual assessment" (Kreuter MW, 2000). In practice, Brug et al. suggested interpreting this as a combination of nutrition information or dietary change strategies, aimed at a specific person, based on this person's dietary habits and/or stage of change and the determinants of these behaviours (Brug et al., 1998). Studies have shown that such tailoring creates a personal relevance, avoids useless information and produces a greater influence on attitudes and behaviour (Hawkins et al., 2008).

To determine the efficacy of upscaling tailored interventions we need to understand how tailoring was implemented and assess the impact on weight loss. Among three recent systematic reviews of tailored weight loss interventions, there is little homogeneity in the search criteria, sear terms and aims. As a result, between 6 and 15 studies were included with little overlap in the RCTs selected (Lau et al., 2020; Ryan et al., 2019; Sherrington et al., 2016). Ryan et al. (2019) conducted a meta-analysis of eight articles, relating to six digital, tailored interventions (Ryan et al., 2019). Characteristics used to inform tailored feedback included measures of target behaviour (diet and PA), personal data (previous weight loss, gender), physical measurements (weight, height) and psychological aspects (health-related habits, confidence in weight management). Digital platforms used to acquire this data included online questionnaires, mobile applications and social media. Four of the six articles reported that tailoring was more effective when compared to a control or a wait-list.

Lau et al conducted a systematic review to synthesise the evidence on the effectiveness of digital interventions for weight loss and determine factors associated with this success (Lau et al., 2020). The results confirm previous findings that tailoring is effective, reducing body weight, waist circumference and blood pressure. An important contribution to the field is the result of a meta-regression analysis revealing that increasing age is associated with increased weight loss (Lau et al., 2020). The results show that mean weight loss increased from 19 to

54 years, suggesting that tailoring was most effective among middle-aged populations. However, assessing the age of the participants revealed only two of the 15 studies included young adults, and neither were designed for weight loss, but focussed on dietary change (Kerr et al., 2016) and preventing weight gain (Nikolaou et al., 2015). It could be that middle-aged adults are just more engaged with weight loss as they experience more obesity and diet-related chronic disease (Australian Bureau of Statistics, 2015; Saint Onge & Krueger, 2017). Even so, digital interventions have been viewed as particularly appealing to young adults, with some concern that technology may exclude or deter older adults. In Australia, a national survey of 3,600 adults >50 years, found 90% had access to the internet with the majority accessing the internet via a smartphone (Australian Institute of Health and Welfare, 2018). This finding provides a rationale for assessing the suitability of digital intervention features with users, reflecting the demographics of the target group, during the development of the intervention.

There are some significant limitations in studies assessing the effectiveness of tailored interventions for weight loss. Firstly, the algorithm used to assign tailored feedback to a particular behaviour is often not fully described (Foley et al., 2016; Luley et al., 2014; Shuger et al., 2011). This prohibits a meta-analysis to compare the results between methods, and limits future researchers from replicating the protocol. Another problem is that most tailored feedback is not based on objective measures of the behaviour they are trying to change. Self-reported dietary behaviour is particularly problematic and subject to significant under-reporting (Gemming & Mhurchu, 2016; Moran et al., 2018), influenced by social desirability, and limited by the participant's knowledge of the ingredients and cooking methods (Mete et al., 2017). Improving reporting standards for tailored interventions may help mitigate these problems and improve the design of future digital interventions.

Behaviour change theory

Guidance for the development of complex interventions state the need to embed theory into the design, implementation and evaluation stages (Agarwal et al., 2016;

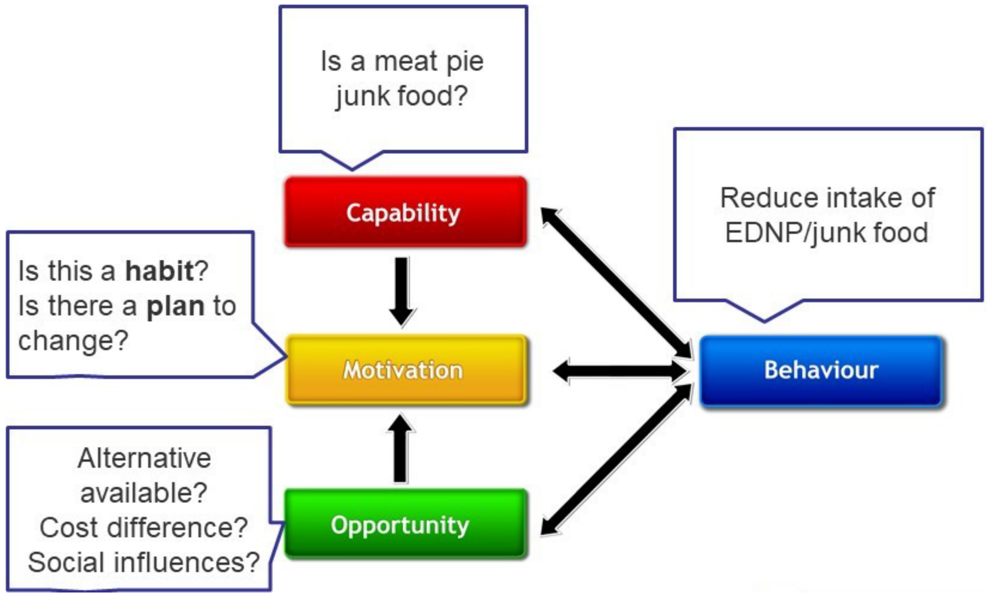
Brendryen et al., 2013; Lewin et al., 2009). For digital interventions this also requires special consideration as to how theories are translated using technology. In practice most digital interventions are developed without a specific theory base. This may be because most theories do not fit the dynamic and evolving approach to digital interventions. Also, existing guidelines lack instructions on how to embed theory into digital interventions, which often include multiple components, for example, an app with text message support, and monthly telephone support (Beleigoli et al., 2019). Another obstacle to embedding theory in digital interventions is the large number of available theoretical models, which makes it challenging to identify which theory is suitable for the behaviour and intervention.

A behaviour change technique (BCT) is a component of the intervention that changes behaviour (Michie et al., 2013). Weight loss is unique in that it requires change in multiple behaviours and, although they need to be personalised for each individual, they often include reducing intake of alcohol and EDNP, self-monitoring of diet, increasing PA and reducing sedentary time. It is important to identify each BCT and the possible mechanism for its action. Michie et al. hypothesised the five BCTs that would be key components of effective physical activity and healthy eating interventions: goal setting, self-monitoring, feedback on performance, prompt intention formation and goal reviews (Michie, 2009). They examined 26 behaviour change techniques from 122 physical activity and healthy eating evaluations in a meta-analysis to identify which techniques were most effective. Healthy eating interventions including self-monitoring were most effective but the effect size doubled with self-monitoring plus one other technique (0.54 self-monitoring plus one other vs 0.24 without self-monitoring). The review concludes that self-monitoring is the single most effective behaviour change strategy and should be a key feature of future interventions.

COM-B model

The COM-B model is based on the premise that an individual's capability, opportunity (O) and motivation (M) are all required to perform the desired behaviour (B). Figure 2.8 shows how all three elements of the models are work together to influence behaviour. Examining each behaviour with the COM-B model helps researchers to select suitable intervention functions (or strategies) that are most likely to achieve behaviour change. Additionally, there is guidance on how to match these intervention functions to a taxonomy of 93 replicable behaviour change techniques. The process provides a transparent process as to how to develop and evaluate interventions (Michie et al., 2013). Of the three components, the capability is often the focus of interventions aiming to improve diet quality. For example, the ability to identify EDNP food and beverages, or correctly interpret food serving sizes for fruit and vegetables, are crucial determinants of diet quality (Harray et al., 2017; Pettigrew et al., 2017). Opportunity relates to the broader environment (advertising of junk food and product placement) as well as food purchased for the home. Motivation includes beliefs, plans and habits. In the current environment, with an excess of poor quality weight loss information, motivation is often to achieve the desired goal but not to follow the dietary guidelines for good health. The COM-B model suggests exploring each of the three components to identify which are hindering the progress to achieving the desired behaviour.

Figure 2-5 The COM-B System – a framework for understanding behaviour (Michie, van Stralen, et al., 2011)



Adapted from Michie et al. (2011). The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/21513547

Behavioural Interventions Technology model

Models used to develop face-to-face interventions have limited application to digital interventions, which are susceptible to software updates, technical problems, being quickly superseded by new technology and requiring the ability to work on different platforms (e.g. android and Apple). The behavioural interventions technology (BIT) model uses a technological framework that assimilates clinical aims, behaviour change techniques and user preferences into a functional intervention feature (Mohr et al., 2014). Acknowledging the evolution of digital intervention features, the BIT model allows for the methods to change during the intervention period. While this may deviate from the published protocols, it allows flexibility in using the technology as well as evolving to meet the expectation of the user. For example, the POUNDS Lost study initially sent dietary feedback at the end of the day, then one year into the study changed to providing feedback immediately after each entry (Anton et al., 2012). The change was made to improve intervention use following user engagement in the development and preliminary testing (Yardley et al., 2015). Using the BIT model to design a digital intervention allows the researcher to modify the protocol or intervention design while maintaining the fidelity of the evaluation.

Self-determination theory

Self-determination theory (SDT) is a framework for exploring and understanding human motivation (Deci & Ryan, 1985b, 2000; Ryan & Deci, 2000). SDT comprises three core psychological needs.

1. Competence – is feeling confidence or effective in their ability to achieve a specific goal.

2. Autonomy – having control over their behaviour and choices; for example, an individual deciding to lose weight without any external pressure or reward.

3. Relatedness – is feeling connected or belonging to other people. For example joining a weight loss group that provides peer support.

Evidence suggests that interventions that support these three essential needs are more likely to result in positive behaviour change with examples from PA

(Markland & Tobin, 2010; Rahman, Thøgersen-Ntoumani, Thatcher, & Doust, 2011), diet (Schüler & Kuster, 2011) and psychological wellbeing (e.g., Edmunds et al., 2007; McDonough & Crocker, 2007; Rahman et al., 2011). Within the context of weight loss, autonomy is supported by a model where the client is given information and support to make their own choice about behaviour change, acknowledging the potential challenges and tailoring the information to their personal circumstances. Competence is promoted through actionable feedback and developing the individual's capability of behaviour, for example with nutrition education. Relatedness is fostered with empathy, good interpersonal skills and a non-judgemental environment.

Self-determination theory differs from other motivational theories by considering the quality of motivation, in addition to the quantity. Autonomous types of motivations are intrinsic and associated with more positive outcomes, and adherence to new behaviours. This theory is often used to explain why a weight loss intervention might produce more weight loss among research participants compared with those referred from a health service (P. J. Teixeira et al., 2012). The act of making an independent decision to join a weight loss intervention may be a sign of existing autonomy and intrinsic motivation. According to SDT, long-lasting behaviour change is most likely to occur when behaviour change is autonomously motivated with intrinsic drivers and when individuals feel confident and capable of change. Internal reasons for weight loss behaviours may be: (a) activities are fun, interesting and satisfactory (intrinsic regulation); (b) the behaviours are viewed as important and personally valued (identified regulation); or (c) health behaviours have been adopted as part of their identity (integrated regulation) (Pedro J. Teixeira et al., 2012). In contrast, those with a lack of autonomous motivation engage in healthy activities for external reasons – often experiencing a sense of pressure – and the behaviour is driven by reasons such as (a) potential of a reward or to conform with social expectations (external regulation), or (b) to avoid guilt or shame (introjected regulation) (Coumans, 2020).

In the context of weight management, evidence suggests that perceived autonomy support is associated with weight loss (e.g., Powers, Koestner, & Gorin, 2008; Silva et al., 2011). One of the earliest studies was conducted by Williams et al. (1996). In the study, 128 adults with severe obesity (mean BMI = 41) entered into a 26-week weight loss program, with weekly group meetings. Williams et al. showed that participants' perceived autonomy support predicted their autonomous motivation for weight loss, which in turn predicted higher attendance and greater weight loss (Williamson et al., 2015). A 2018 study of 1,433 adults with type 2 diabetes who had tried to lose weight in the last 2 years found autonomous motivation and self-care competence were predictors of success in weight management (Koponen, 2018). The study made recommendations for health care professionals to help clients to internalise the value of behaviour change and weight loss. The results suggest this that males and adults under 50 years are most likely to have this internal value of behaviour change. Including these participants in the development of a digital intervention may give more accurate insight into factors that may motivate ongoing participation in weight loss behaviours.

Summary of the literature review

Adherence to the Australian Dietary Guidelines in low across all sectors of the population in Australia. Most notably, vegetables and fruits have been displaced by energy-dense and nutrient-poor food and beverages. The resulting impact on weight gain and risk of chronic disease has prompted a surge in digital interventions that could potentially reach more people that traditional face-to-face approaches. The evidence suggests that digital interventions that provide tailored feedback and based on theoretical constructs of behaviour change are most likely to be effective. The emerging studies in this area have prompted some international clinical guidance on how to develop and implement digital interventions. In Australia, there are no current guidelines for face-to-face or digital weight loss interventions, leaving a gap in treatment options and support for those with moderate and uncomplicated obesity.

Studies trialling digital interventions suggest that tailoring the content to the specific preferences and characteristics of the individual increases the engagement and effectiveness. Current digital interventions providing feedback have shown varying results, ranging from clinically significant weight loss to no observed difference in weight. The studies reviewed highlight the heterogeneity of these interventions, specifically the range of digital platforms used for disseminations, the method used to collect behavioural data and the duration and frequency of self-monitoring. Although some studies have examined some of these factors, it is not clear which approach is most effective and which approach is most acceptable to the participant.

Chapter 3 Systematic review (submitted for publication)

Introduction

(Objective 1) Systematically review the protocols for DA methods used to inform tailored feedback in digital weight loss interventions, examining the digital platforms used for data collection, type of DA and duration of the assessment

This chapter provides the final manuscript submitted for publication. The candidate was responsible for designing the study protocol, search terms, inclusion criteria and creating the data tables; for screening the studies and writing the draft manuscript. The candidate registered the review with PROSPERO, an international database of prospectively registered systematic reviews.

Abstract

Digital tailored interventions have shown small to modest effects on weight loss and diet quality. The effectiveness of the tailored feedback may be limited by the quality of the dietary assessment (DA) upon which it is based. This study aimed to systematically review the protocols for DA methods used to inform tailored feedback in digital weight loss interventions, examining the digital platforms used for data collection, the type of DA and duration of the assessment. The search strategy included five databases PubMed – National Library of Medicine database, MEDLINE, Cochrane Library of Systematic Reviews, Web of Science and ProQuest. It used the preferred reporting items for systematic reviews and meta-analyses (PRISMA) approach. Searches used a combination of terms related to five groups: dietary assessment, weight loss, clinical trials, technology and tailoring. Thirteen articles were eligible for the systematic review. The majority of studies (n=10) used a dietary record linked to a food database providing instant feedback on energy intake. The duration of dietary assessment ranged from 12 weeks to 30 months, and dietary feedback was provided using text messages, email, mobile applications and intervention websites. This review highlights the inconsistency in DA methods used in tailored weight loss interventions, which may account for the range of results reported. Most digital dietary feedback focussed on reducing energy

intake without providing feedback to enhance diet quality. Future interventions should publish the protocol describing how dietary intake data was used to inform dietary feedback.

Keywords: dietary assessment; digital; intervention; tailored; weight loss; clinical trial; obesity; systematic review

Background

The Global Burden of Disease Study has identified poor diet and obesity as major contributors to the high burden of non-communicable chronic diseases (NCD) (Collaborators, 2019). Therefore improving dietary behaviours of the population is a public health priority (Aune et al., 2017; Collaborators, 2019; Reedy et al., 2014). The complex interaction between environmental, biological, economic and individual factors associated with obesity provides challenges and opportunities for preventative strategies. Interventions targeting NCDs, including obesity, should aim to improve dietary behaviours of individuals and populations, with digital technologies a possible avenue to achieve this outcome (Melaku et al., 2019). There is an urgent need to identify effective and scalable weight loss interventions to support the increasing number of people living with overweight and obesity. Digital tailored interventions have the potential to be scalable but to date have shown small to modest effects on weight loss and diet quality (Springvloet et al., 2015; Teasdale et al., 2018). A key component of these interventions is personalised or tailored dietary feedback. In Europe and the United States, clinical guidelines for the management of overweight and obesity recommend personally tailored dietary feedback, with behaviour change techniques (BCT) such as self-monitoring diet and personalised feedback to reduce energy intake and improve diet quality (Stegenga et al., 2014; Yumuk et al., 2015). One factor that may limit the effectiveness of the tailored feedback, and therefore the intervention effectiveness, may be the quality of the dietary assessment (DA) upon which the feedback was based.

Still, there is concern that lengthy assessment tools used to generate tailored feedback may increase attrition if applied to digital platforms where engagement is already problematic (Van der Mispel et al., 2017).

The most commonly used DA methods for dietary feedback are dietary screeners, food frequency questionnaires (FFQ) and dietary records. Although these methods are used to provide tailored dietary feedback, there are large differences in the type and quality of feedback that is possible. For example, screeners typically use one to two questions for a specific behaviour such as fruit and vegetable intake, whereas dietary records ask participants to keep a detailed record of all food and beverages consumed over a set time frame (usually 4 to 7 days). Through advances in technology there are now digital and image-based DA methods available for researchers (Ahmad et al., 2016; Bathgate et al., 2017; Gemming et al., 2015). Digital food records use either a website or app to record food and beverage intake. These are referred to as 'open', where the participant records their intake with free text (Hageman et al., 2017), or 'closed' where the participant chooses from a pre-determined list of foods and beverages and enters the amount consumed (M. C. Carter et al., 2013; Chen et al., 2015; Patel et al., 2019). With image-based methods, images of food and beverages are captured using a mobile device and automatically uploaded to a secure server where they are reviewed either by a trained analyst or automated algorithm (Boushey et al., 2017; Doumit et al., 2016; Gemming et al., 2015; O'Loughlin et al., 2013).

A systematic review to examine it how digital health has been used for self-monitoring of diet and physical activity included thirty-nine studies from 2009 to 2019. Sixty-seven interventions with digital self-monitoring were included, weight was tracked in 72% of them, diet in 81%, and physical activity in 82%. However, only one passive intervention feature recorded dietary behaviour and this was a bite counter. The Bite Counter is a wrist-worn device that detects when the wearer has taken a bite of food. The device is linked to an app which uses an algorithm to estimated calorie intake, based in the number of bites. During eating, it displays bite count for the current eating activity and allows users to review total bites consumed. While this feature was coded as wearable and passive, the device must be turned on at the start of eating and off at the end, thus still having the limitation of an active method. In addition, liquid calories such a sugar-sweetened beverages, smoothies and alcohol are not counted. The review highlights that passive methods had higher engagement rates than active self-monitoring methods. However, passive methods for self-monitoring of dietary behaviours are not practical or easy to implement at this time, particularly for the provision of feedback.

Image-based approaches are dependent on the captured images as the main source of information and only supplemented with input from the user as to clarify details such as the type of food or if missing items. Alternatively, the image capturing can be passive (for example, wearable cameras), meaning that the participants does not need to actively capture the image. This passive assessment of dietary intake includes a camera, worn around the neck of the individual that continually collects data on food and beverage intake. The main advantage of this technology is the continuous collection of real-time image data which can capture unconscious eating and food consumption that may be difficult to monitor (social events, eating while driving). Despite these advantages, wearable devices pose challenges in content analysis of the image, which each participant’s camera capturing up to 4,000 images per day (Davies, 2021). The benefit of passive monitoring high portability, facilitates real-time self-monitoring, reducing errors. Passive methods may also be well suited to those who are reluctant to self-monitor their behaviour in certain scenarios which may cause embarrassment; for example at a social function or while at work. Moreover, passive approaches lessen barriers around health literacy and ability to utilise technology.

Previous reviews have explored various factors that affect digital tailored weight loss including how tailoring is implemented (Ryan et al., 2019), adherence to self-monitoring (Cavero-Redondo, 2020) and the specific BCTs used (Sherrington et al., 2016) but none have yet examined the role of DA. This study aimed to systematically review the protocols for DA methods used to inform tailored feedback in digital weight loss interventions, examining the digital platforms used for data collection, type of DA and duration of the assessment. Table 3-1 provides a list of definitions for standard terms to describe procedures for assessing dietary intake.

Figure 3-1 Definition of dietary assessment methods

Dietary assessment	The collection of data on food and beverages consumed over a specified time that is coded and processed to compute intakes of energy and other nutrients (Dao et al., 2019).
Self-monitoring	Self-monitoring requires a person to deliberately observe and record their behaviour or behavioural outcome e.g. self-monitoring weight or diet (Michie et al., 2013).
Method	In the current paper, the term 'method' refers to the different dietary assessment methods (e.g., diet record or FFQ as the dietary assessment method).
Food Frequency Questionnaire (FFQ)	Questionnaire to assess habitual dietary intake, based on a defined list of foods and beverages. Participants are asked to indicate their typical frequency of consumption over a specified period in the past, usually with multiple-choice questions with options ranging from 'several times per day' to 'never' (Thompson et al., 2015)
Dietary record (open)	Intake of food and beverages completed at the time of consumption where the participant details his/her intake with free text (Dao et al., 2019).
Dietary record (closed)	Intake of food and beverages completed at the time of consumption where the participant chooses from a pre-existing list of foods and beverages, and enters the amount consumed (Dao et al., 2019), e.g. MyFitnessPal
Image-based dietary record	Images of food and beverages are captured using a mobile device and automatically uploaded to a secure server where they are reviewed by a trained analyst or automated algorithm (Boushey et al., 2017).
Dietary screener	A short questionnaire to collect basic information about dietary intake. This can be a short food frequency questionnaire or questions on dietary behaviours (Thompson et al., 2015)

Methods

The methodology for this review follows the guidelines of the Cochrane handbook for systematic reviews of interventions (Furlan, Pennick, Bombardier, & Van Tulder, 2009). The preferred reporting items for systematic reviews and meta-analyses (PRISMA) were used to report findings (Moher, Liberati, Tetzlaff, & Altman, 2009). The review was registered with PROSPERO (CRD42017065795).

Search strategy

Electronic databases searched were: PubMed – National Library of Medicine database, MEDLINE, Cochrane Library of Systematic Reviews, Web of Science and ProQuest for studies published in English between January 1990 and December 2019. Databases were searched with a combination of the following search terms and synonyms. We searched each database using a combination of five groups of search terms: (1) **dietary assessment**: dietary record, food record*, food intake*, diet record*, dietary record*, dietary assessment*, dietary intake*, dietary measurement*, energy intake*, caloric intake*, nutrient intake*, nutritional intake* and nutrition* assessment*; (2) **weight los***s*: "weight loss", "Weight maintenance", "obesity"; (3) **clinical trials**: Randomised controlled trial, clinical trial; (4) **technology**: Internet, web, computer, online, telemedicine; and (5) **tailoring**: eHealth, mHealth, personalised, tailored, individualised. Consultation with an experienced Health Sciences librarian was sought to verify the search terms, strategies and results. The references of included articles were hand searched for further studies. Authors were not contacted for further details as the aim of the review was to examine the protocols described in published articles.

Eligibility criteria

Eligibility criteria for included studies are detailed in Table 3-2. Only weight loss studies that used a digital method for dietary assessment were included. For this review, 'digital' was defined as including the use of email, internet, mobile telephone, mobile device, online or mobile phone application, tablet or text message. Included studies must involve weight-loss interventions targeting changes in diet, or physical activity and diet, include technology in the dietary assessment (email, internet, mobile telephone, mobile device, app, tablet or text message) and be published in peer-reviewed journals. Studies involving children or adolescents and those using pharmaceutical or surgical methods of weight loss were excluded.

Screening

Records were imported from the selected databases into Covidence (www.covidence.org/home). Duplicates were removed and the remaining records were screened by the candidat, firstly by title and abstract and then by full text. A random sample of 10% of the data was double screened by a second person. Discrepancies were resolved by re-examination of the study and discussion between them.

Data extraction (selection and coding)

Data extraction was conducted using the Covidence tool which included a custom data extraction form. The following study details were recorded: number, gender, age and body mass index of participants; dietary assessment tools used for providing tailored feedback and baseline dietary assessment; duration of dietary assessment; frequency of tailored feedback and key outcomes reported. Studies that referenced a known procedure (i.e. validated FFQ, publicly available app or published protocol) were included and the relevant information extracted from additional sources. Due to the lack of heterogeneity between dietary assessment methods, study durations and sample, a meta-analysis was not conducted

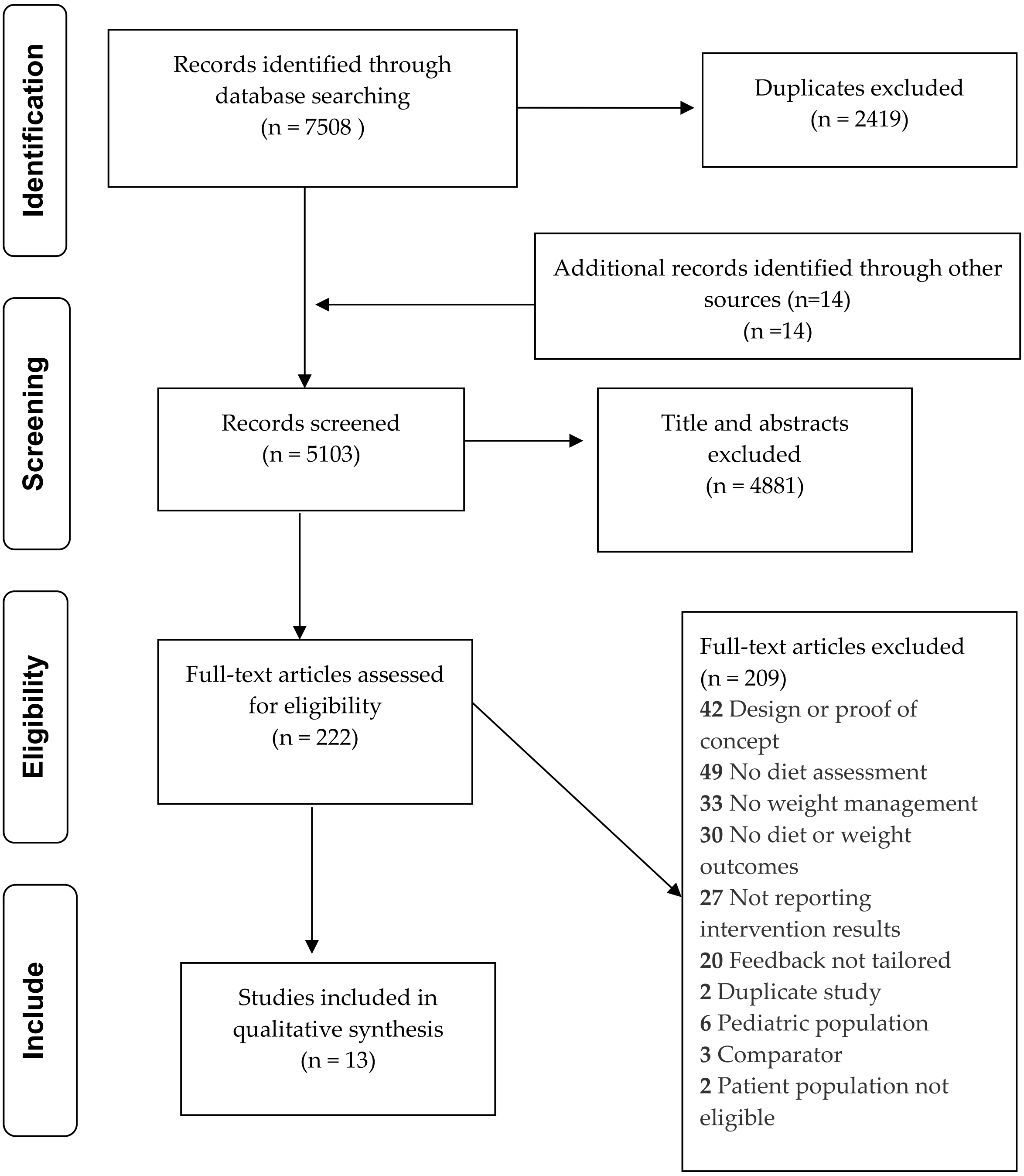
Table 3-1 Criteria for identifying studies to be included

Inclusion criteria	
Population	Adult (18+ years) participants with Body Mass Index (BMI) > 25 kg/m^2
Interventions	The dietary assessment methods used with online, tailored weight-loss interventions and their features. A digital weight loss interventions providing tailored dietary feedback where all, or part of the intervention is delivered by text message, website, email, mobile application or any other electronic communication. Interventions will need to include a dietary assessment to be included in this review. Uses digital methods to assess diet
Comparator	Includes tailored dietary feedback
Outcome	Studies were excluded if they do not report the dietary assessment methods used, did not use technology to assess diet, or assess dietary intake for a purpose other than weight loss. Only papers relating to results of randomised controlled trials, including aged 18 years and over with a BMI > 25 were considered.
Study design	Duration of dietary assessment Validation of dietary assessment against biological or standardised measures Provision of dietary feedback given to the participant Timing and frequency of dietary feedback
Additional outcomes	Randomised controlled trials Other features of the intervention such as health professional input or option to manually enter missed foods; the intervention effectiveness, sample characteristics

Results

A total of 7,508 articles were identified through online searching and 14 additional reports from searching reference lists and review protocols were screened for inclusion. After exclusion of duplicates and articles not meeting the inclusion criteria, 222 articles were retrieved and full-text articles were assessed for assessment of eligibility. Further studies were excluded for the following reasons: insufficient dietary assessment used or reported (Shuger et al., 2011), weight loss medication (Little et al., 2016), dietary feedback not provided (Jakicic et al., 2015) weight loss not an outcome (Chambliss et al., 2011; Foley et al., 2016; Gans et al., 2015), no digital assessment of diet and sample not overweight (Gilson et al., 2017; Kerr et al., 2016; Mouttapa et al., 2011). Thirteen articles were included for full qualitative assessment (Figure 3-1 PRISMA flow diagram PRISMA diagram).

Figure 3-2 PRISMA flow diagram



Study characteristics

Thirteen studies included are presented in Table 3-3. The sample size varied from 43 to 446. Participants were mainly recruited from the general population with the majority of the sample being female except one study which recruited participants from a military base (Hunter et al., 2008) and two studies that recruited men only (Hunter et al., 2008; Morgan et al., 2013), and Phelan et al. (2017) specifically recruited low-income postpartum women and tailored the intervention for those breastfeeding (Phelan et al., 2017). Seven studies were conducted in the USA, three in Australia and the remaining studies in Europe. The majority of studies (n=8) had participants with a BMI between 30 and 35, one study had a mean BMI of 43 (M. Carter et al., 2013) and two studies had a mean BMI of 29 (Hunter et al., 2008; Hutchesson et al., 2018). Two studies did not report the mean BMI (Hageman et al., 2017; Patrick et al., 2011). Attrition rates varied between 7% (M. C. Carter et al., 2013) and 30% (Haapala et al., 2009; Patrick et al., 2011).

Platform

The platform for data collection included custom-developed software on a personal digital assistant (PDA) (Burke et al., 2009) or a mobile telephone app (M. C. Carter et al., 2013; Foley et al., 2016; Hutchesson et al., 2018). Luley et al. collected dietary data on an accelerometer that allowed for the recording of meal calories that participants could read on the display (Luley et al., 2014). The remaining studies used web-based platforms for dietary recording which could be accessed via a smartphone or computer.

Dietary assessment method

Table 3-4 lists the method used to collect dietary data to inform tailored feedback and the duration of the dietary assessment undertaken. Six studies used a digital (closed) dietary record where participants selected their intake from a pre-determined list of meals or foods (Burke et al., 2009; M. C. Carter et al., 2013; Haapala et al., 2009; Morgan et al., 2013; O'Brien et al., 2014; Phelan et al., 2017). All closed dietary record were linked to a database providing nutrition information, sourced from branded products and recipes, to derive commonly eaten foods developed by an accredited practising dietitian or national food composition tables.

Men in the SHED-IT trial used a web-based digital (closed) dietary record using commercially available software (CalorieKing™ Australia) with an Australian-specific food database (Australia) (Morgan et al., 2013). Burke et al. provided participants with a personal digital assistant (PDA) installed with a program to calculate energy and fat consumption and assess energy intake against daily goals (Dietmate Pro©) (Burke et al., 2009). O'Brien et al. used a commercial online program, The Australian Biggest Loser Club. A protocol paper describes the web-based dietary record in detail (Collins, 2010). My Meal Mate used a custom-designed diet record app on a smartphone using a food and beverage database specific to the UK (Carter et al., 2017). This study is the only app developed by researchers that is available in the public domain. Two studies described a closed digital dietary record but did not state the source of the dietary data or associated database (Phelan, 2015;Haapala, 2009).

Four studies used an open diet record where participants used free text entry of foods and calories. Tate et al. provided a calorie book and instructed participants to report their calorie and fat intake into a secure website every day for the first month (Tate et al., 2003). Hageman et al. asked users to calculate their daily energy using a book provided, and to enter this data to the intervention website (Hageman et al., 2017). Luley at al. also asked participants to estimate calories and enter this into an accelerometer – data was prompted by meal, for example, breakfast or snack followed by options of “mini,” “normal,” or “maxi” to estimate portion sizes (Luley et al., 2014). Luley et al. did not provide a resource to calculate calories but offered a 2-hour training session on how to determine portion sizes and record dietary data. Hunter provided in-person training where “participants were instructed to log-in and complete self-monitoring food and exercise diaries at least five times a week” (Hunter et al., 2008, p. 121).

Patrick et al. was the only study to use a dietary screener to assess fruit, vegetable, wholegrains and saturated fat intake (Patrick et al., 2011).

Table 3-2 Characteristics of studies included in the systematic review

First author, year, country	Sample size	Mean BMI of the intervention group (SD)	Mean age (years)
Burke, 2009, USA (Burke et al., 2009)	210	31.4 (4.5)	49
Carter 2017, UK, (M. Carter et al., 2013; Carter et al., 2017)	43	34 (4)	41
Haapala, 2009, Finland (Haapala et al., 2009)	125	30.6 (2.8)	38.1
Hageman, 2014, USA (Hageman et al., 2017)	301	Not reported	53
Hunter, 2008, USA (Hunter et al., 2008),	446	29.4 (3)	34
Hutchesson, 2018, Australia (Hutchesson et al., 2018) (Hutchesson et al., 2018)	57	29.4 (2.5)	27
Luley, 2014, Germany (Luley et al., 2014)	184	Not reported	50
Morgan, 2013, Australia (Morgan et al., 2013)	159	32 (3.5)	47.5
O'Brien, 2014, Australia (O'Brien et al., 2014)	289	32 (3.9)	41.6
Patrick, 2011, USA (Patrick et al., 2011)	441	Not reported	43.9
Phelan, 2017, USA (Phelan et al., 2017)	192	31.7 (5.1)	28
Schroder, 2011, USA (Schroder, 2011)	91	34 (5.4)	42.6
Tate, 2003, USA (Tate et al., 2003)	91	33.1 (3.5)	48.5

Intervention design

While all studies aimed to achieve weight loss by reducing energy intake, the dietary approach to achieving this varied across studies. Schroder and O'Brien specifically aimed to assess the impact of their intervention on diet quality (O'Brien et al., 2014; Schroder, 2011). Luley used a low carbohydrate diet with an emphasis on carbohydrates with a low glycaemic index (Luley et al., 2014). Phelan et al. used both a calorie goal of 1200 to 1800 kcals/day and less than 35% energy from fat (Phelan, 2015). Haapala focussed on reducing energy-dense nutrient-poor (EDNP) foods (Haapala et al., 2009) whereas Hageman et al. focussed on energy from fat (Hageman et al., 2017).

Dietary analysis methods

All studies reported a change in energy intake as a primary or secondary outcome of the intervention. Two studies used a human to conduct the dietary analysis but it is not reported if they used any dietary analysis software (Hageman et al., 2017; Tate et al., 2003). Tate et al. (2003) state that the counsellor providing dietary feedback had postgraduate qualification in nutrition, health education or psychology (Tate et al., 2003). For this study, the protocol for dietary analysis is described as using the counsellor's clinical judgment 'to assess and interpret participants' diet records'. Hunter et al. did not report on the training or qualifications of the people analysing dietary data.

An online dietary record was exclusively analysed by computer software in seven studies (Foley et al., 2016; Haapala et al., 2009; Hutchesson et al., 2018; Luley et al., 2014; O'Brien et al., 2014; Patrick et al., 2011; Phelan et al., 2017). Carter et al. (2013) used a purpose-built dietary record app where users selected foods from a commercial database with over 40,000 items (M. C. Carter et al., 2013). Burke et al. (2009) used a mobile application on a PDA (Burke et al., 2009). The Australian Biggest Loser Club is a commercial weight loss program, delivered on a web-based platform with a built-in dietary record. The dietary data is informed by an international food and exercise database, including 20,000 Australian foods and the source of the data is described in the protocol.

Frequency of data collection

Burke et al. specified the longest period of data collection, requesting daily reporting for 24 months. My Meal Mate did not specify the frequency of data collection to participants. After the first week they were instructed to use the app "as often as they please" (Carter et al., 2017). Haapala et al. stated their intervention was designed to support self-directed users so no guidance on the frequency of entering data was provided (I. Haapala et al., 2009). Hageman et al. was the longest intervention (30 months) asking participants to record their dietary intake daily for the first 6 months, bi-weekly from 6–18 months and then 'encouraged' from 18–30 months (Hageman et al., 2017).

Dietary feedback

Feedback was provided on a variety of digital platforms: emails, text messages, web-based platforms and mobile applications. Most studies (n=8) that used a closed diet record were able to provide participants with immediate feedback on estimated energy intake (Burke et al., 2009; Carter et al., 2017; Haapala et al., 2009; Hutchesson et al., 2018; Morgan et al., 2013; O'Brien et al., 2014; Phelan et al., 2017; Schroder, 2011). Four studies used a researcher to generate dietary feedback from reviewing the dietary records (Hageman et al., 2017; Hunter et al., 2008; Hutchesson et al., 2018; Tate et al., 2003). Hunter et al. states that "Each participant was assigned one Internet counsellor for the duration of the intervention and these counsellors spent 10–15 minutes per participant each week providing written feedback" (Hunter et al., 2008, p. 121). Participants received feedback on food, PA and weight data as well as personalised suggestions for weekly lessons on behaviour change strategies. Tate et al. describe counsellor written emails that provide support in addition to tailored feedback on the dietary records submitted to the website (Tate et al., 2003). Two studies explicitly state that dietary feedback was provided by a registered dietitian. Hutchesson et al. provide a detailed description protocol for developing tailored feedback, informed by participants' responses to an online quiz, and dietary data collected with the Easy Diet Diary app (Xyris Software, Australia), a closed dietary record (Hutchesson et al., 2018). Participants received immediate feedback on nutrition and energy intake from the app as well as tailored feedback, developed by an accredited practising dietitian, on goal setting and eating behaviour (Hutchesson et al., 2018). Hageman et al. also employed a dietitian to provide tailored feedback informed by the Dietary Guidelines for Americans with a focus on reducing fat, and energy and nutrient-dense foods. Email feedback was based on the 5A's Model for Behavioral Counselling (assess, advise, agree, assist and arrange) (Glasgow, 2006).

Patrick et al. (2011) provided computer-generated graphical feedback on participants' dietary records which was available on the intervention website (Patrick et al., 2011). In addition to digital feedback, four interventions provided counselling support via telephone (Hunter et al., 2008; Luley et al., 2014) and in-person (Phelan et al., 2017; Schroder, 2011).

Three interventions provided instant feedback on energy intake, followed by more comprehensive behavioural feedback sent at regular intervals (Burke et al., 2009; Hutchesson et al., 2018; Morgan et al., 2009). Morgan et al. (2013) tailored the feedback on participants' engagement with meal plans, grocery lists and physical activity plans (Morgan et al., 2013), and Hutchesson used performance in online quizzes, self-reported motivation for weight loss and achievement of virtual rewards (Hutchesson et al., 2018). Burke et al. employed a specially trained researcher to analyse dietary data and provided additional written feedback (Burke et al., 2009).

My Meal Mate intervention provided instant feedback informed by self-reported energy intake and estimated energy expenditure (M. C. Carter et al., 2013). Food items recorded on the My Meal Mate app were uploaded to a secure administrator website for further analysis of macronutrient intake by the researchers but not used to inform dietary feedback.

Outcomes

All studies reported changes in body weight, BMI and waist circumference at baseline and post-intervention. Two studies reported no difference in weight loss between the intervention and control groups (Hutchesson et al., 2018; Patrick et al., 2011). Four studies reported weight loss in the intervention group that was not statistically significant (Foley et al., 2016; Hunter et al., 2008; O'Brien et al., 2014; Phelan et al., 2017). The remaining seven studies reported statistically significant weight loss of about 3 kg (Burke et al., 2009; M. C. Carter et al., 2013; Haapala et al., 2009; Hageman et al., 2017; Luley et al., 2014; Morgan et al., 2013; Tate et al., 2003).

All studies included energy intake in their dietary outcome, but the methods and data reported were not consistent or comparable. One study used software that rated the diet quality between 1 and 5 stars (Schroder, 2011). Six studies reported outcomes related to diet quality by analysing intakes of fat, fruit, vegetables, fibre, alcohol and EDNP (Burke et al., 2009; Haapala et al., 2009; Hageman et al., 2017; Morgan et al., 2013; O'Brien et al., 2014; Schroder, 2011). Changes in the Australian Recommended Food Score, a measure of overall diet quality derived from a validated food frequency questionnaire, (Collins et al., 2008) were the primary outcome of one study (O'Brien et al., 2014).

Figure 3-3 Features of included studies

Author, year, country	Platform	DA method used to inform tailored feedback	Sample period	Attrition (%)	Dietary analysis	Frequency of dietary feedback	Dietary outcomes assessed
Burke et al. 2009 USA (Burke et al., 2009)	PDA[a]	Closed dietary record	Daily for 24 months	14	Computer-generated, nutrient database used	One automated daily feedback email plus written feedback from researcher.	Personalised energy limit and fat intake <25% calories.
Carter et al. 2017, UK (Carter et al., 2017)	Website	Closed diet record	Not specified	7	Computer-generated, nutrient database used.	Instant, automated feedback on energy balance and weekly text message	Estimated energy intake
Haapala et al., 2009 Finland (Haapala et al., 2009)	Mobile computer/web access	Closed diet record	Not reported	30	Computer-generated	Daily text message	Energy-dense food score; estimated energy intake
Hageman, 2017, USA (Hageman et al., 2017)	Website	Open diet record	30 months	28	Researcher generated, dietary analysis software used	Weekly email feedback	Energy goal of 1,200-1,200 kcal; fat 20-35% of energy

Hunter et al. 2008, USA(Hunter et al., 2008)	Website	Open diet record	At least 5 times per week for 6 months	17	Researcher generated	Weekly written feedback through intervention website plus 2 phone calls.	1200–1500 kcals/d per day fat <30% energy
Hutchesson, 2018 Australia (Hutchesson et al., 2018)	Mobile app Easy Diet Diary (Xyris Software Australia)	Closed diet record	Daily for 26 weeks	25	Dietitian and computer-generated, dietary analysis software used	Email feedback, 4 times in 26 weeks	Estimated energy intake
Luley et al. 2014 Germany (Luley et al., 2014)	Accelerometer	Open diet record	Daily for 12 months	18	Computer-generated, nutrient database used	Weekly written feedback on energy intake and monthly phone call	Estimated energy intake
Morgan, Australia (Morgan et al., 2013)	Website	Closed diet record	2 weekday and 2 weekend days for for 12 weeks	11	Computer-generated, nutrient database use. Plus researcher input.	7 times over the 3 months; researcher generated plus instant feedback on energy	Estimated energy intake
O'Brien, Australia (O'Brien et al., 2014)	Website	Closed diet record	Minimum 4 times per week for 12 weeks	16	Computer-generated, nutrient database used.	Weekly, automated plus text messages and phone calls.	Australian Recommended Food score

Patrick, 2011, USA (Patrick et al., 2011)	Website	Diet screener	Not reported	30	Computer-generated, nutrient database used	Weekly, source of feedback not described	% energy from total fat, saturated fat and g/1000 kcal/day for fibre, fruit and vegetables
Phelan, 2017, US(Phelan et al., 2017)	Website	Closed diet record	Not specified	11	Computer-generated tailored feedback using dietary analysis software	Weekly text message for 4 weeks	Meeting calorie of 1200to1800 per day with300 additional calories for breastfeeding.
Schroder, 2011 USA (Schroder, 2011)	Computer software	Closed diet record	7 days minimum but no upper limit	28	Computer-generated, nutrient database used.	Instant feedback on energy balance and compliance with dietary guidelines	Reduced energy, fat and sugar intake; increase fruit, vegetables and fibre and 1-5 star diet quality rating.
Tate, 2003, US(Tate et al., 2003)	Website	Open diet record	Daily for the first month then weekly	23	Researcher with related masters or doctoral degrees. No database reported.	Five times per week for one month.	Feedback on self-monitoring of diet, recommendations for change and general support.
	[a]PDA- personal digital assistant						

Discussion and conclusion

A systematic review of the DA methods used to inform tailored feedback was conducted on thirteen digital weight loss interventions. The results highlight the inconsistency in DA methods and variability in the quality and content of tailored feedback which may hinder the effectiveness of the intervention. In the majority of studies, dietary feedback focussed on creating an energy deficit to achieve weight loss with only three studies addressing overall diet quality (O'Brien et al., 2014) and intake of fruit, vegetables and fibre (Patrick et al., 2011; Schroder, 2011).

A critical factor in assessing the suitability of dietary assessment is the ability to produce reliable results suited to the purpose of the appraisal, in this case, dietary feedback for weight management (Kirkpatrick et al., 2019). Eleven of the studies in this review only included energy intake in the dietary feedback, which may be due to the limitations of the dietary data collected or the protocol used for assessment. Although energy balance is important, nutrition knowledge is an essential mediator for weight loss (Shoneye, 2019 ;Keay, 2018). Digital weight loss interventions should follow clinical guidelines to address reduce energy intake by displacing EDNP food and beverages with vegetables, fruit, legumes and whole grains, improving diet quality independent of weight loss (Yumuk et al., 2015) (Stegenga et al., 2014). However, digital intervention have inherent problems with engagement and participants have expressed a preference for continuous feedback, energy intake and the option scan barcodes – features available in many closed dietary records (Tang, Abraham, Stamp, & Greaves, 2015). Interventions that used a closed DA to provide instant feedback on energy with additional researcher feedback are most likely balance intervention features that are both evidence based and engaging.

A novel finding of this review is that self-monitoring tools were often used to inform the tailored feedback while the DA tools were used to measure dietary change as an outcome. This finding is notable given that most studies report some positive change in behaviour and weight. A possible explanation could be the known problems around inaccuracy of dietary reporting (Macdiarmid & Blundell, 1997; Vuckovic, Ritenbaugh, Taren, & Tobar, 2000); deliberately not reporting food eaten, reducing food consumption to make reporting easier   and difficulties in using the assessment tool (Connor, 2020; Macdiarmid & Blundell, 1997; Scagliusi, Polacow, Artioli, Benatti, & Lancha Jr, 2003). Individuals may change their usual intake to consume more pre-packaged food that can be quickly recorded, particularly in the closed diet records that can scan bar codes (Vuckovic et al., 2000). In this study, there is no clear link between the type, duration or frequency of DA and weight loss. This has been found previously with frequency and consistency of recording dietary data, more important for weight loss than accuracy (Peterson et al., 2014) but further studies are needed to understand the impact on diet quality.

Dynamic tailoring that is continually informed through ongoing assessment has more personal relevance than a static tailoring, based on a single assessment performed at baseline (Krebs, 2010). Self-regulation theory suggests feedback works by providing individuals with reports on their progress towards a set goal(s) (Locke, 2002;Carver, 1982) so is most effective when received at the time of performing the behaviour or 'just-in-time'. One promising technique is the mobile food record (mFR™) an image-based dietary assessment tool that uses the integrated camera on a smartphone (Zhu et al., 2015). In an intervention with young adults, a trained analyst assessed the images and provided tailored feedback via text messaging on serves of fruits, vegetables and energy-dense nutrient poor food and beverages (Kerr et al., 2012). As this technology evolves with more automated methods it has the potential for real-time personalised, image-based feedback (Shoneye et al. 2020) including the estimation energy intake (Fang, 2019).

This review highlights problems with the terminology used in this field. The term ‘dietary record’ has been described by authors to encompass a range of approaches which are distinctly different: entering free text into a website (open) and selecting individual foods from a database on a mobile application (closed) (Chen et al., 2015). Entering free text relies on the participant to adequately describe the food, cooking method and quantity, which may be more challenging for those with lower levels of literacy (Ortega, 2015). Still, it is limited to the items available in the associated database, which may not include food available in specific regions or preferred by some cultures. The terms ‘open’ or ‘closed’ dietary record have been described in papers reviewing dietary assessment methods but were not used in any of the studies examined for this review (Shim, 2014 ;Dao, 2019). Future studies should consider adopting existing terminology and definitions to describe the dietary data collected in more detail. An exemplar is Collins et al., who represented the online food diary as a self-monitoring tool identifying the source of the nutrition information and the commercial platform on which it is available, and then explained how this data was used to inform the computer-generated, tailored feedback (Collins, 2010).

Likewise, the term ‘feedback’ is a behaviour change technique meaning to monitor the behaviour and provide informative or evaluative information on the performance of that behaviour (Michie et al., 2013). In the context of delivering tailored feedback it may refer to a specially trained researcher analysing dietary intake and behaviour to provide written feedback (Hageman et al., 2017; Hunter et al., 2008; Kerr et al., 2016), or an app that provides numerical feedback on energy consumed and expended (M. C. Carter et al., 2013; Teixeira et al., 2018). The latter has the distinct advantage of being a stand-alone and instant, but it is not actionable, meaning that it lacks specific instructions on when, where and how to perform the desired behaviour (Michie et al., 2013; Schembre et al., 2018). A practical framework for designing tailored feedback identified four key features: personalisation, just-in-time, actionable and founded on a behavioural assessment (Schembre et al., 2018). All studies in this review included both a behavioural assessment and personalisation, but none had all four. It will be necessary for emerging digital weight loss interventions to publish a full description of how dietary feedback was generated to compare the effectiveness of different approaches.

The range of methods used for DA in this systematic review may be due to the evolving field of digital technologies to assess diet. There has been a rapid transition from paper-based methods to web and mobile methods over the past two decades. For example, the study by Burke et al., published in 2009, used a PDA that today is no longer available. However, this review examined methods to collect dietary data that are inappropriate for a scientific study. Luley et al. instructed participants to record and calculate their energy intake using a calorie book and submit this data into an accelerometer (Luley et al., 2014). While the authors state that this is designed as a psychological prompt, the dietary data was used to inform written, tailored feedback. As participants in this study were already diagnosed with metabolic syndrome a more comprehensive method to assess diet could significantly increase nutrition literacy and diet quality, essential for reducing the risk of developing type 2 diabetes (Gruss et al., 2019).

Previous reviews highlight the heterogeneity of outcomes and approaches used but none have specifically examined the role of dietary assessment and dietary feedback. (Ryan, 2019 ;Teasdale, 2018 ;Sherrington, 2016;Lau, 2020 ;Broekhuizen, 2012 . For example, Lau et al. (2020) examined 15 tailored interventions, revealing a 2.77 kg difference in weight between the intervention group and control (Lau et al., 2020). This ranged from 9.4 kg in adults with extreme obesity (mean BMI 44.1) (Martin et al., 2015) to 1.7 kg in healthy weight adults (mean BMI 24.3) (Kerr et al., 2016). Ryan et al. examined the data used to inform tailored feedback in 8 studies; one asked participants to use a Calorie King book to work out their calorie intake and submit this via text (Napolitano et al., 2013) and another used a validated food frequency questionnaire (Mouttapa et al., 2011). While dietary behaviour was assessed as tailoring parameter the DA method was not factored into the meta-analyses (Lau et al., 2020; Ryan & Yockey, 2017). As weight management relies of dietary change, this review provides a much needed evaluation of the DA methods to help inform the design and reporting of future digital tailored weight loss interventions. .

Strengths and limitations

A broader review to capture DA methods used in people with a healthy weight may provide a broader scope of the available DA methods. None of the dietary assessment studies included image-based reporting of food and beverage intake as these had not yet been trialled in populations with overweight and obesity. Studies with young adults and people with intellectual disabilities have found a preference for image-based dietary assessment (Bathgate et al., 2017; Kerr et al., 2017). Gemmings et al. (2015) examined studies evaluating image-assisted methods of dietary assessment for estimating energy intake (Gemming et al., 2015). Their results indicated that image-based, assisted DA improves self-reporting by reducing misreporting errors, and is a valid estimate of energy intake. Image-based approaches may also facilitate the inclusion of those with limited literacy and intellect – groups who are at greater risk of poor nutrition but often under-represented in research (Bathgate et al., 2017). Including studies with a BMI of less than 25 will also include studies aiming to prevent weight gain or support weight loss maintenance. Anton et al. used a web-based platform for dietary assessment and dietary feedback, providing instant feedback through graphs showing deviation from macronutrient and energy goals (Anton et al., 2012). This is one of few studies to use a DA to inform feedback and provide feedback that is visual and not limited to energy. It was not included in this review as there was no dietary outcome assessed. Future reviews should assess digital dietary assessment methods beyond those used for weight loss interventions.

Adhering to the PRISMA process, double reviewing 10% of results, and searching 5 key databases are important strengths of this review. A limitation is the inclusion of four studies with a sample of fewer than 100 participants (M. C. Carter et al., 2013; Schroder, 2011; Tate et al., 2003). The objectives of this review were not to quantify the effectiveness of the different DA methods described, which is an area to be explored in future research. To progress the knowledge in these areas we recommend that future studies describe the protocol for assessing dietary behaviour to inform tailored feedback, and use language consistent with existing studies to describe the methods. This will enable a future review to conduct a meta-analysis of the effectiveness of the DA used for weight loss in digital interventions.

Conclusions

This review highlights the inconsistency in DA methods used in tailored weight loss interventions, which may account for the range of results reported. Most digital dietary feedback focussed on reducing energy intake without providing feedback to enhance diet quality. This may reflect the evolving nature of dietary assessment methods with new technologies. Future interventions should publish the protocol describing how dietary data was used to inform dietary feedback.

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writing – review and editing, CS, DK, BM, CP, CB and DAK. All authors have read and agreed to the published version of the manuscript.

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Links to other chapters

Overall findings of this systematic review reveal the heterogeneity of methods used to assess dietary intake. Tailored dietary feedback was mostly based on dietary data from self-monitoring tools, and dietary assessment tools were used to assess diet as an outcome. The novel findings of this study showed the lack of consistency in the terminology and procedures for assessing diet to inform tailored dietary feedback. This is the first review to assess the method, frequency and platform used to collect dietary data for informing tailored dietary feedback.

The results reveal a range of methods including those that are validated and thorough, and others which are inadequate and brief. A closed diet record was commonly used to inform brief feedback on energy intake. While the review shows these can be effective for weight loss, further studies are needed to explore their effect on diet quality. This study highlights a focus on kilojoules and weight loss among digital interventions. This is not in line with clinical guidelines that suggest that interventions aim to displace discretionary food with vegetables, fruit and wholegrains, which will reduce the risk of some chronic disease, independent of weight loss. The following chapter explores the users' perspective on using a digital dietary assessment tool and receiving tailored dietary feedback, to expand our understanding of how these digital tools work in a real-world setting.

Chapter 4 Image-based dietary assessment and tailored feedback using mobile technology: Mediating behaviour change in young adults

Introduction

(Objective 2) Report on young adults' experiences of receiving the dietary feedback following the 6-month dietary intervention and determine whether those experiences were associated with positive improvements in dietary intake.

This chapter presents the final manuscripts published, after addressing comments and edits from reviewers. The aim of the current study was to report on young adults' experiences of receiving the dietary feedback following the 6-month dietary intervention, and to determine whether those experiences were associated with positive improvements in dietary intake.

The candidate was not involved in the design or data collection of the CHAT study, which was conducted prior to this thesis. This study that comprises chapter 4 involved secondary analysis of data collected during the CHAT study; participant's responses to the tailored feedback, post intervention questionnaires. The candidate was responsible for the design of the process evaluation; a qualitative analysis of the free text responses, examination of the relationship between participant's perception of tailored feedback and observed change food group serves and preparing the manuscript.

Reference: Shoneye, C. L., Dhaliwal, S. S., Pollard, C. M., Boushey, C. J., Delp, E. J., Harray, A. J., Howat, P. A., Hutchesson, M. J., Rollo, M. E., Zhu, F., Wright, J. L., Pratt, I. S., Jancey, J., Halse, R. E., Scott, J. A., Mullan, B., Collins, C. E., & Kerr, D. A. (2019). Image-Based Dietary Assessment and Tailored Feedback Using Mobile Technology: Mediating Behavior Change in Young Adults. Nutrients, 11(2), 435. https://doi.org/10.3390/nu11020435

Abstract

Assessing the implementation of nutrition interventions is important to identify characteristics and dietary patterns of individuals who benefit most. The aim was to report on young adults' experiences of receiving a dietary feedback text messaging intervention. Diet was captured using an image-based 4-day mobile food record application (mFR™) and assessed to formulate two tailored feedback text messages on fruit and vegetables and energy-dense nutrient-poor (EDNP) foods and beverages. At 6-months 143 participants completed a second mFR and a questionnaire evaluating the dietary feedback. Participants who agreed the text messages made them think about how much vegetables they ate were more likely to increase their intake by at least half a serve than those who disagreed [odds ratio (OR) = 4.28, 95% Confidence Interval (CI): 1.76 to 10.39]. Those who agreed the text messages made them think about how much EDNP foods they ate, were twice as likely to decrease their intake by over half a serve (OR = 2.39, 95%CI: 1.12 to 5.25) than those who disagreed. Undertaking detailed dietary assessment ensured the tailored feedback was constructive and relevant. Personal contemplation about vegetable and EDNP food intake appears to be a mediator of dietary change in young adults.

Background

Poor diet is associated with increased risk of diseases such as cardiovascular disease; type 2 diabetes; and some cancers, with obesity a mediating factor Australian (Ng et al.). Dietary patterns vary throughout the life course and it is important to re-establish good eating habits in young adulthood to protect against preventable disease. Dietary guidelines recommend regular consumption of diets high in fruit and vegetables, limiting consumption of alcohol and avoiding energy dense nutrient-poor (EDNP) foods high in added sugars, saturated fat and sodium to reduce the risk of diet-related diseases (National Health and Medical Research Council, 2013b). Dietary patterns vary throughout the life course and it is important to ensure good eating habits are maintained into young adulthood to protect against preventable disease. Compared with other age groups, Australian young adults consume the least amount of fruits and vegetables and the most alcohol and EDNP foods and beverages with more than one-third (35%) of total energy coming from

EDNP food and beverages (Australian Bureau of Statistics, 2013). Consequently, young adults are gaining weight more rapidly than any other age group, leading to an earlier onset of overweight and obesity than in previous generations putting them at a greater risk of preventable diet-related disease (Australian Bureau of Statistics, 2013). Young adults, a group in transition from adolescence to adulthood, represent an important target group for improving dietary habits and preventing weight gain (Australian Bureau of Statistics, 2013). Developing effective interventions requires an understanding of the motivators and barriers for healthy eating, as well how best to engage young adults over time (Munt, 2017;Ashton, 2017).

Digital communications, including email and text messaging, have been shown to effectively engage young adults in dietary interventions (Kerr, 2016 ;Partridge, 2016 ;Hutchesson, 2016). Digital behaviour change interventions (DBCI) combining these approaches are evolving rapidly, introducing new challenges for evaluation including understanding their role in effective engagement with end users (Michie, 2017). Evaluation of a text message intervention in young adults found website and mobile app engagement to be low during the study period, with participants preferring self-monitoring apps and individualized resources (Partridge, 2016). In a systematic review of internet-delivered weight loss interventions, personalised feedback targeting diet and physical activity behaviours appeared to be an important behaviour change technique (Sherrington et al., 2016). Feedback based on characteristics unique to the individual, provide the user with personalised or tailored feedback, which can be delivered as printed material, email or text message. Tailoring information places less cognitive load on the individual and enhances engagement (Noar, 2007). Using mobile technology in tailored dietary interventions may be a cost-effective way to engage young people in evidence-based, behaviour change interventions, with potential for a population level reach.

An important aspect of tailoring is to ensure feedback to individuals has personal relevance. Accurate and timely dietary assessment is paramount for tailored dietary interventions. Personally relevant and effective feedback can guide individuals to identify dietary changes to improve their health (Lustria et al., 2013). Collecting dietary data via mobile devices enables real time data collection, reducing the risk of recall bias and participant burden (Boushey et al., 2016). Young adults are more willing to record their diet either online or with mobile devices compared with a written food record (Kerr, 2017;Boushey, 2015;Hutchesson, 2016).

The Connecting Health and Technology (CHAT) study was a 6-month randomised controlled trial that evaluated the effectiveness of tailored dietary feedback and weekly text messaging to improve intake of fruit, vegetables and EDNP food and beverages in young adults (18 to 30 years) (Kerr et al., 2016). The term EDNP foods, colloquially referred to as 'junk food' in communications with participants (Pettigrew et al., 2017), are those foods and beverages high in energy, saturated fat, added sugar, salt or alcohol, and low in nutritional value. The CHAT study protocol and outcomes have been previously published (Kerr et al., 2016). In brief, after baseline assessment, participants were randomly assigned to one of three groups: 1) combined dietary feedback and weekly text messages; 2) dietary feedback text messages; or 3) control group who did not receive any text messages. Tailored dietary feedback alone led to a decrease in consumption of EDNP foods in men and sugar-sweetened beverages (SSB) in women, and a 1.7 kg reduction in body weight (Kerr et al., 2016). However, additional weekly text messages did not appear to have any further benefit, reinforcing the need to further evaluate factors associated with effectiveness of the dietary intervention.

Assessing the implementation of DBCI is important in order to better understand and identify the characteristics and diet of individuals who benefitted most from tailored feedback. This will help guide future interventions design in young adults. The aim of the current study was to report on young adults' experiences of receiving the dietary feedback following the 6-month dietary intervention, and to determine whether those experiences were associated with positive improvements in dietary intake.

Methods and materials

Study design and participant recruitment

Data were collected from a population-based sample of 247 young adults (18 to 30 years) taking part in a 6-month randomised controlled trial (RCT) to evaluate the effectiveness of tailored dietary feedback and weekly text messaging support to improve diet. Only young adults randomised at baseline to dietary feedback text messaging intervention groups were included in this analysis (n=164). The study protocol and trial outcomes have been published previously (Kerr, 2012;Kerr, 2016). Participants were selected from 57 suburbs within the Perth metropolitan area in Western Australia to provide representation across socio-economic status through the Commonwealth electoral roll, a compulsory enrolment system for Australian adults. After receiving a letter of invitation, those who wished to take part underwent eligibility screening either by telephone or the study website. Exclusion criteria applied if people were unable to complete the 6 month study, undertaking extreme forms of physical activity, on a special diet, currently studying or had studied nutrition, pregnant or breastfeeding, unable to attend the study centre to complete the face-to-face assessments or affected by serious illness. The study was approved by the Curtin University Human Research Ethics Committee and the Department of Health, Western Australia Human Research Ethics Committee (HR 181/2011) and all participants signed an informed consent. The trial was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12612000250831).

Intervention: Dietary feedback

Dietary intake was assessed in participants using an image-based dietary assessment system known as Technology Assisted Dietary Assessment or mFR^{TM} (Zhu et al., 2010; Zhu et al., 2008). Participants were instructed to record their food and beverage intake using the mFR^{TM} for four consecutive days (Wednesday to Saturday) with the investigator-supplied iPod Touch (iOS6) loaded with the mFR^{TM} application. When taking an image, participants were instructed to include a provided reference object known as a fiducial marker (a checkerboard pattern of known shape, size and color) to assist with food identification and portion size estimation (Xu, 2013;Zhu, 2010 ;Xu, 2012).

They were instructed to record food and beverage items not captured in an image using the iPod notes section. A week later participants attended a second baseline visit to return the iPod Touch and complete additional written questionnaires. At this visit the researcher interviewed each participant to verify the content of the images and probe for any forgotten food and beverages. The trained analyst assessed the mFRTM using a quality scoring of food items by food group according to the Australian Guide to Healthy Eating (AGHE) standard serves (Smith et al., 1998). For each participant, an average serve per day was calculated for fruits, vegetables, EDNP foods and beverages. Once scoring was complete, two tailored dietary feedback text messages were sent to the intervention participants one week apart, with one message for fruits and vegetables and the other for EDNP food and beverages.

A standard message template previously described (Kerr et al., 2012); was used for each dietary feedback text message but personalised for each participant according to the results of the dietary analysis. Briefly, for the fruit and vegetable messages, participants received a message based on three levels of intake. Low intake was considered 0 to < 3.5 servings of fruits and vegetables; medium was 3.5 to < 7 servings of fruits and vegetables; and at least 2 servings of fruits and 5 servings of vegetables per day met the recommendations. For example, for a low intake, "Hi Jane, it's Kate from CHAT with your feedback. So how did you score? Ave fruit serves = 0. 5, ave veg serves = 0.5. Your fruit serves varied from 0-1, veg from 0-1 over 4 days. What's the goal again? 2 fruit and 5 veg a day. You can only go up from here!". For EDNP serves, participants received a message based on three levels of intake and personalised to the participant's dietary intake. For EDNP serves of 3 or more per day, the message was personalised with key sources of EDNP serves identified from the mFRTM. For example, "Hi Pete, It's Kate from CHAT with your junk food score. Ave serves = 5, varying from 4-8 over 4 days. Junk foods are fatty or sugary foods that are high in calories. So try to only eat these foods sometimes and in small amounts. Could you try eating less fatty foods e.g. pies and sweet biscuits?". A low intake of EDNP serves (0 – 3 serves daily serves) included the text "looks like you are on the right track"(Kerr et al., 2016); was used for each dietary feedback text message but modified for each participant according to the results of the dietary analysis. The language and tone of voice of the dietary feedback messages were constructed from message preference testing with focus groups (Pollard, 2016), with an autonomous supportive style of communication (Resnicow, 2008).

Outcome: Changes in dietary intake suggesting benefit from intervention

All participants undertook a 4-day mFR^{TM} at baseline and at the end of the intervention and were analysed as described in Section 2.2. Participants were assessed to have benefited from the intervention if they increased their intake of vegetables or fruit by half a serve per day, or decreased their intake of EDNP foods, sugar-sweetened beverages (SSB), or alcohol by half a serve per day.

Participant experiences with dietary feedback

Post-intervention, participants completed a 13 item written questionnaire with 5-point Likert scales ranging from 'strongly agree' to 'strongly disagree' to measure participants' agreement with statements concerning their perception of the dietary feedback text messages (Table 4-2). Examples of questions relevant to this paper were: the text message on my diet: (1) Told me things I did not know about my diet and what I eat, (2) Told me things about my diet I already knew, (3) Were useful in helping me to understand my diet, (4) Helped to motivate me to change my diet, (5) Made no difference to my motivation to change my diet, (6) Made me feel better about my diet, (7) Made me feel worse about my diet, (8) Made me think about the foods I eat but only for a short while, (9) Made me think about how much fruit I eat, (10) Made me think about how much vegetables I eat, (11) Made me think about how much junk food I eat, (12) Made me think about how much soft drink and sugary drinks I have. To further explore young adults' experiences of receiving dietary feedback, four additional open-ended questions asked: (1) List what you liked most (if anything) about the feedback on your diet?; (2) List what you liked least (if anything) about the feedback on your diet; (3) Is there anything else about your diet you would have liked feedback on; and (4) additional comments on Was the short feedback your received with the text messages sufficient?. These open-ended comments and free text responses were imported verbatim into NVivo 12. Qualitative data were coded and patterns identified using thematic analyses by three researchers (DK, CS, CP) independently. Descriptive labels were then applied to categorize information into themes. The researchers met and reviewed together the findings to confirm key themes. Discussion and revision of themes were made where required.

Analyses

Frequencies of responses to the tailored feedback questionnaire were collated for each question and responses categorized. Reference values were derived using the 5-category Likert response scales used in the dietary feedback questionnaires. These were recorded as agreed (strongly agree and agree) or, neutral and disagree (strongly disagree and disagree). Logistic regression was used to analyse the change in food group serves (by 0.5 serves) from baseline with participants' perceptions on whether the dietary feedback text messages made them think about consumption of vegetables, fruit, EDNP, SSB or alcohol. The results were adjusted for age and sex. Preliminary analysis revealed that BMI, ethnicity, education level, and socioeconomic status were not associated ($p>.1$) with change in food group serve, hence were not included in the multivariable model. Statistical software SPSS version 22 (SPSS Inc., Chicago, IL, USA) was used for all analyses.

Results

Participant characteristics at baseline are shown in Table 4-1. Of the 164 participants who consented to participate in the CHAT study, 143 (87%) completed two 4-day mFRTM (baseline and at 6-months) and post-intervention feedback questionnaires.

Figure 4-1. Baseline characteristics of study participants randomized to receive the dietary feedback text messages (n=164).

Variable	Male (n=57)	Female (n=107)	Total (n=164)
Mean ± SD			
Age (years)	24.4 ± 3.3	23.8 ± 3.3	24.0 ± 3.3
Body mass (kg)	77.4 ± 14.3	64.8 ± 15.3	69.2 ± 16.1
Height (cm)	177.7 ± 7.6	164.3 ± 6.7	169.0 ± 9.5
Body Mass Index (BMI; kg/m^2)	24.4 ± 4.0	24.0 ± 5.8	24.2 ± 5.3
BMI categories (%)			
BMI ≤ 18.5	7 (12.3%)	12 (11.2%)	19 (11.6%)
BMI > 18.5 < 25	25 (43.9%)	65 (60.7%)	90 (54.9%)
BMI ≥ 25 < 30	21 (36.8%)	17 (15.9%)	38 (23.2%)
BMI ≥ 30	8 (7%)	13 (12.1%)	17 (10.4%)

Ethnicity (%)			
White	45 (78.9%)	81 (75.7%)	126 (76.8%)
Asian	5 (8.8%)	24 (22.4%)	29 (17.7%)
Other	7 (12.3%)	2 (0.0%)	0 (0.0%)
Level of Education			
Year 12 or lower	22 (38.6%)	37 (34.6%)	59 (36%)
Trade or diploma	22 (38.6%)	22 (20.6%)	44 (26.8%)
Bachelor degree or higher	13 (22.8%)	48 (44.9%)	61 (37.2%)
Food group serves median (IQR)			
Fruit serves (150g)	0.6 (0.2 - 1.5)	0.8 (0.3 - 1.4)	0.8 (0.3 - 1.4)
Vegetable serves (75g)	1.6 (1.0 - 2.4)	1.9 (1.2 - 2.5)	1.8 (1.2 - 2.4)
EDNP food serves	3.2 (2.1 - 4.6)	2.9 (2.0 - 4.1)	3 (2.0 - 4.2)
SSB	0.4 (0.0 - 0.9)	0.3 (0.0 - 0.6)	0.4 (0.0 - 0.7)
Alcohol serves	0.0 (0.0 – 1.0)	0.0 (0.0 - 0.8)	0 (0.0 - 0.8)
Total EDNP food & beverages[1]	4.4 (2.8 - 6.6)	3.9 (2.5 - 5.1)	4.1 (2.5 - 5.7)

[1]Total energy-dense nutrient-poor (EDNP) food group serves includes EDNP foods, sugar-sweetened beverages (SSB) and alcohol.

Table 4-2 shows participants' perceptions regarding dietary feedback. Approximately 62% of participants agreed the text messages were useful in helping them to understand their diet and about half (52%) agreed the text messages helped to motivate them to change their diet. Thirty per cent of participants reported the text messages made them feel worse about their diet. More women (52%) agreed the text messages made a difference to their motivation, compared with 33% of men ($p<0.05$). The majority of participants agreed the text messages encouraged them to think about how much fruit, vegetables and EDNP food they consumed (67%, 71%, and 65% respectively). Only 20% thought text messages made them think about how much alcohol they drank. Only 13% of participants felt the intervention provided novel information, but still found this useful (Table 4-2). Men were more likely than women to report that they learnt something they did not already know (21.7% compared to 8.3%, $p<0.05$). In response to the question, if the short dietary feedback was sufficient, 47% thought it was sufficient, whilst 47% wanted more feedback (remaining 6% unsure).

Perception of dietary feedback text message and dietary intake

Table 4-3 reports logistic regression analysis relating participants' perception of the text message dietary feedback to actual change in food groups serves. Participants who agreed that the text messages made them think about how much vegetables they ate were more likely to increase their vegetable intake by more than half a serve than those who disagreed [OR = 4.28, 95% CI: 1.76 -10.39, p=.001]. These participants were more likely to reduce their intake of EDNP food (OR = 2.78, 95% CI: 1.28-6.04, p=0.010]. Participants who agreed that text messages made them think about 'how much junk food' they ate were more likely to decrease their EDNP food by more than half a serve [OR = 2.47, 95% CI: 1.12-5.25, p=0.025]. All associations were independent of age, sex and BMI.

Responses to open-ended comments on dietary feedback

Participants' responses to the four open-ended questions regarding the dietary feedback, were coded into themes. Table 4-4 shows examples of responses to the four open-ended questions about the dietary feedback text messages. Of the 143 participants, 103 provided comments to 'List what you liked most about the feedback on your diet'; 75 to 'List what you liked least about the feedback on your diet'; 91 to 'Is there anything else about your diet you would have liked feedback on?'; and 36 provided additional comments on 'Was the short feedback you received with the text messages sufficient?'. The dietary feedback messages were viewed positively by participants and five emerging themes were identified (Table 4-4).

What participants appeared to like most about the text messages were that they made them think more about their diet and encouraged and motivated them to change their dietary behaviours. Participants also valued that the messages were personal and specific to them. Many said this personalized approach was important for their motivation to change. Messages were described as constructive and helpful. Some participants were shocked and surprised by the feedback.

When asked to comment on what they liked least about the text messages, some participants found the feedback confusing and vague. They also commented they would have liked more detailed feedback. This is consistent with requests for more detailed dietary feedback when asked ‘Is there anything else about your diet you would have liked feedback on?’. Others participants, however, thought the feedback was “short and to the point”.

Figure 4-2 Comparison of perceptions for intervention group participants (n=143) regarding the text message dietary feedback.

Statements regarding the dietary feedback text messages	Responses, n (%)		
	Strongly agree or agree	Neither agree or disagree	Disagree or strongly disagree
The text messages on my diet:			
Told me things I did not know about my diet and what I eat	57 (39.9%)	39 (27.3%)	47 (32.9%)
Told me things about my diet I already knew	18 (12.6%)	32 (22.4%)	93 (65.0%)
Were useful in helping me to understand my diet[1]	88 (61.5%)	35 (24.5%)	20 (14.0%)
Helped to motivate me to change my diet	74 (51.7%)	36 (25.2%)	33 (23.1%)
Made no difference to my motivation to change my diet[1]	66 (46.2%)	34 (23.8%)	43 (30.1%)
Made me feel better about my diet	22 (15.4%)	61 (42.7%)	60 (42.0%)
Made me feel worse about my diet	43 (30.3%)	51 (35.9%)	48 (33.8%)
Made me think:			
About the foods I eat but only for a short while	87 (60.8%)	19 (13.3%)	37 (25.9%)
About how much fruit I eat	96 (67.1%)	19 (13.3%)	28 (19.6%)
About how much vegetables I eat	102 (71.3%)	18 (12.6%)	23 (16.1%)
About how much junk food I eat[2]	93 (65.0%)	23 (16.1%)	27 (18.9%)
About how much alcohol I drink	22 (20.0%)	38 (34.5%)	50 (45.5%)
About how much soft drink and sugary drinks I have[3]	46 (38.3%)	30 (25.0%)	44 (36.7%)

[1]Statistically significant ($p<0.05$) difference between men and women. [2] Junk food = EDNP foods. [3] soft drink and sugary drinks = SSB.

Figure 4-3. Logistic regression analyses adjusted for age and sex relating participants' positive perception on text message dietary feedback to actual change in food group serves (by 0.5 serve).

Effects are represented as odds ratio and associated 95% confidence intervals. Odds ratio represent the increase in likelihood of participants who agreed compared to those who disagreed, that the text messages made them think about how much they ate and their actual intake.

	Actual change in food group serves (by 0.5 serve)					
Perception questions[1]	Increased vegetables	Decreased EDNP foods	Increased fruit	Decreased SSB	Decreased alcohol	Decreased total EDNP foods and beverages
Vegetables	4.28 [1.76-10.39] p=0.001	2.78 [1.28-6.04] p=0.010	2.41 [1.10-5.27] p=0.027	-	-	2.39 [1.12-5.10] p=0.024
Fruit	-	1.94 [0.93-4.08] p=0.079	-	2.34 [0.85-6.28] p=0.097	-	2.66 [1.27-5.60] p=0.010
EDNP food	-	2.47 [1.12-5.26] p=0.025	-	-	-	1.93 [0.92-4.06] p=0.083
SSB	-	-		-	-	2.05 [0.01-4.63] p=0.084
Alcohol	-	-	-	-	4.59 [1.53-43.7] p=0.006	-

[1]Perception questions undertaken at completion of the intervention where those who agreed compared with those who disagreed (Reference group): Vegetables: Made me think about how much vegetables I eat. Fruit: Made me think about how much fruit I eat. EDNP foods: Made me think about how much junk food I eat. SSB: Made me think about how much soft drink and sugary drinks I have. Alcohol: Made me think about how much alcohol I drink.

Figure 4-4. Open-ended responses of young adults regarding the dietary feedback.

Themes	Examples of comments	
What participants liked most about the dietary feedback text messages		
Made me think	"Just a reminder and made me think about eating fruit for a snack rather than something else"(female).	"interesting comments … made me think momentarily about my diet … but I continued old habits almost straight away"(female).
Constructive, helpful and useful	"I appreciate having a greater depth of consciousness as to what healthy food I can eat & found your directions helpful"(male).	"It was constructive. Helped to change my eating ways"(female).
Encouragement or motivation	"It was a wakeup call as to the horrible truth which is my poor diet choices! It motivated me to think more about changing my diet however time has certainly been a restriction"(female).	"Wasn't all criticism, there was encouragement also" (male).
Personal, specific to me	"I loved the data given about my personal diet habits. They made me realize how much fruit and veg I SHOULD be eating"(male).	"specific to me not just a guideline in a magazine"(female).
Shocked and surprised	"I liked knowing that I ate a minimal amount of fruit and veg as it shocked me into making dietary changes. I'm not sure how long lasting these changes were though"(female)	"I was surprised that my fruit + veg consumption was lower than 2 fruit + 5 veg. I have tried to increase this since"(female).
What participants liked least about the dietary feedback text messages		
More detail	"It was very general feedback. It would have been good to have feedback more specific to the individual (e.g. Daily energy expenditure etc.)"(female).	"It wasn't very comprehensive, compared to the data collected! I expected much more detailed analysis of what I should/had eaten for my age, weight, sex etc. Not just fruit veg and junk"(female).
Confusing or vague	"	"The description of junk food was confusing. I did not

	"Junk food recommendations a bit vague 'try only eat these foods sometimes' something like 'try not to have more than 4 serves a week' (eg) would have been more helpful"(female).	understand what it meant" (female).
What else participants would have liked feedback on		
Portion size or quantity	"Overall quantity of food eaten - whether I should be eating more or less"(female).	"portion sizes, additional critiques about small changes that could be made"(male).
More about me	"more about MY diet" (male)	"Potentially specific things I need like iron and calcium. Important for my health condition"(female).
Enough protein	"Carb, protein, GI, energy levels for my own body, or eg. Meal 32 was great! Because.."(female)	"protein (enough? Too much?), variety of my diet, GI or sustained energy tips"(female).
If the text messages were sufficient		
More feedback	"Text messages were good, however an email with more personal findings would have been beneficial" (male).	"Maybe a bit more detailed feedback via email would be good to help ensure the things that I was doing well and continue to provide more feedback on areas I could improve i.e. healthier options"(female).
Short and to the point	"I liked that it was short and to the point and gave great handy tips" (female).	"It was to the point and focused on the important aspects of my diet that needed improvement. Any longer would have been a hassle to read."(female).

Discussion

This six-month RCT evaluated young adults' experiences of receiving the dietary feedback following a 6-month text-messaging intervention. A key finding of the intervention was that contemplation about vegetable and EDNP food intake appears to be an essential mediator of dietary change in young adults. Participants who agreed that dietary feedback made them think about their eating behaviours were more likely to improve their diet during the intervention period. Those participants who agreed thinking about how much vegetables they ate were four times more likely to increase their vegetable intake by more than half a serve per day than those who disagreed. Also, participants who agreed that text messages made them think about how much 'junk food' they ate were twice as likely to decrease their EDNP food by greater than half a serve. An essential aspect of the intervention was the inclusion of a detailed dietary assessment using an mFRTM. This ensured the tailored feedback was constructive and relevant to the individual; features that appeared to be valued by the participants.

Findings of the current study suggest young adults who believe healthy eating is important and they have a healthy diet experience cognitive dissonance when presented with contrary dietary feedback to what they were expecting. Cognitive dissonance suggests individuals experience a psychological state of discomfort when holding conflicting attitudes or beliefs, which may lead to a change in behaviour to reduce that discomfort discourse (1999). This, in turn, may have driven the observed improvements in dietary intake. According to the self-determination theory (SDT) used to inform the framework underpinning the CHAT intervention, autonomous motivation is a positive predictor of long-term behavioural change (Ryan, 2000). SDT distinguishes the different types of motivation. For instance, more autonomously motivated individuals are more likely to engage with a given behaviour because it is enjoyable whereas in controlled motivation people may feel pressured to engage in the behaviour for social approval or to avoid guilt (Ng, 2012). Applying SDT, a cross-sectional study of nearly 3,000 US adults found autonomous motivation and perceived social support were associated with increased fruit and vegetable intake (McSpadden et al., 2016). This finding emphasizes the importance of providing personally relevant dietary feedback, that can assist people to identify for themselves the dietary changes most likely to improve their health (Krebs et al., 2010). An important aspect of SDT (Deci, 2012) embedded in the CHAT intervention was to provide relevant dietary feedback for the person to use in making informed dietary choices.

In a systematic review of lifestyle interventions for preventing weight gain in young adults, Hebden et al. recommended future trials include dietary self-monitoring and tailored feedback to increase the personal relevance to the individual (Hebden et al., 2012). Dietary self-monitoring has been shown to be an effective behaviour change strategy by raising a person's awareness of what they are eating (Burke et al., 2011). With mobile technology now readily accessible, together with the level of interest in mobile technology amongst young adults, collecting dietary intake data using mobile devices may lead to improved cooperation to record diet in this age group. Most dietary interventions have based tailored feedback on brief instruments that use only a few questions to assess diet rather than more detailed dietary records limiting the type and quality of feedback that can be provided to the participant REF. A systematic review of dietary assessment methods used to evaluate interventions found that dietary components, such as fruits, vegetables, SSB and fast food, were most often assessed by single questions or brief instruments (Kirkpatrick, 2014). The findings of this study emphasize the importance of undertaking a detailed dietary assessment to ensure the personal relevance of the feedback.

Participants who thought about their vegetable intake as a result of receiving dietary feedback were more likely to reduce both EDNP foods and increase vegetable intake. Previous studies have reported an association between increased consumption of vegetables and a reduction in consumption of EDNP food and SSBs (Crawford et al., 2007; Partridge et al., 2015). Our results suggest this association may be mediated by intervention features that prompt individuals to think about their vegetable intake.

Young adults in the CHAT intervention appeared to be shocked and surprised about the feedback on their dietary intake. For example, a comment from a young women "I was slightly shocked about my junk food consumption and very happy to receive the feedback." This implies a gap between the participant's perception of their own dietary intake and what they recorded from the 4-day mFR. This perception may be derived, in part, from a lack of knowledge and maybe a barrier to change as young adults may believe their diet to be healthier than it is.

This over-optimistic perception of young adults is evidenced by the low intake of fruits and vegetables. The median daily intake was 120 g (0.8 serves) for fruit and 135 g (1.8 serves) for vegetables; much lower than the recommended two serves of fruit and five serves of vegetables per day (National Health and Medical Research Council, 2013b). This is similar to Australian population data of 18-34-year-olds, where a median intake of 1.3 serves of fruit and 2.1 serves of vegetables was observed (Nour, 2017). In the current study, a median intake of 4.1 serves daily of EDNP food and beverages was reported. This is equivalent to more than 2400 kJ per day. Cross-sectional analysis revealed young adults who perceived their diet to be low in EDNP foods consumed less EDNP food than their peers, nevertheless, their daily intake was 2.8 serves or 1,700 kJ per day (Harray et al., 2017) and inconsistent with dietary guidelines (National Health and Medical Research Council, 2013b). Compared with the general population for this age range, men and women in the current study consumed fewer serves of fruit and vegetables per day and had a lower BMI(Australian Bureau of Statistics, 2015). Such observations are not unusual, with other studies reporting similar dietary patterns among those who report a concern about personal dietary choices (Riebl et al., 2015).

Most studies to date, have based participant dietary feedback on short questions rather than more detailed dietary records. A significant strength of this study is the collection of dietary intake using a 4-day mFRTM which provided a more detailed and personalized measure of dietary intake. This enabled an evaluation of whether young adults' experiences of receiving the dietary feedback were associated with positive improvements in dietary intake. Of note, there are some limitations to this study. Diet was assessed using a 4-day mFRTM at baseline and 6-months and these data may not be representative of dietary intakes throughout the intervention period. Participants may have misreported their dietary intake by either not capturing all food and beverages consumed or modifying their intake during the recording period (Subar, 2015). The current study did not include measures of autonomy and self-regulation. To further understand motivations towards changing dietary behaviours, future studies should study these motivational processes when planning dietary interventions. This should include examining autonomy for non-adherence in young adults whilst being respectful of their dietary choices (Anton et al., 2012).

Conclusion

Assessing participants' view on various intervention components such as importance, motivational impact and frequency of communication provides useful insights for future health promotion interventions. Findings of the current study show the complexity of an individual's perceptions, beliefs and behaviour in relation to changing dietary behaviours in young adults. The effectiveness of the intervention appears to be a result of prompting, with participants encouraged to think about their intake of fruit, vegetables, EDNP food and beverages. Using text messages, together with the mFR dietary assessment, maybe a practical approach for increasing motivation and awareness of dietary behaviour. For young adults, text messages that provided dietary feedback were integral to dietary change. Contemplation about fruit, vegetable, EDNP food intakes appears to be an important mediator of dietary change in young adults. This study makes an important contribution to the evidence base, providing qualitative and quantitative insights into the participants' experience of the intervention and mediators of behaviour change.

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Link to other chapters

This study contributes insight into the mediators of behaviour change for young adults receiving feedback on dietary behaviour. Results suggest that successful behaviour change was mediated by making participants think about their dietary choices and creating discomfort about how their current diet had been assessed and compared to the guidelines. The study showed this mediates a significant decline in discretionary food, likely causing some unintended weight loss. At that time, text messaging was limited to a set number of characters, limited the detail of dietary feedback that could be sent. Recent advances in technology allow text messages to utilise a wider range of digital platforms for communication including embedding website links, images and using unlimited characters. This leads us to question whether more frequent and detailed feedback can further decrease discretionary food and result in clinically significant weight loss.

The following chapter will explore if the mediator and experiences described in this study are shared among older adults who are actively seeking weight loss. The study will also examine the feasibility of providing more frequent and comprehensive feedback. Specifically, which platform (text, email, website) and the content (language, images, length).

Chapter 5 Qualitative study to inform the development of ToDAy

Introduction

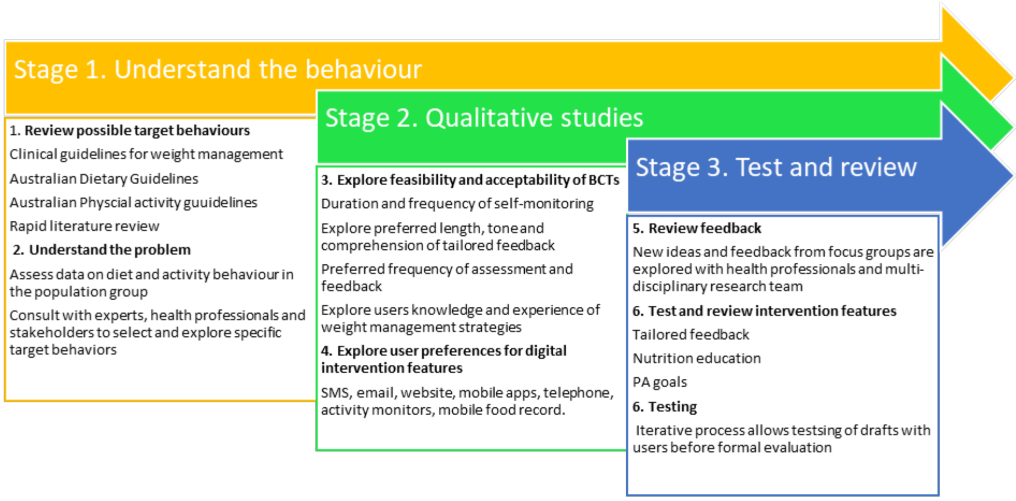
(Objective 3) Conduct a formative focus group study to inform the development of a digital, tailored weight loss intervention and identify behaviour change techniques for weight loss.

(Objective 4) Explore preferences for digital intervention features that are proven to be effective in changing dietary behaviours.

As shown in Figure 5-1 Intervention development process , the process focussed on understanding and incorporating the preferences and needs of the user through qualitative studies (Yardley et al., 2015). The principle feature of this approach is including a wide range of potential users in qualitative research. This chapter provides the final, published manuscript, on the qualitative studies conducted to inform the development of ToDAy. The candidate developed the study design, scripts and conducted all the recruitment, data collection, data analysis and coordinating feedback from users, health professionals, consumers representatives and expert advisors. The candidate wrote the draft manuscript, submitted the manuscript for publication and coordinated the feedback and submission of the final paper.

Reference: Shoneye, C. L., Mullan, B., Begley, A., Pollard, C. M., Jancey, J., & Kerr, D. A. (2020). Design and Development of a Digital Weight Management Intervention (ToDAy): Qualitative Study. JMIR mHealth and uHealth, 8(9), e17919.

Figure 5-1 Intervention development process



Background

Excess weight has overtaken smoking as the leading cause of non-communicable disease in Australia, with 7 out of 10 males and almost 6 out of 10 females living with overweight or obesity (Australian Bureau of Statistics, 2013). The causes of this are multifaceted (Mullan et al., 2017), at a personal level, poor diet and inactivity are major contributors. In Australia, excessive intake of alcohol, sugar-sweetened beverages (SSBs), and *discretionary foods* (foods considered to be of little nutritional value; often high in saturated fats, added sugar, and salt; and alcohol or *junk* foods) are observed across all age groups (Australian Bureau of Statistics, 2015). Mass media campaigns, targeting healthy weight, achieve wide-reaching awareness but may not lead to changes in behaviour (Croker et al., 2012; Kite et al., 2018; Morley et al., 2013). LiveLighter® is a Western Australian public health education and social marketing campaign that aims to encourage people to eat well, be physically active, and maintain a healthy weight. The campaign engages with the community through paid and unpaid social media, web-based and printed resources, advocacy, and retailers. Campaign messages include graphic images of *toxic* fat, followed by messages with single actions to reduce the risk of weight gain, for example, by avoiding SSBs or junk food (LiveLighter, 2019). The advertisements also direct people to a campaign website where there is an option to enroll on the web to access a meal planner, recipes, and weight monitoring tools and to receive update emails. The Tailored Diet and Activity (ToDAy) study aims to extend the campaign by building on its awareness with a digital intervention that provides individualized tailored feedback on dietary and activity behaviours.

In Australia, the evaluation of the LiveLighter® mass media campaign targeting sugary drinks indicates a high campaign recall and modest reductions in SSBs (Morley et al., 2014). However, more than 60% of adults in Australia do not usually consume SSB and may disregard the campaign, even if they stand to benefit from some of the other elements (Australian Bureau of Statistics, 2015). A growing body of evidence supports the notion information is best tailored specifically to the unique characteristic and behaviours of the individual, (Hawkins et al., 2008; Krebs et al., 2010; Lustria et al., 2009) with significant effects reported for nutrition and physical activity interventions (Ryan et al., 2019; Springvloet et al., 2015; Walthouwer et al., 2015).

Australian clinial guidelines for weight management recommend a multidisciplinary team of health professionals using specific behaviour change techniques with ongoing follow up for a minimum of 12 months (Samdal, 2017). High attrition rates, low availability of trained health professionals and logistical issues of providing equitable care are among common reported barriers to putting this in practice (Miller & Brennan, 2015; Pirotta et al., 2019). Digital interventions that clinical and tailored content with the reach of mass media could be a cost effective solution (Rollo, 2018).

Developing digital interventions

The process of developing a digital intervention requires integrating the behaviour change theory with intervention features that are engaging and acceptable to the target group. Evidence from other digital behaviour change interventions suggest an iterative and multidisciplinary approach that includes a qualitative investigation with the end user before implementation (Michie et al., 2017; Mummah, King, et al., 2016). Specifically, the person-centered approach recommends using qualitative research to explore and test intervention features with the target group (Yardley et al., 2015). This allows researchers to adapt the intervention features based on the preferences and needs of the user. A BCT is the *active ingredient* or intervention component that changes the desired behaviour (Michie et al., 2013). For example, BCT 2.3 is self-monitoring of behaviour, the most commonly used BCT in effective diet and PA interventions (Michie, 2009). Evidence suggests that self-monitoring works through behavioural regulation; for example, dietary self-monitoring increases the awareness of food choice, portion sizes, and improving diet quality (Burke et al., 2011; Turk et al., 2013). Exploring digital interventions for weight management that combine the reach of mass media campaigns with tailored and clinical support could be a cost-effective and practical approach.

Focus groups and interviews are commonly used to generate discussion and explore participants' experiences as well as their needs, knowledge, and preferences (Lewin, 2009). However, weight stigma inhibits participation and the willingness to share personal beliefs (Brown, 2013;Lozano-Sufrategui, 2016). One strategy to address is to show participants hypothetical scenarios and ask them to provide advice for weight loss (Cleary et al., 2014; Lewin et al., 2009). Another strategy to address this is to use hypothetical scenarios where information about a person's PA levels or images of their meals is shown and participants are asked to provide advice on weight loss. To date, this unique approach has not been undertaken in this population.

Although men are more likely to be living with excess weight and experience health related illnesses, they are less likely to participate in lifestyle interventions, making up only about 20% of participants (Pagoto, 2012). Studies aiming to reduce gender imbalance have reported that self-monitoring technology, including apps and wearable devices, are great incentives to engage men in weight management (Donnachie et al., 2017; Quested et al., 2018). To date, few weight management studies included the views and experience of men aged over 25 years (Robertson, 2014). This study aims to address this shortcoming by purposely sampling equal number of male and female participants.

This study aimed to describe the qualitative study and iterative process used to develop ToDAy, a digital, tailored, weight management intervention. A full description of the aims of the 12-month intervention and the protocol has been published elsewhere (Halse et al., 2019). A 12 month, randomized controlled trial in adults with a BMI between 25 and 40 will evaluate the intervention. The objectives of this study were to (1) identify BCTs for dietary and PA changes concerning weight loss and (2) explore preferences for digital intervention features that would be effective in changing diet and PA behaviours.

Methodology

The methodological approach used in this research was a general inductive qualitative approach (Thomas, 2006). The consolidated criteria for reporting qualitative research (COREQ) for interviews and focus groups were used to ensure rigor in the presentation of the findings (Tong et al., 2007). ToDAy will incorporate learnings from an earlier trial where a mobile food recording app (mFR) was successfully used to assess dietary intake and provide tailored feedback on fruit, vegetable, and junk food intake in young adults (Kerr et al., 2012; Pollard et al., 2016). Open-ended questions and example intervention features were used to explore the usability and acceptability of the self-monitoring tools, knowledge about effective weight loss strategies, and acceptability of the tailored feedback.

We used an iterative intervention development process applying the behavioural intervention technology (BIT) theory (Mohr et al., 2014) and the person-based approach (Yardley et al., 2015). An overview of the 3 stages of intervention development is provided below.

Stage 1

To derive the measurable and clinically significant behavioural changes that could be expected from the intervention, we reviewed the recent literature and evidence-based guidelines from the Australian scientific authoritative bodies. These included the National Health and Medical Research Council's clinical guidelines for weight management (National Health and Medical Research Council, 2013a), the Australian Dietary Guidelines (National Health and Medical Research Council, 2013b), and the Australian government's PA guidelines (Australian Government Department of Health, 2018). We determined the clinically significant target behaviours for the intervention as follows:

Dietary:

1. Daily dietary energy reduction of 2000 kJ.
2. Avoiding or limiting energy-dense nutrient-poor (EDNP) foods, SSBs, and alcohol.
3. Eating less at meals or additional snacks (except fruits and vegetables).
4. Eating less often.

PA:

1. Daily step count ≥10,000.
2. ≥30 active minutes (spent in moderate-to-vigorous PA).
3. ≥250 steps per hour.

Weight loss:

1. 5% reduction in body weight.

Target behaviours: The ToDAy study investigated whether a digital, tailored intervention can improve diet and PA behaviours in adults with overweight or obesity. A total of 16 health professionals with expertise in dietetics, PA, health promotion, and community engagement were consulted in a series of 5 workshops and meetings to explore the target behaviours needed to achieve the clinical aims and where, when, why, and who they occur with (Michie, van Stralen, et al., 2011).

Stage 2

The research team developed a user-friendly script for the focus groups and interviews with a male and female consumer representative (Miller et al., 2017). Focus groups and interviews were conducted with volunteers to explore the acceptability of the selected BCTs and their preferences for digital intervention features. The findings of these focus groups are presented in this paper.

Stage 3

Target behaviours were mapped to possible intervention features by the research team with reference to previous research (Curtis et al., 2015; White et al., 2016) and following guidelines for developing complex behaviour change interventions (Agarwal et al., 2016; World Health Organization, 2016). Focus groups and interviews were followed by a review of intervention features by the research team.

This was repeated in a cyclical manner to allow continued user involvement in the design and development of the final intervention.

Approval for the study was granted by the Curtin Human Research Ethics Committee (HR E2016-0271). All participants agreed to an audio recording of their focus group or interview and provided informed consent. All data were collected between October and November 2016 in Western Australia (spring).

Theoretical frameworks

Several guidelines exist for the development and assessment of evidence-based apps and web-based interventions (Agarwal et al., 2016; Craig et al., 2008). As this intervention uses a combination of digital tools, that is, an mFR, a wearable PA tracker, text messages, and emails, a combination of theoretical approaches and guidelines was drawn upon. The BIT framework was used to identify the technology and procedures for delivering clinical aims and BCTs (Objective 2) (Mohr et al., 2014). The models help to identify clinical aims and link these with suitable intervention features for testing with the user as shown in Table 5-1Table 5-1.

Then, the capability, opportunity, motivation, and behaviour (COM-B) model was used to guide the selection of intervention features and strategies such as self-monitoring, goal setting, motivation enhancement, and feedback on performance (Objective 1) (Michie, van Stralen, et al., 2011). The COM-B model aims to specify behavioural targets and support psychological theories when developing interventions. The COM-B model states that 3 factors are needed to change behaviour: capability (C), opportunity (O), and motivation (M). According to this model, performing a behaviour (B) first requires individuals to be capable (C) or have physical and mental abilities (eg, nutrition knowledge, cooking skills). Following this is opportunity, which includes both practical and social aspects (eg, access to healthy food that is culturally acceptable and within social norms). Finally, motivation includes automatic drivers like habits as well as beliefs, plans, and impulses. Figure 5-1 illustrates the steps in the development process—why, how, what, and where? The *what* includes the BCT and associated taxonomy number to identify each BCT from the Behaviour Change Technique Taxonomy v1 (BCTTv1) (Michie et al., 2013).

Table 5-1 Relationship among clinical aims, behaviour change techniques, and intervention features (technology).

Why? Clinical aim or population health focus	How? Action	What: behaviour change techniques[a] What: Behaviour change techniques (Michie et al., 2013)	Where: potential intervention features tested in qualitative research
Reduce BMI by 5% (National Health and Medical Research Council, 2013a)	Reduce energy intake by 2000 kJ per day and increase PA[b] (10,000 steps)	Provide information on the consequences (5.1), goal setting (behaviour and outcome; 1.1, 1.3), and review of behaviour goals (1.5)	Tailored feedback, weight tracker, PA tracker
Reduce Energy dense nutrient-poor (EDNP) foods (National Health and Medical Research Council, 2013 ;Sui, 2017)	Increase awareness of EDNP intake	Goal setting (behaviour and outcome; 1.1, 1.3), review of behaviour goals (1.5), provide feedback on behaviour (2.2), and social comparison (6.2)	Mobile food record; tailored feedback and tailored education; app alerts, eg, Have you had any snacks today?
Reduce SSBs[d] (National Health and Medical Research Council, 2013 ;Hendrie, 2018)	Increase awareness of energy in SSBs and intake	Self-monitoring of behaviour (2.3), goal setting (1.1), barrier identification, provide feedback on behaviour (2.2), and social comparison (6.2)	Mobile food record tailored feedback and tailored education
Increase fruit and vegetable consumption (Aljadani, 2013 ;National Health and Medical Research Council, 2013)	Increase awareness of current intake	Self-monitoring of behaviour (2.3), discrepancy between current behaviour and recommendations (1.6), action planning (1.4), problem solving (1.2), and instruction on how to perform behaviour (4.1)	Mobile food record tailored feedback and tailored education
Reduce alcohol intake (National Health and Medical Research Council, 2013b)	Increase awareness of current intake	Information on health consequences (5.1), motivational interviewing, and self-monitoring of behaviour (2.3)	App alerts, eg, How confident are you about having an alcohol-free dinner tomorrow night?

aBehaviour change technique and associated taxonomy from the Behaviour Change Technique Taxonomy v1 (BCTTv1).

bPA: physical activity.

[c]EDNP: energy-dense nutrient-poor.

[d]SSBs: sugar-sweetened beverages.

Recruitment

Recruitment was specific and purposeful (Palinkas, 2015); aiming for a similar number of males and females and including people with overweight or obesity who had some experience of the LiveLighter® campaign. A single recruitment email was sent to 20,000 adults who had registered with the LiveLighter® website in October 2016. The email was sent to the entire mailing list of LiveLighter® members, inviting them to take part in the study by clicking on a study web link where participants completed web-based consent and screening. The website was closed after two days as 245 respondents had completed the screening questionnaire. The respondents who met the criteria were sent further details on how to participate in a focus group or interview. There were 145 eligible participants, who were >18 years and had a BMI of $\geq$25 kg/m^2. The time, date, and location of the focus groups were sent to the eligible participants to allow them to choose the most convenient time. As 85% of the sample were women, additional recruitment strategies were employed to encourage male participants, such as offering a one-to-one telephone call and men-only focus groups. When these additional approaches were not successful, we contacted a workplace with a high proportion of males was contacted, and an onsite focus group was arranged, with 14 men in attendance.

Script development

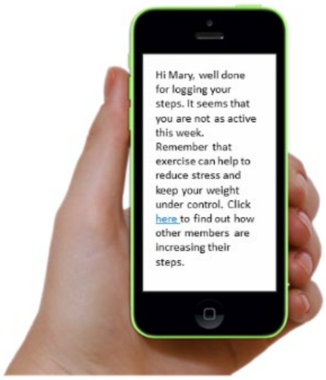
A semi-structured focus group and interview guide with open-ended questions was developed by the authors, which allowed an iterative, person-centered data collection process (Mummah, 2016;Yardley, 2015). The topics covered in the focus groups and interviews were informed by the literature as important features for weight loss interventions and included self-monitoring of diet and PA behaviour, feedback on performance, reducing intake of discretionary food drink and alcohol, reducing sedentary time, and increasing steps per day. The script was pilot tested with researchers at Curtin University and 2 consumer representatives where feedback on clarity was provided. Focus groups were conducted in community settings, community centres, place of work, and Cancer Council meeting rooms. For each session, the script was accompanied by a visual presentation of example images and draft intervention features. Table 5-2 Script for focus groups and interviews contains the primary script used.

Table 5-2 Script for focus groups and interviews

Ice Breaker
1. Use the iPad to take a photo of this food (plastic food or real food provided).
Online weight management
2. What do you think about weight loss support on your mobile phone or on the internet?
3. If you were going to design an online weight management program what kinds of things would you include?
4. What do you think would encourage you to stay engaged with an online weight management program?
Mobile food record app
5. We have an app to help people monitor their food and drink. You take a photo of your food/drink before and after you eat or drink. The app automatically sends us the photos with the time and date. This allows us to send personalized feedback to help with weight loss. Use the iPad to have a go at taking a picture of this apple?
6. Imagine you were asked to use this app. What might you like/dislike? How long would you be willing to use it for?
Advice to help people lose weight (slides shown in this section evolved based on feedback from previous focus groups and interviews)
7. Have a look at this picture (examples included large portion, junk food, excess alcohol and physical inactivity). What advice do you think we should give this person to help them lose weight?
8. Have a look at the feedback we plan to send
a. How would you rate this message?
b. Who do you think the message should come from?
c. Is there any other information you would like?
d. Can you suggest any support to help make this change?
e. Can you think of anything that might get in the way?

f. How easy do think it would be to maintain this new behavior?
Example questions on target behaviors (junk food, portion sizes, alcohol and physical activity)
a. If you were getting feedback about how to (change x behavior); what type of information would be helpful?
b. The last group suggested that dietary feedback include the participants own food images in their feedback so they could see where the junk food came from. What do you think of this idea? Have a look at this example. Is there anything you would change?
Engagement and support
9. Imagine you have been selected to take part in this study.
g. What sort of messages or support would you find helpful?
h. Is there anything that you would not like?
i. Another group suggested we sent testimonials from other participants. What do you think of this idea?
j. Another group suggested we send links to online resources and further information. What do you think of this idea?

Figure 5-2 Example of physical activity feedback shown to participants for their comment.



A semi-structured focus group and interview guide with open-ended questions were developed, which allowed an iterative, person-centered data collection process (Mummah, King, et al., 2016; Yardley et al., 2015). As a result, a variation of the script was used in each session. For example, “the last group suggested the dietary feedback include their food images so they can see where the junk food came from. What do you think of this idea? Have a look at this example. Is there anything you would change?”

Figure 5-3 Example of an image shown to participants where they were asked what advice they would give this person to help them lose weight

User Preferences

Preferences for digital intervention features explored willingness to use the digital self-monitoring tools as well as the frequency and duration of self-monitoring. Preferences for digital feedback explored the format, frequency, length, and content of the tailored diet and PA feedback. With regard to digital content to address the target behaviours, participants were asked to suggest helpful advice and potential barriers to changes for a particular behaviour, for example, “What feedback could we send to help this person lose weight?” and “What sort of things do you think might get in the way?”

Self-monitoring tools

The usability and acceptability of the self-monitoring tools were explored. First, participants were given an opportunity to use the mFR. This image-based dietary assessment tool uses the integrated camera in a smartphone to capture images of food and beverages (Ahmad et al., 2016; Boushey et al., 2017; Zhu et al., 2015).

The images are automatically uploaded to a server for dietary analysis by the research dietitian and used to inform the tailored dietary feedback. The usability and acceptability of the mFR to monitor dietary intake and a wearable device to monitor PA were explored.

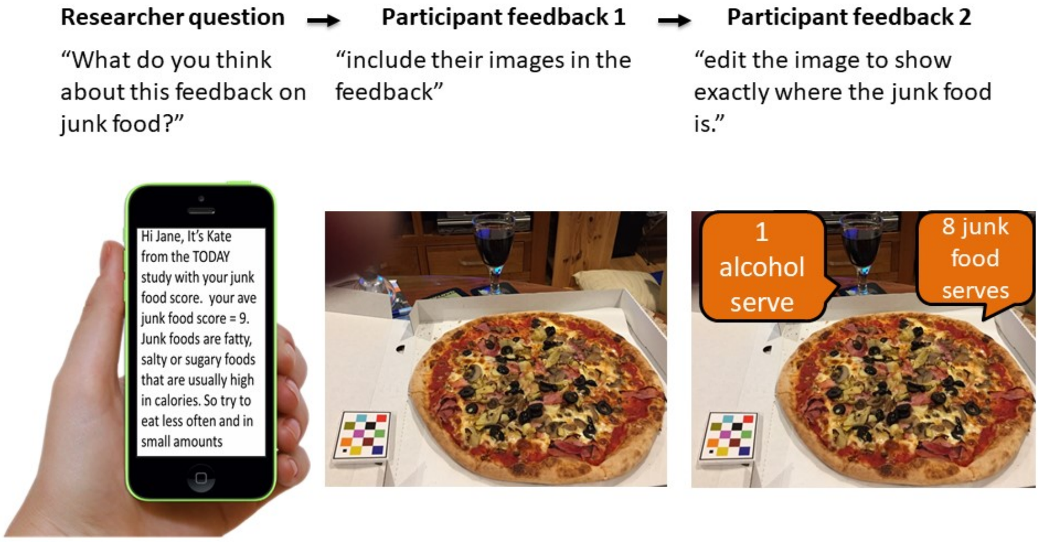
Behaviour change beliefs regarding weight loss

Participants were given examples of a scenario and asked to provide advice to a hypothetical person to help them lose weight. For example, “people in this study will use an app on their phone to take pictures of their food and drink. Imagine we received this picture from a man wanting to lose weight, what advice should we give him?” (Figure 5-1). Participants, who were interviewed on the phone, were emailed this information and the images in advance.

Acceptability of the feedback messages

The acceptability of feedback messages, including the length, content, and tone, was explored. Example feedback on diet and PA behaviour were shown to participants with questions to explore their understanding and acceptability of the feedback. For example, Figure 5-2 shows an example of PA feedback where participants were asked to “imagine we sent a person this feedback. How do you think they might feel about receiving this feedback? Is there any other information you would add?” After each focus group, new ideas were discussed with the research team (qualitative researcher, dietitian, exercise physiologist, and health psychologist) and potential digital intervention features were developed. The script was adapted after each session using an iterative process to incorporate participant ideas and feedback, which were then explored in the subsequent sessions. Figure 5-4 provides an example of how intervention features evolved using feedback from participants.

Figure 5-4 Example images showing how new ideas on how to provide dietary feedback were incorporated using an iterative process based on feedback from the previous focus group and interviews.



Data Collection

All interviews were conducted over telephone by author 1, a dietitian (the candidate) who has qualitative research experience (Shoneye et al., 2011) and guidance from another author (AB), an established qualitative researcher (Begley et al., 2019; Russell et al., 2019). Participants in the interview completed a consent form and demographics questionnaire on the web. The focus group participants completed a consent form and a demographic questionnaire on arrival. JH facilitated the male-only group, with CS as a co-facilitator. CS (the candidate) facilitated all other groups, with 1 assistant moderator. Before the interviews and focus groups, participants had no relationship with the researchers and knew the study was about helping to develop a digital weight management intervention.

All focus groups and interviews started with an overview of the proposed ToDAy intervention, where participants monitor their PA with a wearable tracker and record their food and beverage intake with the mFR app. This information was used to provide feedback to help them lose weight. The first activity was a chance to employ the mFR used to capture images of food and beverage intake. The facilitator demonstrated how to use the app to take pictures of plastic food models. Participants were then given an opportunity to use the mFR on a mobile device. This exercise served as an icebreaker as well as capturing the questions and comments of participants using the app. This was followed by open-ended questions to start the discussion. Focus groups and interviews lasted between 34 and 78 minutes and were conducted until reaching saturation of ideas. At the end of each focus group, the facilitator summarized the main ideas or themes that participants had raised in that group and gained agreement from participants.

Data analysis

All audio recordings were professionally transcribed verbatim and reviewed for accuracy by the first author and managed in NVivo. As this study used scripts that evolved between groups, the analysis used a thematic analysis to analyse and code data through the lens of the COM-B model (Michie, 2017). Qualitative data were analysed in using thematic analysis; familiarization through reading each transcript, highlighting key points, and discussion with the cofacilitators (Braun & Clarke, 2006). The first author led the analysis and developed themes aligning with capability, opportunity, and motivation. Then, the cofacilitators for the focus groups independently reviewed the scripts. Finally, any discrepancies were reviewed and discussed by the first author. The quotes were then aligned to the final themes.

Results

Participant Characteristics

Table 5-7 provides an overview of the characteristics of the participants. A total of 56 adults (32 female and 24 male) from Western Australia participated in 6 telephone interviews and 6 focus groups (average of 5 per group). Of these, over one-third had a BMI >30. Half were employed full time (52%), and most were aged between 25 and 40 years (61%). All participants owned a smartphone (iPhone or Android) and had some experience using apps.

Table 5-3 Characteristics of interview participants (N=56).

Characteristics	Values, n (%)
Age (years)	
25-40	34 (61)
41-65	17 (30)
>65	5 (9)
Gender	
Male	24 (43)
Female	32 (57)
BMI (kg/m^2)	
<25	10 (18)
25-30	23 (41)
>30	23 (41)
Ethnicity	
Australian	47 (84)
Indigenous Australian	5 (10)
Asian	4 (7)
Employment status	
Employed full time or part time	39 (70)
Unemployed	8 (14)
Retired	9 (16)
Household income Aus $	
<50,000 (<35,695)	21 (38)
50,000-150,000 (35,695-107,085)	22 (40)
>150,000 (>107,085)	13 (22)

Feedback from focus groups and interviews provided important insights into the acceptability and comprehension of tailored feedback messages. For example, feedback suggesting healthier alternatives to junk food was rejected as these options may not be available and could not be tailored to the individual's preferences.

Qualitative Analysis

Emerging qualitative themes and subthemes were mapped to the COM-B domains. This helped to identify that participants needed support in all 3 areas of capability, opportunity, and motivation.

Capability: Misinformation

Capability refers to knowledge and skills related to behaviour. Participants' knowledge of weight loss behaviours was examined by asking them to provide dietary advice to a hypothetical client based on a picture of their food and drink. Responses were themed as misinformation when they provided inaccurate information or nutrition advice. The majority of the discussion focused on giving misinformation as dietary advice. This revealed their knowledge and beliefs about which behaviours are best for weight management. For instance, 2 main examples were discussed. First, potatoes were considered fattening and second, excess alcohol was not a major contributor to weight gain. There was a focus on individual food being responsible for weight gain rather than a holistic view of the total diet.

Carbohydrates cause weight gain

Participants were shown an extra-large roast dinner with large meat portions, 3 small potatoes, 3 serves of vegetables, and 6 bottles of beers and asked, "What advice would you give this person to help them lose weight?" All groups commented on the potatoes, only later mentioning the large serve of meat and 6 bottles of beer:

> It's not a healthy meal if it's got a potato. [Female, FG2]
>
> Cut down on the carbs, only 2 potatoes. [Male FG3]

Alcohol consumption does not cause weight gain

The discussion did eventually focus on reducing the 6 bottles of beer, but there were a number of misinformed views about alcohol situations where 6 beers would be *OK*. For example, if it was a low-carb beer, consumed with fresh lemon, watching football, consumed over the course of an afternoon, the participant has eaten well during the preceding week or has a physical job that would work off excess energy.

Some participants were dismissive of the kilojoule content of alcoholic drinks but aware that alcohol may lead to choosing discretionary foods:

> So the kebab or the burger is a lot more appealing after a few drinks than it may be if say, while sober. [Male, PI 1]

> It's not the beer itself that's the problem, it's the food you have with it. [Female, FG2]

Opportunity: Environmental support and social norms

The *opportunity* component of COM-B relates to physical opportunities, such as the environment and availability as well as social opportunities, including social influences. Both emerged as important themes in the data.

Lack of Environmental Support

Environmental factors were discussed as the main barriers to avoiding junk food. One group, in particular, expressed frustration at the density of fast food outlets and the promotion of very low-cost meals that would appeal to children and those on a low income:

> When I first came in 1982 there was hardly any fast food places. Now you've got 8 or 9 different ones all down the road from each other. Kids have got 2 dollars where are they going to go? For a $2 burger. [Male, FG 5]

Participants expressed that the social marketing campaigns and interventions for individuals were futile without addressing the food environment:

> …that goes back to the government again because the government has put no restrictions on how much fast food can be in local vicinities. If you look at where they are, it's not in the high-class areas it's in the low socio-economic suburbs. [Male, FG 5]

Unhealthy food is everywhere

Many participants thought that most food options purchased outside the home were not healthy and the serving sizes were too large. Some mentioned added fat, sugar, and salt. Others noted that savory meals often come with chips and sweets are served with cream or ice cream:

> When you buy food out... It all tends to be fattening. [Female, FG 2]

Most groups brought up opportunistic eating as a key facilitator of eating discretionary food. Events such as at sporting occasions, bake sales, and *sausage sizzles* were given as common examples:

> You can't buy a healthier option at a sausage sizzle, they only have sausage, white bread, and sauce. [Male, FG 4]

Social norms

There has been some discussion about the difficulty of social opportunities. Most participants agreed that the expectations of consuming junk food at social occasions were problematic. When eating out, both men and women agreed that it is not socially acceptable for men to ask for healthy options or modification to their order. Regarding swapping chips for vegetables, a man said:

> It's not seen to be manly to be seen like, eating vegetables. [Male, FG 3]

> If it comes with chips, I'll eat chips. [Male, FG 4]

When discussing ways to reduce alcohol consumption, participants suggested practical methods, such as alternate alcohol with sugar-free soft drinks or choosing a low-strength beer. However, there was an overwhelming consensus that these suggestions were unrealistic and not socially acceptable for men:

> …might be difficult if you're down at the club or in the pub with the guys and then you really get the Mickey taken out of you [Male, FG4]

> You could suggest having water for every other drink, but who is going to listen to that? [Male, FG 5]

Motivation

The main theme that emerged from the motivation domain of COM-B was confidence.

Confidence

Participants were uncertain about their knowledge or beliefs about food, PA, or weight management. Some of this was linked to the perception that the guidelines from professionals were *always changing*. There was a sense of complacency about the need to or the importance of achieving health recommendations:

> What would have been recognized as a healthy meal years ago, these days it's not a healthy meal because it's got potato; carbs. [Male, PI 3]

Already doing enough

In relation to PA, most adults felt they were already active with daily activities, including looking after children, gardening, housework, and those in non-sedentary employment (eg, nurse, carpenter, and plumber). Motivation to engage in PA was limited by the belief that their lives were already active and busy:

> ... A mother of 3, busy all day, being told to go for a 45-minute walk. They can't otherwise they would have done it. [Female FG 2]

Concerning eating, most agreed that there was a place for junk foods, namely takeaways, confectionery, and desserts. Making healthy food choices was said to be important, especially for those with health problems like diabetes and high blood pressure. There was a variety of beliefs about how often people should make healthy food choices. Some used broad terms, such as sometimes or not too often. Others believed that healthy eating and being active were part of the working week and not applicable on the weekend:

> I mean you can eat healthy but every now and again you can always have take away. But not every week or every day. If you know what I mean? [Female FG 1]

> During the week it's structured. You've got, you know, time to get to work and your lunch break at work or whatever and then, you know, you come home and it's dinner time and then that's that. Then your weekends are your time to just flop. It's like a treat. Weekends are your time to relax and enjoy life I guess. [Female, PI 2]

Reality of change

When the group was shown potential feedback to address alcohol intake, there was general agreement that changing would be difficult or even impossible. Specifically, several people thought that any feedback to reduce alcohol intake would be futile:

> You could tell him to stop at four beers, but by then he won't know what he's doing. [Male, FG 5]

Ambivalence

There was a conflict in the expectations of the interventions. Some felt that feedback should tell them the negative consequences of their poor health choices:

> In three years at that rate, your liver is going to look like this. [Male, FG5]

However, feeling judged or reprimanded was cited as a barrier to keeping people engaged and honest about self-reporting. Participants wanted a specific example of food they could swap rather than a general *avoid this* or *chose a healthier option*. At the same time, they said specific advice would be unrealistic:

> All well and good to suggest a healthy option but you can't get your chicken parmigiana grilled with a baked potato at my local, it comes deep-fried with chips. [Female, FG 3]

These comments reflect the ambivalence about eating junk food outside the home; something they want help to avoid because it is expensive, is unhealthy, and leads to overeating but something they do because it is convenient and enjoyable.

Functions and Features of the Intervention

Results from the focus groups and interviews informed the selection of user preferences, intervention functions, and acceptability of the intervention. Table 5-4 shows the results on the acceptability of digital tools proposed for self-monitoring diet and PA. Participants found the mFR app to be intuitive and convenient in comparison with other digital tools or paper-based methods. All participants shared experiences of using a pedometer and saw the option for a wearable PA tracker as an incentive to join the study. Feedback on the clinical aims highlighted gaps in their understanding of the guidelines for diet and PA. Participants agreed that personalized feedback would promote health-enhancing habits by enhancing confidence and motivation.

The focus groups and interview data were reviewed for 3 intervention functions expected to mediate a behaviour change, for example, education, modelling behaviour, and persuasive communication.

1. *Education* (to increase knowledge on how to identify EDNP food and on PA guidelines).
2. *Modelling behaviour* (annotating food and beverage images by feedback on intake).
3. *Persuasive communication* (images and motivation enhancement using positive reinforcement in tailored communications).

Table 5-4 Understanding user perspectives and experiences of participants on the clinical aims using the mobile food record app and their experiences or views about using a physical activity monitor.

Clinical aims	Examples of questions or activity	Participant quotes
Self-monitor diet		
	Practice using the mobile food record app	"It's really intuitive and easy; better than the apps where you need to find the food"
	How easy/difficult would it be to use to capture all your food and drink for 4 days?	"I wouldn't use it if I was at the club with the guys. I wouldn't use it at work (nurse)"
Self-monitor physical activity		
	Have you ever used an activity tracker? Prompt for wearable device, pedometer, mobile app	"I used to use a watch that tracked steps and heart rate, it was good at first then all the alerts got annoying"
	Any advice or support that helped?	"Yeah it's good to see that you've done like ten thousand steps in a day"
Increase fruit and vegetable consumption		
	How much fruit and vegetables are recommended each day?	"2 fruit and 5 veg but I'm not sure if it has to be 5 different types"
	What advice would you give this person to help them lose weight? (Shown example meal)	"your vegetables are supposed to be half your plate so many people don't know that"
	What type of feedback could we send to help this person to get them to eat more vegetables?	"If someone sends you a picture, send it back saying 'that's at least one serve of your five today'"
	What sort of things might get in the way?	"No one eats that much veg, it's impossible"
Reduce EDNP[a]		
	What advice would you give this person, to help them lose weight?	"because you've eaten this you have to run ten kilometers to work it off, sort of thing"
	What sort of things might get in the way?	"…you go to Bunnings (national hardware chain with fundraising barbecues) you're going to get your sausage, there's no other options"

Reduce intake of alcohol		
	What advice would you give this person, to help them lose weight?	“Would be much better if he switched to a lighter beer, like only 4%”
	What sort of things might get in the way?	“If you’re out, say watching sport in the afternoon, everyone else is drinking it would be hard to have water”
Increase active minutes/decrease sedentary behaviour		
	How much physical activity is recommended each day?	“The adverts tell you half an hour a day and ten thousand steps. You can’t do ten thousand steps in half an hour, it doesn’t make sense”
	Any ideas of how we could support them to do this?	“Show it like your bank account where you can track it and see where it’s going”
	What might make it easier/difficult?	“It needs to be friendly and informative and helpful”

[a]EDNP: energy-dense nutrient-poor.

Table 5-5 summarizes the stages of applying COM-B to the focus groups and interview data to identify nutrition, PA, and weight management intervention functions and features.

New ideas from participants were explored for feasibility and consistency with evidence-based diet and PA guidelines. Rejected ideas included individual assessment of vitamin and mineral status and details on how much weight could be lost with a specific number of steps, as this was not consistent with evidence-based advice. Accepted ideas were the inclusion of participant food and beverage images from the mFR into the tailored dietary feedback. For PA, accepted ideas included using graphs for self-comparison of PA levels throughout the study, positive re-enforcement to acknowledge improvements in activity, and regular goal setting. There was a strong preference for visual feedback for both diet and PA. This was not feasible with text messages; therefore, feedback was primarily provided by email. Digital intervention features may continue to develop during the intervention and include aspects that were not originally mapped in this development phase (Mohr et al., 2014).

Table 5-5 Summary of stages of applying capability, opportunity, motivation, and behaviour framework to the focus groups and interview data to identify nutrition, physical activity, and weight management intervention functions and features.

COM-B[a] and themes	User preferences	Intervention functions	Intervention features
Capability: psychological			
Misinformation	Simple expert advice; links to further information	Education; tailored feedback on performance	Mobile food record; dietary goals
Capability: physical			
Environmental support	Dietary self-monitoring tools is easy, quick, and subtle	Training: how to use the mobile food record app	Mobile food record
Environmental support	PA monitor is easy to use and is visually appealing	Training: how to use the Fitbit charge 2	Fitbit Charge 2; tailored movement goals
Opportunity: physical			
Environmental support	Feedback provides visual information, basis their food choice	Education: link to Australian guidelines for diet and PA[b]	Tailored dietary feedback
Opportunity: social			
Social norms	Feedback is nonjudgmental, supportive tone	Supportive and friendly tone	Tailored feedback, tailored education
Motivation			
Confidence	Goals for diet, PA, and weight change are realistic goals	Modelling; personalized examples of how to improve their current behaviour	Tailored feedback; Fitbit Charge 2; tailored movement goals

[a]COM-B: capability, opportunity, motivation, and behaviour.

[b]PA: physical activity.

Discussion

This study reveals a lack of knowledge and confidence about evidence-based weight management behaviours and susceptibility to misinformation about nutrition. The results also suggest that the BCTs of self-monitoring and feedback on performance are well suited to this group. This paper follows previous examples of combining theory and the experience of users and experts to develop digital interventions (Curtis et al., 2015). Our findings explored factors affecting weight management behaviour, all of which could be mapped to the COM-B model. Participants expressed concerns about their capability; misinformation and opportunities; availability of alternatives and motivation or plans to change their behaviour.

The capability theme was most notable, with lack of knowledge and misinformation being most prevalent. Despite awareness and positive attitudes toward the LiveLighter® social marketing campaign, participants were still unaware of how to implement the messages from the campaign into their own lives. Several researchers have identified this as nutrition literacy, the ability to interpret and use nutrition information (Velardo, 2015;Silk, 2008;Heather, 2012;Krause, 2018). Misinformation about effective dietary strategies to manage their weight was evident; the energy content of alcohol was underestimated, and potatoes were described as *fattening*. This highlights the need for more tailored and specific information that addresses participants' ability to understand and implement new behaviours. A recent review recommends interventions providing actionable feedback and information on where and when to perform the new behaviour. For example, using the mFR to assess a meal image (Figure 5-1) and then providing actionable feedback such as identifying sources of EDNP foods and providing suggestions for change (Schembre et al., 2018).

Motivation to change eating habits and reduce alcohol intake was hindered by beliefs, and government guidelines on alcohol were considered unrealistic, a view found previously (Harrison et al., 2011). Similarly, participants were aware of the recommendations to eat 2 serves of fruit and 5 serves of vegetables, but did not believe this was necessary (Kothe & Mullan, 2011). This seems to be compounded by limited or inaccurate knowledge of serving sizes and energy content of foods (Mullan & Novoradovskaya, 2018).

Ambivalence appeared to be a strong theme, with participants describing their competing desires. Although most participants admitted to actively try to restrict their intake of junk food, they also revealed that junk foods were associated with happiness and *time off*. Similarly, eating out was viewed as a major barrier to weight management because of excess portion sizes and lack of healthy options. However, it was also described as a compulsory, normal part of our culture. These views are supported by a previous study, which highlighted that people felt pressured to eat junk food to participate socially and avoid criticism from their peers (Brantley, 2014). In additional, behavioural science has identified that our habits are the salient drivers of behaviour, rather than motivation or intention to change. This suggests that interventions should focus on developing habitual changes and creating healthy options as the default choice (Mullan & Novoradovskaya, 2018).

Social factors appear to be both motivators and barriers to healthy eating. Although most people agree that eating a healthy diet is what *should* be done, the social context of eating was associated with alcohol and junk food. Qualitative studies with Australian men aged 18 to 25 years reported that healthy eating was seen as incongruent with the masculine stereotype (Ashton, 2017). Our study confirmed that this view also exists among older men and women.

Strengths and limitations

A major strength of the study was the large sample of participants living with overweight and obesity and the inclusion of male and female participants. Although men are more likely to have a poor diet, carry excess weight, and experience weight-related disease, they are underrepresented in weight loss interventions. As a result, this study sought to recruit male participants to ensure that their views and preferences were represented in the development of the intervention. The transcripts were coded by gender. However, no apparent differences in preferences or views were found between men and women. Further studies with this cohort would benefit from exploring specific gender differences in the experience of weight loss behaviours and gender preferences for digital intervention features.

This research explored digital technology on several platforms, including the mFR app, wearable PA trackers, email, and text messaging. This made it difficult to apply a single framework exclusively for each of these elements to the intervention. As a result, Australian guidelines for weight management, diet, and physical activity informed target behaviours, rather than a theory-based process such as the behaviour change wheel, intervention mapping, or the Integrate Design Assess and Share framework (Brendryen et al., 2013; Michie, van Stralen, et al., 2011; Mummah, Robinson, et al., 2016).

The use of self-reported height and weight measures was a limitation of the study and may have led to inaccuracies in the reported BMI. At screening, volunteers were excluded if their BMI was <25. However, when asked at the focus groups to self-report their height and weight, 10 participants reported a BMI of <25. Therefore, the views expressed in these focus groups may not entirely reflect those living with overweight and obesity. Study participants primarily registered on the web via the LiveLighter® website and were likely to already have an interest in digital weight management. Their preferences may differ from those who have not previously attempted to seek weight loss information online.

A limitation of the study is that the predetermined intention to develop a scalable digital behaviour change intervention could have likely restricted the themes that emerged from the data. The purpose of this focus group study was to explore which intervention features would be acceptable and feasible to assist participants' behaviour change. The study explored potential barriers and benefits of using technology, rather than the wider context of the lived experience of participants in relation to their weight issues, such as social support. This is a limitation of the study, and further in-depth research is needed to explore this issue. The strength of this research is that it explored participants' opinions on a variety of relatively accessible technological devices to gauge their suitability for intervention. Theoretically, these PA trackers are effective and ideal for hard-to-reach groups. Although they provide objective feedback, little is known about users' experiences or preferences regarding the use of these tools for self-monitoring purposes. Another limitation was that the discussion regarding social support was limited to identifying the desired frequency of researcher contact. This script focused specifically on the supportive features of the intervention and did not explore other social support as they were outside the scope of the study. A further limitation was that the pace at which this intervention was developed and evaluated was protracted in comparison with commercial interventions (Riley et al., 2011). Recent industry and academic partnerships have demonstrated the potential to produce high-quality digital interventions at a commercial pace (Hendrie et al., 2019).

Future directions

Dichotomous thinking about food and activity can impede efforts to make healthy lifestyle changes (Palascha et al., 2015). A more flexible and nonjudgmental approach can lead to better behaviour change and reduce dietary restraint when supporting the psychological well-being of participants (Sairanen, 2014;Pollard, 2016). This intervention aims to adopt this flexible and nonjudgmental tone. The effectiveness of these strategies will be evaluated in a randomized controlled trial and exit interviews. Future studies will assess the relationship between behaviour change and intervention features, consistent with guidelines for developing digital health interventions (Michie et al., 2017).

Conclusions

The ToDAy study was developed using a person-centred approach and behaviour change theory. Focus groups and interviews were undertaken to explore user capability, opportunity, and motivation to perform the targeted behaviours for weight loss. The study revealed a lack of knowledge, confidence, and susceptibility to misinformation about evidence-based weight management behaviours. The findings suggest that a digital weight management intervention using mobile food records and activity trackers to inform tailored feedback may be an acceptable, feasible, and engaging strategy.

Acknowledgements

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Link to other chapters

The aim of this study was to explore a person-centred process of intervention development to develop a digital intervention that would be acceptable and engaging to the target users. The study explored potential intervention features and tailored feedback to determine whether participants had the capability, motivation and opportunity to modify their eating and PA behaviours for weight loss. Results from this chapter suggest that concerns about nutrition misinformation, lack of trust in dietary guidelines and low levels of food literacy. Issues include concerns about the impact of carbohydrates on weight gain and risk of diabetes, confusion about the role of fat and saturated fat in the development of heart disease and conflicting beliefs about the benefits of antioxidants in red wine and dark chocolate (Mete, 2019). Future studies that assess these beliefs may help to tailor content to help address these barriers. For examples, clients can be provided with specific nutrition content to address identified gaps in their nutrition knowledge or misinformation. While a more nuanced and multifaceted approach is required to address such a complex issue, tailored nutrition shows promise to be part of the solution.

The results highlight a lack of knowledge about weight loss behaviours, with widespread misinformation about the effects of alcohol and carbohydrates on body weight. Participants hold beliefs that weight gain is caused by specific foods, rather than a positive energy balance caused by factors effecting both energy intake and energy output. Although the digital self-monitoring tools are acceptable and usable, they also elicit some concern about how their diet and PA behaviour may be viewed by others. This warrants a study design that is able to capture the impact of self-monitoring, independent of the other intervention features (e.g. tailored feedback, goal setting). Participants made invaluable contributions to the final intervention features, contributing unique ideas and perspectives that shape the final intervention. The concept of image-based dietary feedback was inspired by participants', resulting in a novel approach to providing tailored dietary feedback and education. The protocol for the RCT will describe how the impact of this feedback will be analysed with both quantitative and qualitative evaluation.

Chapter 6 Protocol of a randomised controlled trial

Introduction

(Objective 5) Protocol for ToDAy: one year randomized controlled trial (RCT): Investigate whether a tailored intervention using mobile technology can improve dietary behaviours in adults with overweight or obesity.

The chapter is a revised version of the manuscript published detailing the full protocol diet, physical activity, sleep and an economical evaluations. The version focusses on the collection and analysis of dietary data and how this will be used to inform tailored dietary feedback. This review summarises how the evidence reviewed in chapter 2 was implemented into the final interventions. A unique feature of this protocol is the inclusion of intervention ideas from potential participants, describing in detail how dietary data will be collected and the protocol for using this information to inform tailored dietary feedback.

Reference: Halse, R. E., Shoneye, C. L., Pollard, C. M., Jancey, J., Scott, J. A., Pratt, I. S., Dhaliwal, S. S., Norman, R., Straker, L. M., Boushey, C. J., Delp, E. J., Zhu, F., Harray, A. J., Szybiak, M. A., Finch, A., McVeigh, J. A., Mullan, B., Collins, C. E., Mukhtar, S. A., Edwards, K. N., … Kerr, D. A. (2019). Improving Nutrition and Activity Behaviors Using Digital Technology and Tailored Feedback: Protocol for the Tailored Diet and Activity (ToDAy) Randomized Controlled Trial. *JMIR research protocols*, *8*(2), e12782. https://doi.org/10.2196/12782

Background

Excess weight is a major risk factor for chronic disease. Population surveys indicate that more than 63% of Australian adults have overweight or obesity, with higher rates observed in males compared with females (68% versus 55%) (Australian Bureau of Statistics, 2013). The five leading attributable risk factors for burden of disease in Australia are poor diet, high body mass index (BMI), tobacco smoking, high blood pressure, and insufficient physical activity (PA) (Institute for Health Metrics and Evaluation, 2010). Of these factors, diet and PA are recognized as being key to achieving energy balance in the complex development of overweight and obesity (National Health and Medical Research Council, 2013b). The 2011-12 National Nutrition Survey reported just over half of adults met the recommendations for two serves of fruit, and only seven percent met the recommended intake of five serves of vegetables (Australian Bureau of Statistics, 2013). Furthermore, 35% of daily energy intake consumed was from 'discretionary foods' (foods considered to be of little nutritional value, often high in saturated fats, added sugar, salt and/or alcohol or ‘junk’ foods) (Australian Bureau of Statistics, 2013). Key components of effective nutrition and PA behavioural change interventions include self-monitoring, feedback on performance and goal setting (Burke et al., 2012; Eckerstorfer et al., 2018; Michie, 2009; Morgan et al., 2009; Straker et al., 2014; Turk et al., 2013). More recently, there has been a move towards digital interventions utilizing mobile technology (e.g. mobile applications (apps); SMS messaging) to improve population reach, real-time data collection and feedback delivery (Michie, 2017). Cost efficiency is a major potential strength of such interventions, the challenge being to ensure design and implementation are supported by strong theoretical constructs. Although a plethora of healthy eating and weight loss apps have become available, many lack behavioural strategies in their design (Pagoto et al., 2013). A qualitative review of effective technology-based weight loss interventions identified five key features related to effectiveness: self-monitoring; positive feedback, social support, controlled program content, and individually tailored feedback (Khaylis, 2010).

Tailored weight-loss interventions have shown promise for behavioural change yet the effect size has been small and most to date lack objective measures of PA (Krebs, 2010;Kroeze, 2006;Broekhuizen, 2012;Short, 2011). Typically, feedback on behaviour change is taken from self-report questionnaires, limiting scope and relevance of individual diet feedback. With the rapid advances in digital technologies, alternative mediums for delivery of information are now possible, including the use of images and other visual elements. Therefore, interventions incorporating digital features provide a platform to test this concept and address concerns raised about lack of models to inform design of digital behavioural interventions (Mohr, 2014 ;Riley, 2011). For instance, a six month tailored intervention using the mobile food record™ application (mFR™ app) for dietary assessment and tailored feedback improved the diet of young adults (Pollard, 2016

). Features such as usability and willingness to continue to use apps may contribute to greater engagement and motivation enhancement by participants (Mohr, 2014). To date, few digital interventions have addressed both diet and PA behaviours together in an overweight population (Jakicic et al., 2016; Turk et al., 2013; Wang et al., 2018). A unique aspect of this study is the detailed assessment of dietary intake and PA behaviours to inform tailored feedback.

Aim

This study will use mobile technologies to undertake detailed assessment of dietary intake use these data to formulate personalized tailored feedback for study participants. The overall aim of this one year randomized controlled trial (RCT) is to investigate whether a tailored intervention using mobile technology can improve dietary behaviours in adults with overweight or obesity, recruited through the LiveLighter® social marketing campaign in Perth, Western Australia. This paper will specifically focus on the protocol for the collection and analysis of dietary data.

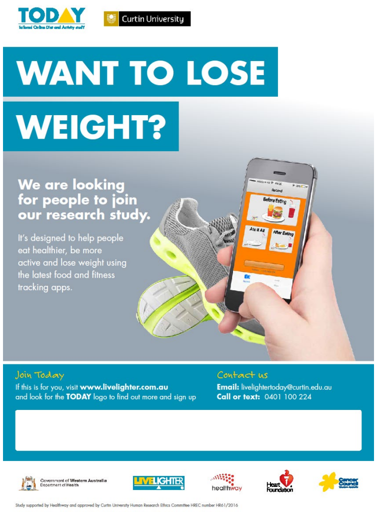
Methods

This study is a one year randomized controlled trial with a six-month intervention and six-month follow-up. Individuals who enrol via the LiveLighter® website (LiveLighter Homepage, 2018) will be invited to participate and, if eligible, will be randomized to one of three groups: 1) tailored feedback (TF) delivered via email at seven time points informed by objective dietary intake (mFR™) and activity (wearable activity monitor); 2) active control (AC) receiving no tailored feedback, but undergoing the same objective dietary and activity assessment as TF, and 3) online control (OC) receiving no tailored feedback or objective assessments (Figure 6-1). All groups will have access to publicly available resources via the LiveLighter® website. The inclusion of the OC group will distinguish monitoring and tailoring effects from those elicited by exposure to the LiveLighter® social marketing campaign and website materials. The project protocol has been approved by the Curtin University Human Research Ethics Committee (approval number HR61/2016) and registered with the Australian New Zealand Clinical Trials Registry (ACTRN12617000554369).

Recruitment

Participants from within the Perth metropolitan area will be recruited using: the LiveLighter® website (LiveLighter Homepage, 2018); LiveLighter® social media campaigns; letter-box drops; and radio interviews directing interested individuals to further information and study registration on the LiveLighter® website (Western Australia). Recruitment material highlighted that the intervention would use tracking apps and directed people to sign up online, as shown in Figure 6-1. Potential participants will complete an online consent and screening questionnaire. Staggered recruitment will take place over 12 months. To be eligible, participants must be: aged 18 to 65 years; have a BMI ≥ 25 and < 40 kg/m^2; own a mobile telephone (iPhone or Android phone); be able to engage in regular PA; have internet access and be available to attend a study centre in metropolitan Perth. Participants will be excluded on the basis of serious illness or medical conditions including diabetes requiring insulin, renal disease, liver disease; weight loss of > 4 kg in the previous 2-months; appetite suppressant use, weight loss or hormone-replacement medication use; pregnancy and/or current breastfeeding; current tobacco smoker; daily alcohol consumption > 5 standard drinks; prior or planned weight loss surgery; regular use of an activity monitor in the previous 12-months.

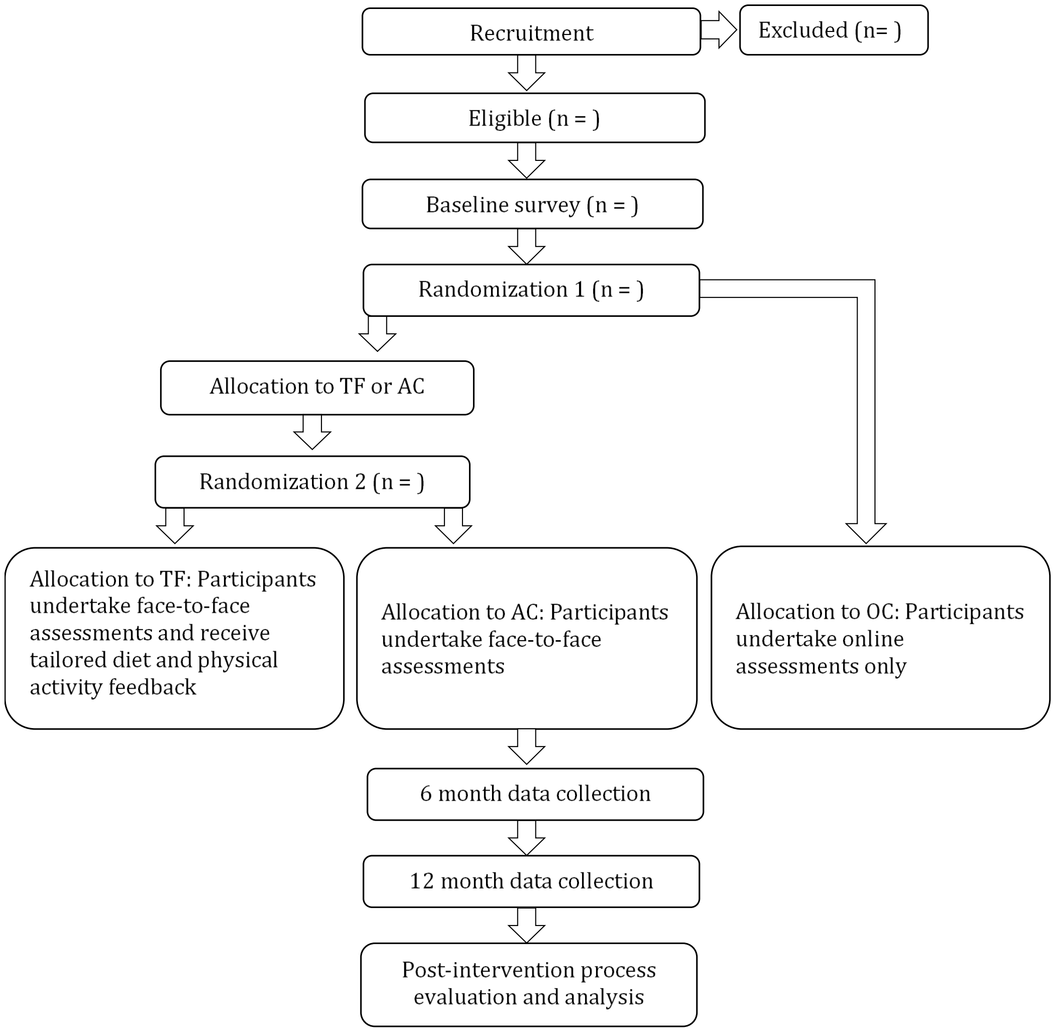
Figure 6-1 Example of recruitment material distributed



Randomisation

A two-staged, block randomization will be used with allocation concealment from the active research team via the use of sealed opaque envelopes. The first randomization will be in blocks of six, with separate sex randomization. The second randomization will be in blocks of four, again with separate sex randomization. Eligible participants will be notified via email and invited to complete an online demographic and lifestyle behaviours questionnaire, as detailed in Figure 6-2, prior to stage one randomization to either OC (n=200) or face-to-face (n=400) groups. Stage two randomization will occur at the second study visit to assign face-to-face participants to either TF or AC. Due to the nature of the intervention, it is not possible to blind participants or researchers to intervention group post allocation. Sequence generation will be conducted by a biostatistician not involved in the implementation of the trial on site using a randomization table created in Stata (version 15). The electronic file will be kept in a secure password protected server by the statistician.

Figure 6-2 Study design with randomization to Tailored Feedback (TF), Active Control (AC) and Online control (OC).



Data collection procedure

Following stage one randomization, TF and AC participants were invited to attend two data collection sessions with the research team, approximately a week apart. At the first baseline visit, participants received training to use of the mFR(Ahmad et al., 2016; Zhu et al., 2015; Zhu et al., 2010). During the second study visit, participants were interviewed to clarify the content of their mFR images. At this visit, height, body mass, waist and hip girth was e measured according to standard protocol (Stewart et al., 2011) and an aerobic fitness test (6-minute walk test) conducted (Rikli, 2000). The same assessments were repeated at 6- and 12-months, along with additional online assessments for all groups at the same time points (Table 6-1 Assessment Frequency for the ToDAy Study for Tailored Feedback

(TF), Active Control (AC) and Online control (OC), groups. All participants had access to LiveLighter® website resources throughout the intervention and will be encouraged to use the materials that include evidence-based healthy recipes and meal plans.

Table 6-1 Assessment Frequency for the ToDAy Study for Tailored Feedback (TF), Active Control (AC) and Online control (OC), groups.

Variables	Group	Baseline	6 months	+2 weeks	12 months
Health status EQ-5D a 5-item scale to assess utility health-related quality of life (Rabin & de Charro, 2001)	TF AC OC	X	X		X
Height, body mass (self-report)	TF AC OC	X	X		X
Height; body mass; BMI; waist; hip girth (measured) in centimeters via standiometer using stretch stature method; in kilograms via weighing scale in minimal clothing at similar time of day; calculated as kg/m^2; in centimeters via tape at the narrowest point between the lower costal border and iliac crest; via tape at the level of the greatest posterior protuberance	TF AC	X	X		X
Socio-demographics and personal characteristics assessed via questions on sex, age, eating behaviour, educational level, country of birth, ethnicity, socioeconomic status and financial status	TF AC OC	X	X		X
Australian eating survey an online food frequency questionnaire with options for automated dietary feedback previously validated in adults (Collins et al., 2014)	TF AC OC	X	X		X
Dietary intake assessed by 4-day mFR™	TF AC	X	X		X
Mobile food record (mFR) usability to assess user feedback and method preference (Boushey et al., 2015; Kerr et al., 2017)	TF AC	X		X	X
3-factor eating survey to measure factors associated with eating behaviour: cognitive restraint of eating; disinhibition; and hunger (Stunkard & Messick, 1985)	TF AC	X			X
Depression anxiety stress scale (DASS) 21 self-report items to assess severity of depression,	TF AC OC	X	X		X

anxiety and stress (Sinclair et al., 2012)					
Fear of negative evaluation twelve 5-point items to assess concern about being perceived unfavorably (Tooze et al., 2004)	TF AC	X			
Social desirability to measure social approval and acceptance (Marlowe & Crowne, 1961)	TF AC	X			
Weight loss history an 8-item tool to assess previous weight loss history (Myers et al., 2013)	TF AC OC				
Technology use questionnaire to assess duration and frequency of technology use indicative of sedentary behaviours (Hands et al., 2011)	TF AC OC	X	X		X
Feedback evaluation questionnaire Activity monitor usability; physical activity; and dietary feedback evaluation	TF			X	X

Research study database

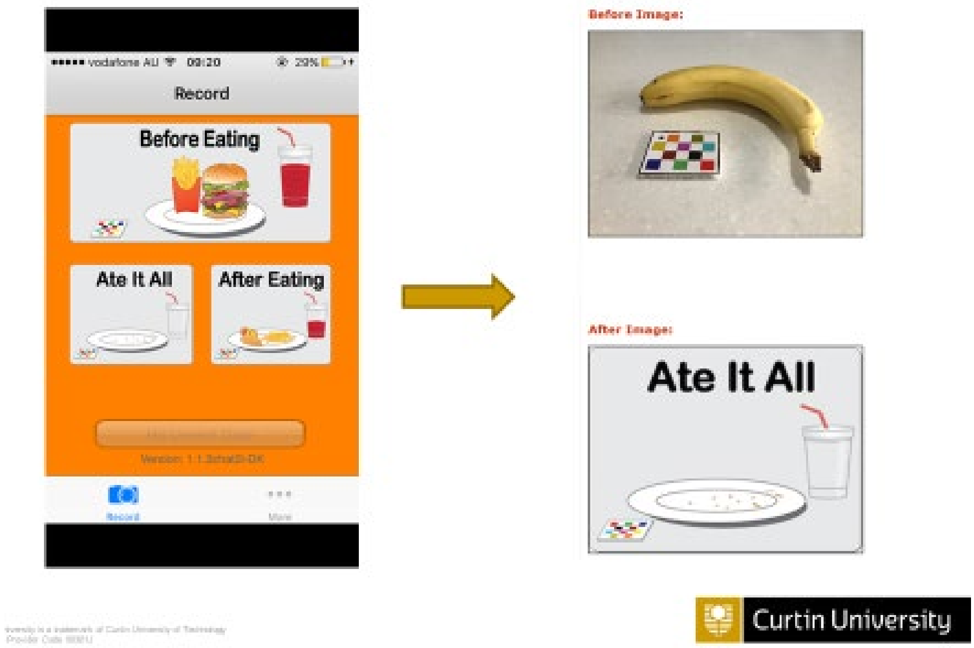
A purpose-built research study database was developed based on findings from prior research (Harray et al., 2015) using a Microsoft Access database platform to track the progress of the study participants at time points outlined in Table 6-1. The database will have the functionality of sending auto-generated emails containing study information and links. To track progress of the TF group requiring face-to-face visits, information regarding upcoming appointment date and time and relevant survey URLs will be sent using auto-generated emails. To remind participants of upcoming appointments email and mobile SMS prompts will be sent from the study database using 'Email to SMS' technology.

An online survey tool (Qualtrics) will be used to capture demographic information as outlined in Table 6-1. The study database will have the functionality of importing data to automatically update participant status with respect to their study compliance. The system will prompt reminders via email and SMS to participants who have not yet completed their tasks.

Dietary assessment

For the face-to-face (AC and TF) groups, diet will be recorded using the mFR app with inclusion of a fiducial marker (an object of known shape, size and coloor) (Zhu et al., 2010) in the image to aid in portion size estimation. “Before eating” and “after eating” images of all foods and beverages consumed over four consecutive days, including one weekend day, will be captured at baseline, 6- and 12- months for each participant. In addition, at 6, 12, 18 and 24 weeks, the TF group will complete a 1-day mFR to encourage self-monitoring of food intake to facilitate feedback. All images will be automatically uploaded to a secure cloud server residing on the Curtin University Bentley campus via Wi-Fi or 3G/4G network. Figure 6-3 provides an example of how the mFR will be used assed dietary intake. All images will be assessed by a research dietitian for serves of fruits, vegetables and energy-dense nutrient-poor (EDNP) foods and beverages according to the Australian Guide to Healthy Eating standard serves (one serve = 600 kJ)(Smith et al., 1998).

Figure 6-3 Demonstration of the mobile food record used for dietary assessment



Intervention content

Intervention content for diet will be informed by evidence-based guidelines (Australian Government Department of Health, 2018;Centers for Disease Control and Prevention. Physical Activity, 2018;National Health and Medical Research Council (Australia), 2013) to support weight loss through reduced energy intake and increased PA. The behavioural intervention technology (BIT) framework, the COM-B model and self-determination theory and previous research will guide development of intervention behaviour change strategies (Mohr, 2014, Pollard, 2016 ;Michie, 2013). These include self-monitoring, goal setting, motivation enhancement (including positive reinforcement in tailoring communications and incentives) and feedback to increase likelihood of engagement (Michie, 2013). To refine the intervention features and content, formative focus group studies with 56 consumers and health professionals were conducted prior to the intervention.

At randomization TF participants will be informed of feedback email frequency and content, and advised they may opt out of correspondence at any time by informing the research team. Email templates will be developed for each of the seven time points, containing personalized dietary and PA feedback content for each participant. Feedback will be consistent with communications from the LiveLighter® campaign, Australian Dietary Guidelines (ADG) (National Health and Medical Research Council, 2013b). The content will address each participant's personal barriers to changing key diet behaviours, reinforce motivation and guide the adoption of health enhancing habits. Tailored feedback on diet will commence within two weeks of baseline, and continue at 4, 6, 12, 18 weeks, 6- and 12 months thereafter. The feedback emails will be sent from Monday to Friday during business hours (9am – 5pm). Components used in tailoring will include self-comparison, preference for autonomy support, intention, motivation, confidence informed by self-determination theory and motivational interviewing (Michie, 2013 ;Resnicow, 2008). As seen in Table 6-2, dietary feedback will be informed by analysis of the images from the mFR and personal data from responses to online questionnaires administered at baseline.

Tailoring involves creating communications in which information about an individual is used to determine specific content he or she receives (Hawkins et al., 2008; Krebs et al., 2010). Positive effects of tailoring have been demonstrated in changing diet and PA behaviours (Krebs, 2010;Kroeze, 2006;Broekhuizen, 2012 ;Wright, 2011). The intention of tailoring, which uses characteristics unique to the individual, is to improve behavioural outcomes by altering processing or making the message more acceptable (Hawkins et al., 2008; Kreuter & Skinner, 2000). These characteristics can include personal behaviours, psycho-social characteristics, and dietary behaviours.

Specific strategies for message tailoring include personalisation, feedback and content matching (Hawkins et al., 2008). This study will focus on personalized feedback (exemplified in Table 6-2 Examples of tailored feedback intervention strategies) using information obtained on diet behaviours at baseline and specific time points throughout the intervention. Digital elements (food and beverage images) will be included to enable the evaluation of these components.

Table 6-2 Examples of tailored feedback intervention strategies

Type[a]	Example	Processing & goals
Descriptive (what is known)	Hi Jane, it's the team with your feedback. So how did you score? Ave fruit serves = 1.5, ave veg serves = 3. What's the goal again? 2 fruit & 5 veg every day. You are halfway there!	Effortful processing Self-referencing
Comparative (contrasts with others)	Hi Jane, so how did you score? Ave fruit serves = 1.5, veg serves = 3.5. Your fruit serves varied from 0 - 3.5, veg from 1.5 - 5.5 over 4 days. So how does your intake compared to others? Ave fruit serves = 1, veg serves = 2.	Effortful processing, self-referencing, normative beliefs and attitudes
Evaluative (interpretation)	Hi Jane, it's the team with feedback on your diet. So how did you score? Ave veg a day = 2.5. What's your goal again? 5 serves a day. You are halfway there!	Effortful processing, self-referencing, normative beliefs & attitudes

[a] Adapted from (Hawkins et al., 2008).

Tailored dietary feedback

Tailored dietary feedback will be formulated by the research dietitian (PhD candidate) based on food group analysis of the 4-day mFR™. Feedback will focus on key messages encouraging daily energy reduction of 2,000 kJ by (i) avoiding or limiting EDNP foods, sugar-sweetened beverages and alcohol, (ii) eating less at meals or additional snacks (except for salad and vegetables) and (iii) eating less often. Food group serves will be categorized for each participant based on three defined target zones (not achieved, almost achieved, and achieved). A template will be used for each dietary feedback email, modified according to results of each participants' dietary analysis. For EDNP serves, the template will be modified according to dietary intake to indicate average daily serves of 'junk' foods, sugary drinks and alcohol and kilojoule intake. Participants will be shown an image of their dietary sources of EDNP food and beverages. For fruit and vegetable serves, a scripted message will be devised for three levels of intake: (1) low: 0 to < 3.5 serves of fruits and vegetables; (2) medium: 3.5 to < 7 serves of fruits and vegetables; and (3) met recommendation: at least 2 serves of fruits and 5 serves of vegetables per day. Individual mFR images will be incorporated into email templates to illustrate sources of EDNP foods, fruits and vegetable serves. Two to three suggested modifications will be provided to each participant to support them in achieving the daily energy reduction goal.

Table 6-3 Tailored email feedback overview for diet behaviours: frequency; content; technique.

Feedback frequency	Feedback content: Diet	Behaviour change techniques (Michie, 2013)
+2 weeks	4d summary (average + range) from mFR™ showing average daily serves (kilojoule equivalent) for EDNP foods, sugary drinks and alcohol Example ADG serves for EDNP foods, sugary drinks and alcohol mFR™ food images showing participants the source of their EDNP foods, sugary drinks or alcohol serves Tailored feedback + goals based on key messages: avoid EDNP foods, avoid sugary drinks, avoid alcohol	Instruction on how to perform the behaviour Feedback on behaviour Tailored personalized message Prompt self-monitoring of behaviour Goal setting Discrepancy between current behaviour and recommendations
+4 weeks	Weight loss goal of 10% 4d summary (average + range) from mFR™ showing average daily serves for fruit and vegetables Example ADG serves for fruit and vegetables mFR™ food images showing participants the source of their fruit and vegetable intake Tailored feedback against recommended serves + goals to increase fruit and vegetable serves	Review behaviour goal Feedback on behaviour Action planning Prompt self-monitoring of behaviour Discrepancy between current behaviour and recommendations

+6 weeks	1d summary from 6 week mFR™ showing daily serves of EDNP foods, sugary drinks, alcohol, fruits and vegetables Comparison against baseline diet mFR™ food images showing participants the source of their EDNP foods, sugary drinks, alcohol, fruits and vegetables Tailored feedback against recommended serves + goals targeting: Avoid or limit EDNP foods, sugary drinks and/or alcohol Eat less at meals or snacks (except for fruit and vegetables); Eat less often (e.g. limit snacking)	Review behaviour goals Self-comparison Feedback on behaviour Tailored personalized message Prompt self-monitoring of behaviour Goal setting Discrepancy between current behaviour and recommendations
+12 weeks	1d summary from 12 week mFR™ showing daily serves of EDNP foods, sugary drinks, alcohol mFR™ food images showing participants the examples of meal or snack behaviours Tailored feedback + goals targeting: Eat less at meals or snacks (except for fruits and vegetables) Avoid or limit snacking	Review of outcome goal Review behaviour goal Feedback on behaviour Tailored personalized message Prompt self-monitoring of behaviour Goal setting Discrepancy between current behaviour and recommendations
+18 weeks	Reiteration of dietary goals + instruction on how to create an energy deficit from diet (e.g. reduction in EDNP food serves) Reiteration of 'what's a serve of EDNP foods' Reminder of dietary goals + suggestions on how to achieve: Avoid or limit EDNP foods, sugary drinks and/or alcohol Eat less at meals or snacks (except for fruit and vegetables); Eat less often (e.g. limit snacking)	Review of outcome goal Review behaviour goals Feedback on behaviour Tailored personalized message Goal setting Discrepancy between current behaviour and recommendations

+6 months	4d summary from 6-month mFR™ showing daily serves with comparison against baseline diet mFR™ food images showing participants the source of their EDNP foods, sugary drinks, alcohol, fruits and vegetables Tailored feedback against recommended serves + goals targeting: Avoid or limit EDNP foods, sugary drinks and/or alcohol Eat less at meals or snacks (except for fruit and vegetables); Eat less often (e.g. limit snacking). Tailored support for unhelpful behaviours: Emotional/restrained/uncontrolled eating (identified in the 3 factor eating questionnaire) Tailored feedback on how to make a healthy diet habitual based on habit index score	Review behaviour goals Self-comparison Feedback on behaviour Tailored personalized message Prompt self-monitoring of behaviour Goal setting Discrepancy between current behaviour and recommendations
+12 months	4d summary from 12-month mFR™ showing daily serves with comparison against baseline Tailored feedback against recommended serves + target goals	Review behaviour goals Self-comparison Social comparison with study participants Feedback on behaviour Tailored personalized message Prompt self-monitoring of behaviour Goal setting Discrepancy between current behaviour and recommendations

EDNP: energy dense nutrient-poor; D: day; mFR™: mobile food record™;

Control groups

The OC group will complete online self-report questionnaires only, while the AC group will also undertake face-to-face data collection and record dietary intake (mFR app) at baseline, 6- and 12-months. Neither group will receive tailored messaging nor feedback on their dietary intake. As an incentive for retention, AC participants will be advised that they will receive feedback upon study completion and the OC group will be entered into a six-monthly prize draw to encourage ongoing participation.

Process evaluation

Impact evaluation will consist of exit interview surveys via telephone at 14-months to assess intervention impact, as well as perceptions of various strategies and materials. Selected program completers and non-completers (TF and AC groups) will be invited to participate in one-on-one interviews concerning their perceptions of the ToDAy intervention.

Process evaluation will assess to what extent the intervention reached target audiences. A brief questionnaire will be used to evaluate participants' perception of the tailored feedback (i.e. message persuasiveness, message tone, readability, easy to understand, usefulness of advice, suitability and relevance to age group), and to comment on features they like/dislike about the program. Usability feedback will also be obtained for the mFR(TF and AC groups) and activity monitor (TF group only).

Power

A sample size of 600 participants (n=200 per group) will have sufficient power to detect a change in the primary outcome variable of at least 0.6 median serves/day of EDNP (discretionary) foods (or equivalent to a 360 kJ/day reduction) between groups at 90% power and 5% level of significance. Assuming a drop-out rate of 20%, a total of 600 participants will be recruited.

Discussion

Improving participation and reach is a challenge for population-based obesity interventions. Worldwide participation rates in population studies are declining (Galea & Tracy, 2007), and while enrollment in studies involving face-to-face recruitment is somewhat higher (Galea & Tracy, 2007), there is a need to evaluate the effectiveness of digital interventions that include multiple strategies to improve engagement (Warner et al., 2013). Interventions utilizing digital technologies may have greater appeal in overweight and obese populations, as participants may feel more comfortable completing self-reported questionnaires in a more anonymous setting (Mejean et al., 2014).

Reasons for lack of adherence to lifestyle recommendations are poorly understood. One contributing dietary factor may be that many adults incorrectly believe their diet to be healthy when it is not (Glanz et al., 1997). This mismatch between perceived and actual intake may be corrected by more accurate, objective dietary assessment, comparison with national recommendations and clear, relatable tailored feedback. Furthermore, despite sustained public health efforts, the majority of Australian adults are ‘inactive’, failing to meet the recommended PA guidelines (Australian Bureau of Statistics, 2011). Thus, focus on the most effective messaging (both content and delivery) to target these behaviours is needed. A systematic review of tailored interventions identified lack of objective measurements in studies on dietary and PA behaviours as key limitations of tailored interventions (Broekhuizen, 2012). This, in part, is due to difficulty in undertaking more objective methods of dietary and PA assessment on a large scale. Exploring digital methods of assessment may allow more cost-effective approaches to be implemented.

Tailoring focuses on characteristics unique to the person with the intention of improving behavioural outcomes by making the message more acceptable to each individual. Characteristics of messages and feedback that can be tailored include personal behaviours, psycho-social characteristics, and diet and PA behaviours (Hawkins et al., 2008). Personal relevance is key and dynamic (on-going assessment) tailoring versus static tailoring (one baseline assessment) has stronger effects over time (Krebs, 2010). Effective tailoring strategies include multiple intervention contacts and iterative feedback [19]. Of note, tailoring may be more effective for men than women (Robertson et al., 2016).

Numerous behavioural theories have been used as a basis for tailored interventions, including the Stages of Change Model and Precaution Adoption Process Model (Noar, 2007 ;Sherrington, 2016). However, there is increasing support for self-determination theory in weight control, diet and PA tailored interventions to address autonomous motivation and self-regulation (Michie, 2013 ;Resnicow, 2008 ;Teixeira, 2012;Friederichs, 2014 ;Miller, 2002 ;Michie, 2011). Central to self-determination theory is an emphasis on autonomous behaviours (originating from one's-self), as opposed to pressure or coercion into a particular course of action when delivering advice (Miller & Rollnick, 2002). This provides a framework for the style of communication to be used in tailored interventions but does not address approaches used in digital technology interventions. Researchers have raised concerns about lack of models to inform design of technology-based behavioural interventions (Mohr, 2014 ;Riley, 2011). In response, Mohr et al. (Mohr, 2014) proposed a BIT framework for interventions that use a range of technologies, including mobile telephones, the Web and sensors aimed at changing behaviour. Features such as usability and willingness to continue to use the app may contribute to enhanced participant engagement and motivation (Mohr, 2014

). Michie et al. (Michie, Abraham, et al., 2011) developed the COM-B model which guides researchers to identify behavioural targets and subsequent psychological theories for behaviour change interventions. The COM-B model identifies capability, opportunity and motivation as the three core categories to perform a behaviour. This means that to perform a behaviour, individuals must be capable with physical and mental ability (e.g. nutrition knowledge, cooking skills) as well as practical and social opportunities (e.g. access to affordable, healthy food). Motivation includes automatic drivers like habits as well as goals, beliefs, plans and impulses. Assessing these determinants is the first step to identify interventions and theories that can help to change behaviour.

Conclusions

The current obesity epidemic is occurring against a background increasingly poor dietary choices, with the incidence of both obesity worsening with age. Promoting and maintaining a healthy diet through personalised, tailored feedback is feasible, novel and potentially cost-effective. Personalized feedback with comparison to recommendations and guidance in forming healthy habits is essential to overcome existing barriers to a lifestyle change. Digital technologies (mobile apps, email and web) have the potential to reach larger populations of healthy adults and those at risk of chronic disease, but to date have not been fully explored. The outcomes of this intervention may have the potential to positively impact health at a broader population level, with findings informing translation of 'best practice' lifestyle intervention aimed at overweight adults.

Acknowledgements

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Link to other chapters

This chapter describes the procedures for the recruitment, data collection, development of tailored feedback and evaluation process for the ToDAy RCT. Developing an intervention that uses objective measures of diet to inform tailored feedback will contribute significant insight into the mediators of digital behaviour change interventions. Building on the experience of the CHAT study, ToDAy adds a more comprehensive assessment of health and health behaviour with increased frequency of self-monitoring and tailored feedback. In response to participant’s feedback in the CHAT study, more comprehensive dietary feedback will include images of their own meals with annotations that provide visual feedback and specific behavioural goals. The following chapter will provide a quantitative analysis of the dietary data at baseline and 6-months post-intervention. The term “LiveLighter” is a registered trademark. The LiveLighter campaign is funded by the Western Australian Department of Health and at the time of this study, delivered by the National Heart Foundation (WA Division), and currently delivered by Cancer Council Western Australia.

Chapter 7 Results from the ToDAy RCT

Introduction

(Objective 6) Investigate whether a tailored intervention using mobile technology can improve dietary behaviours in adults with overweight or obesity.

This chapter presents the results of the ToDAy RCT. The candidate was involved in the recruitment, screening and collection of dietary data, and the design of the questionnaires. As a dietitian she also assisted with the collection and confirmation of mFR image contents, analysis of mFR and development of tailored dietary feedback for the intervention group, and recording participant information in the study database. The Candidate undertook preliminary analysis under the guidance of Professor Satvinder Dhaliwal, a statistician and supervisor of this PhD.

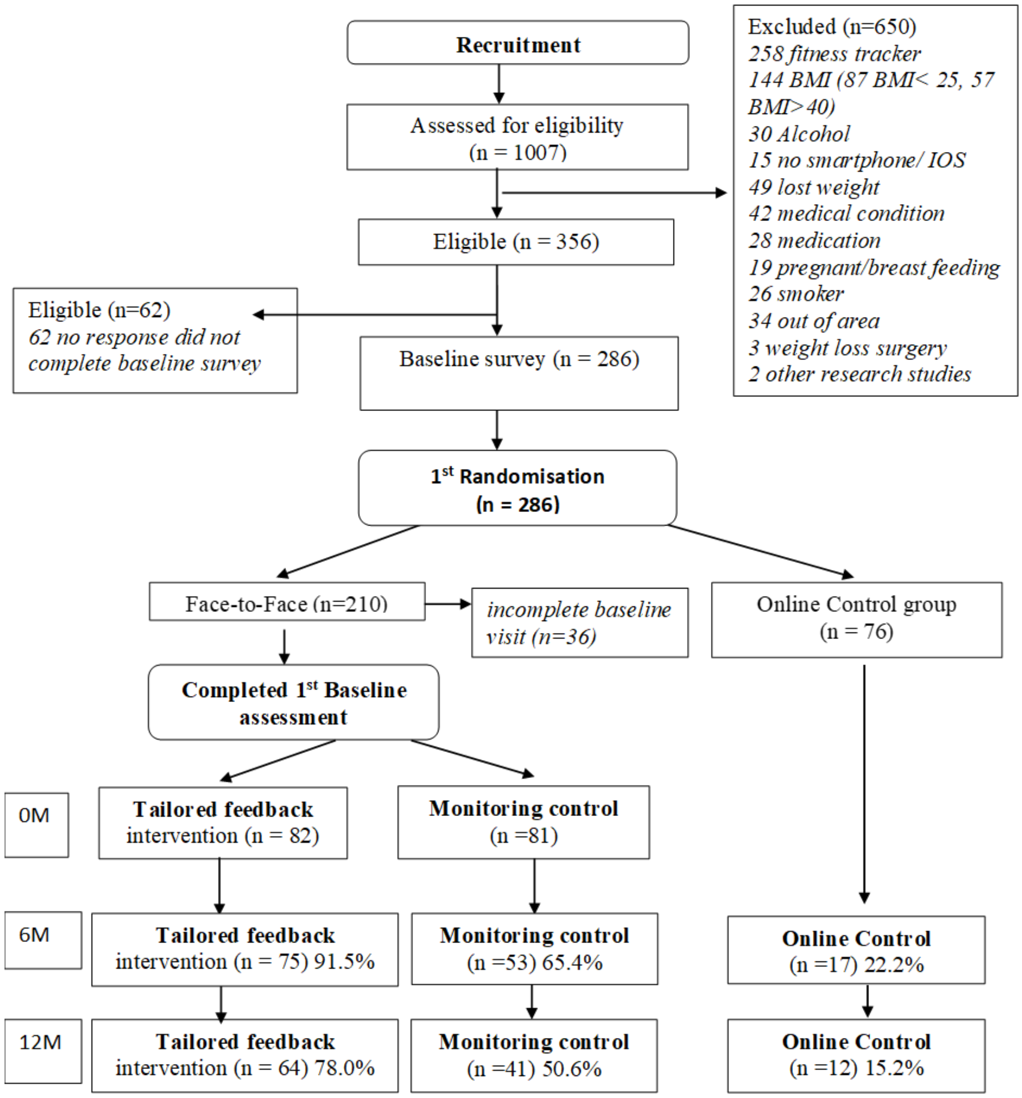
This thesis focused only on the dietary outcomes. The full range of behavioural and psychological measures captured was outside the scope of this thesis. At the onset of the project, the TODAY team included a broad range of researchers who planned to analyse the intervention's impact on habit formation, sleep and dietary restraint.

Summary of results

Over 1,000 participants were assessed for eligibility via a purpose-built online screening questionnaire, using a secure platform (Qualtrics). Participants were presented with a series of questions designed to determine their suitability to participate in the RCT. Questions were structured to automatically exclude participants who were not eligible, leading them to alternative sources of information and support for weight management. Where participants entered inconsistent or unusual data, they were phoned to verify the information, and the researcher assessed their eligibility on the phone. This included those who reported high intakes of alcohol, taking part in another study, taking medication or not having a smartphone. The baseline questionnaire was then sent to the remaining 356 eligible participants, which 286 participants completed. Figure 7-1 Participant flow chart shows the participant numbers for each stage of recruitment, randomisation and follow-up.

Eligible participants were randomised at a 2:1 ratio to either the face-to-face group (210) or the control (76). After the initial assessment, the face-to-face group was randomised again to receive tailored feedback or monitoring. The researchers were blinded to this randomisation. At 6-months, retention proportions in the tailored feedback, monitoring and control were 91.5%, 65.4% and 22.2%, respectively. In anticipation of high attrition in the control group, entry to a prize draw was offered for completion of each online assessment (baseline, 6-months and 12-months).

Figure 7-1 Participant flow chart



Participant characteristics

Baseline characteristics for all participants (n=286) compared by gender can be seen in Table 7-1. About one third of the sample were male, of which 36% were overweight and 64% were obese. Almost 70% of participants were female (n=198) with half overweight and half obese. Despite the exclusion criteria of current smoking status, one male and one female reported being a smoker at baseline. More than half of participants had a university education and most identified their ethnicity as Caucasian. Levels of depression and anxiety were in the normal range, but mild levels of stress were reported.

Table 7-1 Baseline characteristics for all participants (n=286) compared by gender

	Males (n=88)	Females (n=198)
Age in years (mean ± SD)	46.2 ± 10.2	45.1 ± 11.1
BMI (self-report) kg/m^2	31.8 ± 3.7	30.7 ± 4.0
BMI category		
Overweight 25 – 29.9 (kg/m^2)	32 (36.4%)	98 (49.5%)
Obese ≥ 30(kg/m^2)	56 (63.6%)	100 (50.5%)
Ethnicity		
Caucasian	79 (89.8%)	174 (87.9%)
Aboriginal	0 (0%)	2 (1%)
Asian	7 (8%)	12 (6.1%)
Pacific Islander	0 (0%)	1 (0.5%)
Black	0 (0%)	2 (1%)
Mixed	2 (2.3%)	7 (3.5%)
Smoking status		
Current smoker	1 (1.1%)	1 (0.5%)
Ex-smoker	30 (34.1%)	60 (30.3%)
Never smoked regularly	57 (64.8%)	137 (69.2%)
Highest level of education		
Year 12 or lower	14 (15.9%)	34 (17.2%)
Trade or diploma	24 (27.3%)	43 (21.7%)
Bachelor degree or higher	50 (56.8%)	121 (61.1%)
Total household income		

	Males (n=88)	Females (n=198)
Less than $29,999	3 (3.4%)	8 (4.0%)
$30,000 - $59,999	8 (9.1%)	23 (11.6%)
$60,000 - $99,999	20 (22.7%)	40 (20.2%)
$100,000 - $149,999	22 (25%)	54 (27.3%)
$150,000 - $199,999	20 (22.7%)	31 (15.7%)
$200,000 or more	12 (13.6%)	24 (12.1%)
Don't know, not answered	3 (3.4%)	18 (9.1%)

	Males (n=88)	Females (n=198)
Depression and Anxiety Sub-Scale (DASS-21) Median (IQR)		
Total domain score	15 (8 -29)	16 (8 -27)
Depression	4 (2 – 12)	4 (2 – 10)
Anxiety	2 (0 – 6)	2 (0 – 5)
Stress	8 (2 – 14)	8 (4 – 14)

Table 7-2 Characteristics of study participants randomised at baseline (n=163) comparing tailored feedback (TF) and active control (AC) groups

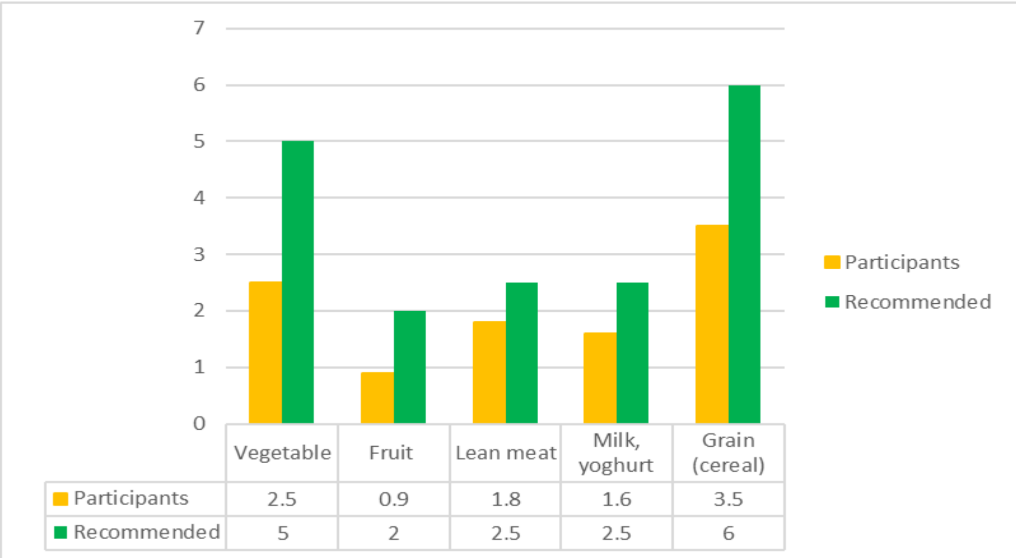
	Tailored feedback (n=82)	Active control (n=81)
Age (years)	46.5 ± 11.2	48.4 ± 11.1
Weight (kg)	90.1 ± 15.5	92.6 ± 16.7
Height (cm)	169.6 ± 9.1	171.5 ± 9.4
Body Mass Index (kg/m^2)	31.2 ± 4.0	31.3 ± 4
Waist girth (cm)	96.6 ± 11.3	97.6 ± 12.8
6-Minute Walk Test (metres)	611 ± 70	603 ± 79
Total MET Minutes per week	1696 ± 2005	1899 ± 1670
Food group servings (average daily serves)[a]		
Vegetable serves (75g)	2.3 ± 1.5	2.6 ± 1.4
Fruit serves (150g)	0.9 ± 0.9	0.9 ± 0.9
Lean meats, poultry, fish, eggs, seeds	1.6 ± 0.9	1.9 ± 0.8
Milk, yoghurt, cheese & alternatives	1.2 ± 0.8	1.9 ± 1.2
Grain (cereal foods)	3.4 ± 1.5	3.6 ± 1.5
Discretionary Food and Drink choices[b]		
Total discretionary food & drinks	3.8 ± 2.2	4.0 ± 2.2
Discretionary food serves	3.1 ± 1.9	3.3 ± 1.8
Alcohol serves	0.6 ± 1.0	0.5 ± 0.8
Sugary drinks	0.1 ± 0.3	0.1 ± 0.3

[a] Serving sizes based on Australian Guide to Healthy Eating (AGHE). [b] One serve of a discretionary food is the amount that contains 600 kilojoules.

Dietary intake

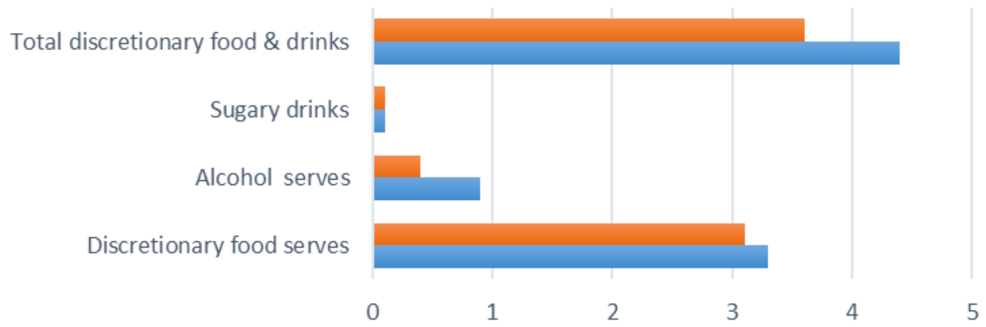
The intake of five core food groups in comparison to the Australian Guide to Healthy Eating is presented in Figure 7-2 below. As illustrated, intakes for all five core food groups were below recommendations. Intake for grains (cereal) was closest to recommendations at 58%. Intake for vegetables and fruit were furthest from recommendations, at 50% and 45%, respectively.

Figure 7-2 Face-to-face study participants randomised at baseline (n=163) compared with Australian Guide to Healthy Eating recommended serves



Total intake of discretionary food, SSB and alcohol was similar for men and women at 3.3 and 3.1 serves per day, respectively. Although intake of SSB was the same, men had double the alcohol intake of women, accounting for the increase in total discretionary food and beverage score.

Figure 7-3 Face-to-face study participants randomised at baseline (n=163) comparing men with women for discretionary food group serves.



	Discretionary food serves	Alcohol serves	Sugary drinks	Total discretionary food & drinks
Women	3.1	0.4	0.1	3.6
Men	3.3	0.9	0.1	4.4

Weight change

Weight loss as a percentage of baseline weight was calculated at 6 and 12 months. Mean weight loss in the feedback group was 1.3 kg at 6 months and 0.8 kilograms at 12 months. In comparison, the monitoring group had a mean weight loss of 1.3 kg at 6 months and 0.5 kg at 12 months. For men, weight loss in the feedback group was similar to that in the monitoring group at 6 months (3 kg versus 2.8 kg). Compared to women, men lost more weight in both groups at 6 months and with data from men and women combined, there was no significant difference in weight loss between groups at 6 months or 12 months ($P > 0.05$).

Table 7-3 Change in weight, anthropometric measures at 6 and 12 months.

	Tailored feedback (n=65)	Active Control (n=41)
Weight		
All participants		
Weight at baseline (kg)	88.6 ± 15	90.9 ± 15.7
Change at 6 months	-1.3 ± 4.8	-1.3 ± 3.9
Change at 12 months	-0.8 ± 5.1	-0.5 ± 5.0
Women		
Weight at baseline (kg)	84.0 ± 13.8	85.1 ± 12.3
Change at 6 months	-0.4 ± 3.5	-0.7 ± 4.2
Change at 12 months	0.0 ± 3.6	-0.3 ± 5.5
Men		
Weight at baseline (kg)	98.2 ± 12.9	104.9 ± 14.6
Change at 6 months	-3.0 ± 6.4	-2.8 ± 3.0
Change at 12 months	-2.6 ± 7.1	-1.0 ± 3.5
Waist girth		
All participants		
Waist girth at baseline	95.8 ± 10.6	95.8 ± 12.5
Waist change at 6 months	-0.8 ± 5.1	-0.9 ± 4.4
Waist change at 12 months	0.5 ± 5.2	0.3 ± 4.8
Women		
Waist girth at baseline	92.6 ± 9.9	91.7 ± 10.9
Waist change at 6 months	0.0 ± 4.4	-0.3 ± 4.5
Waist change at 12 months	1.4 ± 4.2	0.3 ± 5.5
	Tailored feedback (n=65)	Active Control (n=41)
Men		
Waist girth at baseline	102.5 ± 8.9	105.8 ± 10.8
Waist change at 6 months	-2.6 ± 6.0	-2.4 ± 3.9
Waist change at 12 months	-1.3 ± 6.7	0.3 ± 2.6

Clinically significant weight loss

Weight loss of 5% or more over 6 months is considered clinically significant and shown to have health benefits, including lowering blood pressure or delaying progression to type 2 diabetes (Stegenga et al., 2014). Overall, 16.8% of participants lost >5% of body weight at 6 months. Forty per cent of all participants lost < 5% of body weight. The Tailored Feedback group had a higher percentage loss >5 % of body weight, compared with the AC group (20% versus 12%). At 12 months, there was little difference between the groups in those who had lost 5 % or more of their body weight. However, retention in the Tailored Feedback group was higher. Therefore we are unable to determine what occurred in those who were lost to follow up at 12 months. Weight loss for both TF and AC is presented below in Table 7-4.

Table 7-4 Clinically significant weight loss in those participants who completed the study.

	Tailored feedback %	Active control %	Total %
Maintained or lost weight at 6 months			
	n=75	n=50	n=125
Lost 5% or more	20.0 %	12.0 %	16.8 %
Maintained or lost up to 5%	38.7 %	44.0 %	40.8 %
Gained weight at 6 months			
Gained up to 5%	33.0 %	40.0 %	36.0 %
Gained 5 % or more	8.0 %	4.0 %	6.4 %

At 6-months, one fifth of completers with obesity lost more than 5% of body weight, and 80% of them sustained this weight loss at 12-months. Among those with overweight, 11.9% achieved clinically significant weight loss at 6-months. This increased at 12-months (17.3%). Weight gain of more than 5% was more among those with overweight (10.2%), compared to those with obesity (3%) at both 6-months. The percentage of participants who gained more than 5% of body weight at 12-months increased for both those with overweight (17.3%) and obesity (7.4%).

Table 7-5 Clinically significant weight loss in those participants who completed the study by weight status

At 6 months	Overweight (n=59)	Obese (n=66)
Lost weight (5% or more)	11.9 %	21.2 %
Lost weight (0–5%)	40. 7%	40.9 %
Gained weight (0–5%)	37.2 %	34.8 %
Gained weight (5 % or more)	10.2 %	3.0 %
At 12 months	**Overweight (n=52)**	**Obese (n=54)**
Lost weight (5% or more)	17.3 %	16.7 %
Lost weight (0–5%)	32.7 %	37.0 %
Gained weight (0–5%)	32.7 %	28.9 %
Gained weight (5 % or more)	17.3 %	7.4 %

Table 7-6 Change in discretionary food and drink serves (mean ± SD) at 6 months and 12 months.

All participants	Tailored feedback	Active control
Discretionary foods		
Serves at baseline	3.1 ± 1.9	3.5 ± 1.7
Change at 6 months	-1.4 ± 2	-1.4 ± 1.9
Change at 12 months	-1.4 ± 1.9	-1.8 ± 1.8
Sugary drinks		
Serves at baseline	0.1 ± 0.1	0.1 ± 0.2
Change at 6 months	0.0 ± 0.3	0.0 ± 0.3
Change at 12 months	0.0 ± 0.2	-0.1 ± 0.2
Alcohol		
Serves at baseline	0.6 ± 1.0	0.6 ± 0.9
Change at 6 months	-0.4 ± 0.9	-0.4 ± 0.8
Change at 12 months	-0.3 ± 0.9	-0.3 ± 0.7
Total discretionary food & drinks		
Serves at baseline	3.7 ± 2.2	4.2 ± 2.2
Change at 6 months	-1.7 ± 2.4	-1.9 ± 2.1
Change at 12 months	-1.8 ± 2.3	-2.2 ± 2.1

The changes in discretionary food and drink served over the study period are presented in Table 7-6, demonstrating an overall decrease in serves eaten for both the TF and AC groups. The most significant reduction was in discretionary food choices with the Tailored Feedback group reducing portions by 1.4 ± 1.9 serves and the AC group by 1.8± 1.8 serves.

Statistical Plan

The following primary outcome variables will be measured at baseline and 12 months of the intervention: changes in body mass, EDNP food and beverage consumption (sugar-sweetened beverages, alcohol, and take away and other "junk" foods). Secondary outcome variables include changes in fruit and vegetable serves. Data on change in outcome variables in each of the two groups will be compared using analysis of covariance. Assumptions of the analyses will be assessed by examining residuals. Data will be transformed if assumptions of the analyses are not satisfied. Possible covariates considered will include age, sex, country of birth, ethnicity, highest education level, socioeconomic index for area, and baseline value of the variable analysed. P-values < .05 will be considered statistically significant. Effect size of differences between treatment and control will be expressed as adjusted mean difference and associated 95% CIs. Data on change in outcome variables post-intervention and follow-up time points will be converted into binary categorical variables and analysed using multivariable logistic regression and generalised estimating equations. Odds ratio and associated 95% CIs will be reported.

Gender difference

Recruitment of men in interventions is known to be challenging. As we observed lower response rate in men, we actively promoted the study to men through television and radio interviews. The randomisation was undertaken with a separate randomisation for men and women to ensure an equal proportion of men and women across the three groups (online control, active control and tailored feedback).

A systematic review of 244 lifestyle interventions found the samples were on average, 27% male and men from ethnic minority groups were less than 2%

(Pagato, 2012). The SHED-IT trial specifically explored the preferences of male participants and suggest digital tools, and found tailored content to be more effective at engaging men into a digital weight loss intervention (Young, 2012 and Morgan, 2013).

The underlying reasons for gender difference in engagement in weight loss are multifaceted but likely to include differences in hormones, physiological responses to physical activity and social norms about eating (Lovejoy, 2009). In addition, there are difference in food and drink preferences with women choosing options with better nutrition content and lower cost, compared to men (Livingstone, 2020).

Tailored content is able to address these gender difference as the content is based in the individuals responses, reducing redundant information that may be based in previous data in which men are underrepresented. As the number of men in Australia with obesity increases, interventions that consider male preferences and include men and in their development are urgently required. The development of evidence based digital interventions that are tailored for specific groups of the population, are an important public health response to the current trends in poor diet. Our study gives voice to the beliefs and experiences of men who are interested in joining a weight management program. These findings will help inform future weight loss interventions for men and will assist researchers and practitioners to engage men in weight loss research

Chapter 8 An evaluation of a digital tailored weight loss intervention: qualitative study

Objective 7: Conduct a qualitative study to identify intervention features influencing participants' motivation, capability and opportunity to change their dietary and activity behaviours

Objective 8: Explore participants' preferences for intervention features and how the intervention might be improved

Introduction

Using qualitative methods in a process evaluation of a complex intervention helps understand the users' experiences of intervention features. This can highlight adaptations, which may improve behaviour change, engagement or translation to a real-world setting. As the evidence emerges about the effectiveness of digital tailored interventions, examining the potential mechanisms of behaviour change is vital to understand how and why the intervention works with some people and not others. Qualitative studies are well suited to examine how new interventions are used and experienced.

The candidate was responsible for designing the script used for the telephone interviews, collecting and analysing all data and writing the draft manuscript.

Abstract

ToDAy is a digital weight loss intervention providing tailored feedback based on objective measures of dietary and physical activity (PA) behaviour. While a growing number of randomised controlled trials have evaluated behaviour change techniques, intervention features and their impact on behaviour, qualitative studies are needed to understand why interventions are successful for some people and not others. This will help to maximise the effectiveness of future interventions. This study was designed to identify intervention features influencing participants' motivation, capability and opportunity to change their dietary and activity behaviours; explore participants' preferences for intervention features and identify participants' views on how the intervention might be improved.

Nineteen telephone interviews were conducted with participants in the intervention arm of the ToDAy trial. The aim was to explore the participant's experience of implementing the tailored feedback and using the intervention features. Participants were purposely selected to include a similar number of males and females, and include those who had lost weight, maintained their weight or gained weight. The script was designed to assess user's capability, opportunity and motivation to perform new behaviours for weight loss.

All participants were optimistic about the digital self-monitoring tools; the mobile food record and Fitbit. Those who lost weight described the intervention as simple, and their behaviour change as easy. Increasing active minutes and number of steps were the fundamental physical activity behaviours attributed to weight loss. For diet, increasing fruit and vegetable consumption was the main behaviour change associated with weight loss. Most participants who did not lose weight reported a positive experience of the intervention and felt they had significantly improved their diet and PA. Participants reported increased capability and motivation for behaviour change, independent of weight loss.

Background

Diet and physical activity are the primary focus of behaviour interventions for weight loss (Blüher, 2019). Interventions based on behaviour theory are more likely to effect sustained behaviour change and weight loss (Cleo, 2019;Hutchesson, 2015 ;Kwasnicka, 2016 ;Lau, 2020 ;Samdal, 2017). Although weight loss is often defined as a goal, it is, in fact, the outcome of changing behaviours, influenced by both cognitive and reflective factors. For example, to avoid eating fast food may require goals for meal planning, grocery shopping and self-monitoring of diet and PA. The COM-B model encompasses these factors, identifying motivation (M); the intention or desire to change, capability (C); the knowledge and skills needed and opportunity (O); physical access and social support, as prerequisites for a behaviour change. This approach has been used successfully in several digital interventions aiming to change behaviour (Samdal, 2017;Pirotta, 2019 ;Miller, 2015).

Despite growing evidence about the psychology of changing behaviour for weight loss, efforts to lose weight can lead to physical responses that increase appetite, cravings for energy dense foods and reduced energy expenditure during PA (Sumithran, 2011 ;Fabbricatore, 2013;Ostendorf, 2019 ;Montesi, 2016). As a result, weight loss can often plateau despite continued efforts and 80% of those who lose weight will regain in within 2 years (Montesi, 2016). Factors that differentiate those who lose weight with those that do not include social support, lifestyle changes, persistent physical activity and viewing the changes as lifelong (Sawamoto, 2017). However, is not clear if these participants' experience intervention features differently, specifically the impact on their capability, motivation and opportunities to change their behaviour.

Guidelines for the development of interventions recommend the use of a theoretical framework but there is limited evidence about how these can be implemented digitally (Craig et al., 2008; World Health Organisation, 2019). Theory can be implemented to help select behaviour techniques (e.g. self-monitoring), identify people who are most likely to succeed with the intervention (e.g. people who think that healthy eating is important) or to decide which determinant of behaviour to focus on (e.g. nutrition knowledge). Recent studies have shown that habit theory is a promising approach for making small but sustained changes to eating and activity behaviour (Cleo et al., 2019; Kliemann et al., 2019). Habit theory proposes that behaviours learnt through repetition in a consistent context will become automatic or habitual, requiring little motivation or effort (Gardner, 2015). For example, eating a piece of fruit (behaviour) after lunch (contextual cue). Initially, self-regulation is required to repeat the new behaviour, until it becomes automatic, so multiple strategies are often needed, such as self-monitoring and goal setting (Kwasnicka et al., 2016). Qualitative studies with participants could highlight how intervention features support the development of positive habitual behaviours.

ToDAy was a 1-year tailored randomised controlled trial (6-month intervention and 6-month follow-up) to improve diet and PA behaviours leading to weight loss in adults. An image-based mobile food record and FitBit Charge 2 were used to measure diet and PA objectively. Specially trained researchers analysed this data to inform tailored feedback sent via email. The full protocol the randomised controlled trial conducted to evaluate the intervention are described elsewhere (Halse et al., 2019).

RCTs are considered the gold standard for evaluating the effectiveness of interventions as they control for unknown confounders, and measure the impact of various intervention features and behaviour change techniques (Michie et al., 2017). However, they offer limited insight into the participant's experience and few opportunities to obtain feedback. As digital behaviour change interventions are relatively new, and evidence is still emerging, efforts to explore which aspects of the intervention are effective and who they are most suitable for are vital (Lustria et al., 2009; Walthouwer et al., 2015). Qualitative approaches can help to explain variations in effectiveness within the sample, examine the appropriateness of the underlying theory and generate further questions or hypotheses (Lewin et al., 2009).

This qualitative study had two objectives:

1. Identify intervention features influencing participants' motivation, capability and opportunity to change their dietary and activity behaviours

2. Explore participants' preferences for intervention features and how the intervention might be improved

Methods

Recruitment

The ToDAy intervention was a 1-year weight loss intervention for adults (aged 18-65 years) with a body mass index between 25 and 40. After completing a baseline assessment online, two-stage randomization was used to allocate participants into one of three conditions: tailored feedback delivered via email at seven time points; active control; and online control. Primary outcome measures at 6 and 12 months are changes in body mass, BMI, energy dense nutrient poor (EDNP) food and beverage consumption, and daily moderate-to-vigorous PA (measured via accelerometer). Secondary outcomes include change in fruit and vegetable consumption and daily sedentary behaviors. Participants for this qualitative study were recruited from the group receiving tailored feedback. Only those who completed all assessments at 12 months were eligible to take part.

Tailored feedback in the ToDAy study

The tailored dietary feedback was based on food group analysis of a 4-day, image-based, mobile food record (mFR). Feedback messages focussed on daily energy reduction of 2,000 kJ by avoiding or limiting discretionary foods, sugar-sweetened beverages and alcohol; eating less at meals and snacks (except for salad and vegetables); and eating less frequently. Individual mFR images were annotated and included in email templates to illustrate the source and serving sizes of discretionary foods, fruit and vegetables. Appendix E provides an example of the tailored dietary feedback.

Tailored PA feedback was based on data from a wrist-worn activity monitor (Fitbit Charge 2) and included three movement goals: "move more" (step count; toward ≥10,000 steps), (Duncan, 2018;Australian Government Department of Health, 2018), "move harder" (minutes spent in moderate-to-vigorous activity; towards ≥30 active minutes), and "move more often" (hourly movement; towards ≥250 steps per hour).

Participants

For this study, recruitment was specific and purposeful to include both male and female participants experiencing weight loss (weight decrease >2kg between baseline and 6-months) or no weight loss (weight stable or increase > 2kg between baseline and 6-months). Purposeful sampling is used to identify and select individuals who have a particular experience or characteristics and are available and willing to participate (Palinkas et al., 2015). Twenty-two eligible participants who had completed all study components and received their final feedback at 12-months were sent an email invitation to participate. All replied, but only 19 were available to schedule an interview. All interviews were conducted between June and September 2019, approximately 12 weeks after participants completed the intervention.

Data collection

The methodological approach used in this research was a general inductive qualitative approach (Thomas, 2006). The consolidated criteria for reporting qualitative research (COREQ) for interviews and focus groups were used to ensure rigour in the presentation of the findings (Tong et al., 2007). Qualitative interviews conducted by telephone were designed to explore participants' preferences for intervention features and identify participants' views on how the intervention might be improved. The questions also examined intervention features influencing participants' motivation, capability and opportunity to change their eating and PA behaviours. The study was approved by the Curtin University Human Research Ethics Committee (approval number HR61/2016) and registered with the Australian New Zealand Clinical Trials Registry (ACTRN12617000554369).

Data collection

In depth telephone interviews were conducted by the candidate, who was known to most participants. The candidate is a female dietitian who has experience in conducting interviews and focus groups (Shoneye et al., 2011). A statement outlining study procedures was read at the start of each interview to orient participants to their study experience and provide consistency between interviews. Interviews were conducted in a private room and audio recorded. Informed consent was obtained verbally at the start of each interview. The digital audio was transcribed verbatim by a professional transcriber. Interviews lasted between 19 and 50 minutes. All participants were offered a $50 gift card for participating in the interview.

Interview schedule

The interview schedule included 20 questions, probing statements and prompts; the full interview schedule is provided in Appendix F. As well as the COM-B domains, topics explored were changes to diet, PA and weight, tailored feedback, habitual behaviour and their experience of the study. During the telephone interview the interviewer had access to a summary of the participants' diet and PA feedback at baseline, 6-months and 12-months. This allowed for prompts on specific changes in observed behaviour. For example, "I see that your average daily junk food intake went down during the first 6 months. Can you tell me more about that?" The interview schedule was pilot tested with researchers at Curtin University where feedback on clarity of the language was provided. No repeat interviews were conducted and transcripts were not returned to participants for review. Notes were made throughout the interview and these were used to facilitate the discussion of transcripts during data analysis.

Data analysis

Interview transcripts were independently reviewed by the candidate and one other author before being evaluated using thematic analysis (Braun & Clarke, 2006) and managed in NVivo 12. Qualitative data were analysed following the process of thematic analysis: familiarisation through reading each transcript, generating codes in NVivo and then allocating these codes to themes. Themes had to be mentioned by at least three participants to be considered. All themes were independently analysed by two authors and any discrepancies were reviewed and discussed. Common themes were discussed to agree on the definition and significance. A range of verbatim quotes was then aligned to the final themes as examples of the views expressed by participants.

Results

Table 8-1 shows the baseline characteristics of participants taking part in the interviews. Participants were purposely selected to include those who had lost more than 5% body weight at 6-months and a mix of both males and females. Although the majority of the sample were males, there were more men who achieved clinically significant weight loss, which is reflected the higher number of males.

Table 8-1 Participants change in weight at 6 months

	Weight loss (n=9)	No weight loss (n=10)
Gender	3 women, 6 men	6 women, 4 men
Baseline weight (kg)	93.6	88.5
6-month weight (kg)	84.2	90.6
Weight change at 6-months kg (kg)	-9.4	+2.1

Thematic analysis identified eight themes: setting goals, planning ahead, learning something new, small lasting change, difficult emotions, weight change, habits and suggestions for improvement.

Setting goals

A unique feature of ToDAy intervention was the use of a Fitbit, alongside tailored physical activity feedback that highlighted performance in all three movement goals: move harder, move more and move more often. Receiving tailored feedback on their step goal and monitoring their steps on the Fitbit were strong motivators for maintaining activity goals. Reference to goal setting was common among all participants. The most frequent goal for physical activity was "move more" (step count; toward ≥10,000 steps). Achieving 10,000 steps daily was most commonly mentioned by those who had lost or maintained weight at the end of the 6-month intervention. These participants described their determination to complete this goal every day.

Participants who reported regularly meeting 10,000 steps per day were optimistic about the improvements this brought to their quality of life and weight. These participants also described achieving their step goal as part of their daily routine.

Participants who gained weight also referred to the PA step goal but reported being preoccupied with the goal or experiencing negative emotions if they did not achieve the goal.

In contrast, another participant who lost weight expressed less emotion if the goal was not achieved.

Goals framed around positive, actionable behaviours were associated with sustained behaviour change and weight loss. For diet, the most common goals were eating two fruits and five vegetables a day, which was a secondary outcome of the ToDAy study. Participants reported this was easier to sustain and more enjoyable than a 'dieting' approach where the focus was on restriction or following a particular menu. Reducing EDNP foods was a primary goal of the ToDAy study and a focus of the feedback at 6 and 12 months.

Participants who lost weight referred to increasing the fruit and vegetable consumption as a key driver for their weight change. Most described using fruit or vegetables to displace other, EDNP foods in the diet.

> It made me eat a lot more veggies, a lot more fruit instead of snacks. Like I gave muffins up for it so … instead of eating muffins I was eating apples and banana. (1532)

Planning ahead

Those who lost weight reported strategies to help prepare vegetables in advance. Ideas included purchasing large volumes of fruit and vegetables weekly, cooking vegetable-based dishes to store in the freezer and keeping a stock of vegetables at work.

> I buy my vegetables on Saturday and I prep them for the whole week. (1468)

Two men who lost over 10 kg described making changes to their diet as easy.

> Eating more fruits and vegetables was actually a lot easier than I thought it was going to be. (1483)

Poor food choices were associated with a lack of planning, spontaneous decisions or being unorganised. Those who gained weight described situations where they were ill-equipped at mealtimes and only had unhealthy food available. This led to consuming EDNP foods and a sense of helplessness.

> Oh my gosh I haven't got anything for dinner and I haven't been up to the shops and it's six o'clock and I don't feel like going up to the shops. So I'll just have something that is in the house and it might be my son's leftover pizza or my husband's butter chicken. (1484)

Small lasting change

For dietary behaviours, eating vegetables was mentioned as the most significant change for those who lost and maintained their weight. Common examples referred to EDNP consumed typically as a snack during the working day; chocolate, cereal bars biscuits, pies and cakes exchanged for fruit or vegetables sticks.

For PA, the Fitbit was viewed as an essential prompt for making small daily changes. One participant who doubled the number of steps per day during the intervention (7,000 to 16,000 steps) described being opportunistic about making time to walk during his work in a sedentary job.

Learning new things includes strategies to help plan ahead, decoding food labels, self-assess their diet, identify junk foods and estimate serving sizes for vegetables.

For those who lost weight, the tailored feedback was described as the major source of new information, increasing awareness about their behaviour. Most described overestimating their intake of fruit, vegetables and level of physical activity while underestimating their intake of EDNP food and beverages and sedentary behaviour.

> The Fitbit made me very much more aware of how much I was moving or not moving. (1491)

> I thought it would be easier to get lots of steps on the weekends when I was home with my kids but it turned out to be the days that I moved the least. You think that running around after your kids all the time you would do more steps, but that definitely was not the case. (1483)

For dietary change, tailored feedback – including an annotated image of their meal – was noted as a turning point in their knowledge on how to improve dietary behaviour. For example, a meal of chicken curry and rice was sent back with images of animated vegetables, in place of some of the rice and chicken.

> I think I learned that whilst I thought my diet was maybe 5 or 6 out of 10 it was probably more like a 3 out of 10. (1441).

> One that sort of stuck in my head was half your plate needs to be vegetables pretty much. (1519)

> So I see chicken, wrap and salad and I think wow that's a very healthy meal. Then it got pointed out to me that it was two or three servings of junk food because it was crumbed and fried. … Sometimes you think you're doing the right thing and it's not as healthy as you think. (1519).

Those who gained weight reported not learning any new information from the tailored feedback. They expressed confidence in their knowledge of what behaviours should be changed but described social and emotional barriers to achieving them.

Participants were aware of the goal of 10,000 steps per day and reported that the Fitbit was helpful for them to track their progress. Most were surprised at how sedentary they were and describe the information from the Fitbit and PA feedback as 'new' and 'shocking'.

Difficult emotions

Participants described difficult emotions that hindered efforts for eating well and being active but eating well and being active were also seen as strategies to manage difficult emotions. For example, stress was viewed as having both a positive and negative relationship with eating and physical activity. On one hand, physical activity was viewed as a healthy and effective method to manage stress and mental wellbeing.

> Now I try and do the one hour walk before work. Just because it helps reduce the stress of the job. (1443)

> And had a lot of stress in my life at the time … it wasn't healthy. This forced to make time to think about me and my health. (1567)

On the other hand, feeling stressed was also associated with eating junk food and not maintaining physical activity routines.

> I know it sounds a bit feeble my old dog he gets sick now, I've got cleaning up to do and I've got new kittens in the house now. There have been lots of things that have popped up like that and it's made it hard, I just feel overwhelmed. (1483).

The dietary assessment involved recording all their food and drink consumed by taking images on their smartphone. Several participants mentioned that they felt self-conscious or embarrassed about someone else seeing images of their junk food, large serving sizes, fast food or alcohol. Taking images of these meals was described as emotionally difficult, though most reported that this did not have any impact on their engagement with the intervention or their behaviour. Others reported feeling proud when they were taking images of meals that had loads of vegetables or had incorporated suggestions from their dietary feedback. Two participants, who gained weight, expressed feeling 'guilty' and 'embarrassed' when they took images of food they perceived as 'bad'.

Weight change

Those who lost weight described their feedback as informative, easy to implement and sustainable. One participant, who lost 18 kilograms, described a new routine where he packed a lunch instead of purchasing food on the go and reducing his alcohol on the weekend. However, this participant attributed his weight loss to the increase in his PA. Likewise, another participant who lost 9 kg weight felt his weight loss was mainly due to his increased activity. While PA had significantly increased, there appeared to be a greater energy deficit from the changes to his diet.

> Monday lunchtime I drive down I get veggies for the week. So I get a bag of carrots, a bag of spinach, avocado and cucumber and it's fairly easy for me to whip up a salad at work. (1519)
>
> Successful in as much as now I feel better, I weigh much less and I'm a lot more active than I used to be. But it was relatively straightforward. (1524)

Those who lost weight described a flexible approach to setting and achieving goals around their diet and PA. Although the goal was specific and they were motivated to achieve it, they were not aiming for perfection and accepted that is was normal to not achieve each goal, every day.

> It's all about the watch [Fitbit] I kept on looking at the watch. And I said well I had a target. But you know, if I didn't reach the target it wasn't the end of my world. (1532)

> I was eating a lot of junk food, not many vegetables you know lots of meat and bread and putting on weight. Drinking alcohol, lots of alcohol and all the things you shouldn't be doing, I was doing … Now I have cut down, not stopped. (1574)

In contrast those who gained weight described a more rigid approach where not achieving their goal was associated with disappointment or a sense of failure.

> I became a little bit fixated about getting my ten thousand steps in and felt quite annoyed with myself if I didn't. (1482)

> I will still eat a pizza but I feel guilt and ashamed. (1567)

Six participants who did not lose weight reported a positive experience in the intervention and felt successful in improving their quality of life, food choices and physical activity.

> Oh I thought it was fantastic. I absolutely love it. (1484)

> I think if you fixate too much on the weight you lose the point, you know you get to my age, and you're never going to get back to where what you were. I mean so as long as you're eating the right things and keeping fit, your weight will be where it's meant to be. (1443)

Two participants who did not lose weight described the experience of the intervention as challenging and not what they were hoping for. Weight change was not described as concerning eating and activity behaviour but associated with emotional status, self-esteem and motivation. Two participants shared their hope that the study might reveal a scientific issue that would either explain their excess weight or scare them into changing their behaviour.

> So I think maybe that's what I was hoping for you know that maybe you guys would say something in the study and go 'Oh you should be aware of this'. I was hoping there was going to be a reason for this (weight). (1491)

> I was expecting a diet plan, an exercise plan yep just these are the things you have to do each day … that sort of thing. I probably would have made a bit more of an effort if I knew that I was being monitored. (1499)

Habits

References to alerts to move more often and the motivation to reach the step goal were described as 'drivers' for forming new PA habits.

> If I hadn't managed to get to ten thousand [steps] in the evening then I'd go back on the treadmill to try and get it up. I wanted to get that buzz (Fitbit alert) when I reached the goal. (1532)

Behaviours that were performed 'without thinking', 'automatically' and 'part of my routine' were also coded as habits.

> 'Oh gosh I've got to get on the treadmill in the morning' but when my alarm went off it was like right you know up and go. I didn't even think about it; it's just my routine now. (1543)

> One of the things that I do as part of the change is I walk while I'm on the phone. It's just a habit now…at the moment I'm talking, but I'm also walking around the training yard out the back. So, because of this phone call, I'll probably walk about seven hundred metres. (1532)

> When I go to places that have got a choice of an escalator or steps I automatically go for the step option. (1507)

Suggestions for improvement

Some described being accountable to the research team, and knowing that a scheduled visit was approaching motivated them to stay on track with their dietary and physical activity behaviours. Others expressed a need to be held more accountable.

> I just felt I would have been able to do more if I was pushed more or told to. (1437)

Fifteen participants said telephone review would have been helpful and suggested this be included in future interventions.

> Maybe a catch up on the phone I think would be good. (1567)

Discussion

Participants had mixed feelings regarding the ToDAy approach: those who lost weight found it was simple and easy to implement while others, mainly women, were disappointed it was not more prescriptive. Reducing EDNP and increasing fruit, vegetables, nuts, seeds and whole grains is recommended as a first-line intervention to achieve a weight loss of 0.5–1 kg per week (National Health and Medical Research Council 2017; New Zealand Ministry of Health, 2017; Yumuk et al., 2015). Those who were not satisfied with the intervention made comparisons to previous weight loss attempts and programs. It may be that the evidence-based messages in ToDAy contrast with the fad diets that include specific eating plans and promise greater and faster weight loss (Passos, 2020). Those who were successful said the feedback told them something new, indicating little previous experience of making behaviour change for weight loss. For these participants the intervention increased their capability by providing new information about the gap between their current behaviour and their goal behaviour. In future interventions, content tailored to and based on weight loss history may offer a different approach to those with a history of dieting.

To our knowledge, no other qualitative studies have explored the experience of participants who gained weight alongside those who lost or maintained weight. Most participants who did not lose weight described their experience as successful, with positive changes to their diet, PA and increased knowledge of these behaviours. Views expressed by those who lost weight are consistent with those reported elsewhere: weight loss results from consistent, habitual changes to both diet and activity (Mete, 2017 ;Metzgar, 2015 ;Sawamoto, 2017).

Habits were explored under the motivation domain of the COM-B model so questions were asked about the automaticity of their behaviour e.g. As a result of being in the study, have you formed any new habits? All respondents mentioned PA habits initially with only two going on to talk about dietary habits with some probing. One reason for this could be that feedback on PA was quantitative and instant which may make this more engaging. Participants felt the 'buzzing' from the Fitbit was a driver of their increased PA which became then 'automatic'.

The brief theoretical explanation for a habit is when someone is effective in maintaining behaviours that have become habitual and are supported by automatic responses to relevant cues (Kwasnicka et al. 2016). A study on Mindless by Wansink and Sobal (2007) suggests that individuals makes at least 200 food decisions per day most of where are ‘automatic’ or subconscious. As a result, awareness of dietary habits may require more precise probing to draw attention to their eating behaviour. In line with this, de Bruijn & Rhodes (2011) found that exercise is less driven by automatic components and includes a stronger cognitive component. Future studies exploring participant’s changes in PA and dietary behaviour may benefit from more precise questions and probing about specific behaviours.

Self-monitoring of diet and PA behaviours was crucial in helping people become aware of their current behaviour. This was enhanced by tailored feedback, which highlighted how their current behaviour differed from their goal behaviour. Previous studies support this finding, recommending that feedback is personalised to individual users and based on an assessment of the behaviour to be changed (Schembre et al., 2018). Participants viewed the feedback provided as realistic and practical; similar to previous reports that effective feedback is actionable, providing instructions on when, where and how to perform the behaviour (Hysong, 2006 ;Gollwitzer, 1999). In this study, images of meals were annotated to highlight the junk food and suggest where fruit and vegetables could be added, building on the written text feedback trialled in earlier studies (Kerr, 2016 ;Shoneye, 2019).

The role of fruit and vegetables in weight loss unclear with data from observational and experimental studies in adults and children report inconsistent or null findings; suggesting future studies implore better prospective designs (Ledoux et al 2011 and Newby, 2009). Theoretically, increasing energy intake, even from fruit and vegetables poses the potential for weight gain. However, dietetic interventions aim to create an energy deficit by displacing more energy dense foods with fruit and vegetable without reducing food volume. The key benefit of this is approach is improved satiety resulting from the increased fibre. In addition, non-starchy vegetables and fruit are water-rich and low-energy-dense. A systematic review examined evidence from prospective studies and RCTs shows that increased intake of fruit and vegetables is a chief contributor to weight loss in women (Dreher, 2020). The mechanisms are unclear but low glycaemic index, high fibre and reduce rate of eating are likely to contribute. In contrast, another review found increasing fruit and vegetable intake or availability (home delivery) was not associated with weight loss. The review concludes that weight loss advice should only recommend increasing fruit and vegetables to displace other foods which are more energy dense (Kaiser et al. 2014. Despite the mixed messages, clinical guidelines for weight management and dietary guidelines to prevent obesity and type 2 diabetes have included recommendation to increase fruit and vegetables.

A dichotomous or rigid view of weight and weight management behaviour was only observed among those who gained weight. Dichotomous thinking can be described as a disposition to view food as ‘good or bad’, ‘dieting or not dieting’, ‘healthy or unhealthy’ (Oshio, 2009). For example, ‘Sometimes I skip meals to avoid gaining weight’ (Stunkard & Messick, 1985). The opposite is a flexible approach, for example, ‘If I eat a little bit more on one day, I make up for it the next day (Westenhoefer, Stunkard, & Pudel, 1999). In this study participants who lost weight were more likely to describe behavioural goals that were imperfect and not adhered to at all times. Dichotomous thinking about food and activity can impede efforts to make healthy lifestyle changes (Palascha et al., 2015) while a more flexible and non-judgemental approach can lead to better behaviour change and reduce dietary restraint (Sairanen et al., 2014). This implies that being able to self-regulate and make adjustments to eating and PA are essential skills for weight management (Johnson et al., 2012; Phelan et al., 2009). Advancing our understanding of the link between self-monitoring and a flexible eating approach may help future interventions support better self-regulatory skills.

Feedback on PA was quantitative and instant which may make this is more engaging. Increasing PA and engagement with the Fit-Bit was perceived as the primary driver of weight loss among those who lost weight. Other studies support this with a meta-analysis of 37 studies reporting fit-bit use was associated with increases in daily step count and vigorous activity while decreasing sedentary time and modest weight loss (Ringeval et al., 2020). While these improvement in their perceived PA behaviours were also seen in this study, their dietary intake data shows a modest but consistent reduction in EDNP with non-starchy vegetables displacing more energy dense foods. In contrasts to the participants beliefs, this is the likely driver of their weight loss as it causes a greater calorie deficit.

This is one of few studies to report the experience of those who have completed a weight loss intervention but gained weight during the treatment phase. There is an expectation that these users did not engage with the messages or dropped out of the program but participants in this study did neither, describing multiple attempts to implement the tailored feedback as well as the barriers that hindered their progress. Most managed to implement some new behaviours and were happy with the improvements to their lifestyle, irrespective of their weight. European guidelines for weight loss reiterate the importance of acknowledging positive behaviour change, with or without weight loss (Yumuk et al., 2015). This focus on behaviour may help to avoid the disappointment of not losing weight or of regaining weight in the future (Cleo et al., 2019). For instance, if weight loss is not achieved, participants may abandon the new healthy behaviours and deem them as 'unsuccessful' or 'ineffective' (Pearson, 2011). Secondly, a focus on weight may inadvertently reward unsustainable or unhealthy behaviours such as fasting or very low energy intake. The results of these exit reflect the behavioural focus of the ToDAy intervention which focussed on making small and sustainable changed to diet and PA behaviour.

Strengths and limitations

A major strength of this study is that a range of participants were interviewed; the views of males and those who gain weight are often not explored and published. Weight maintenance is often discussed for those trying to sustain weight loss but can also be a first step for those who are gaining weight (Metzgar et al., 2015; Myers et al., 2013; Wieland et al., 2012). For those who did not lose weight, the intervention improved their diet and PA, which have important health benefits, independent of weight loss (Afshin et al., 2019; Blüher, 2019; Forouzanfar et al., 2016). The findings reported in this paper were limited to qualitative data collected from exit interviews. Correlations between dietary restraint, weight loss history and eating behaviour would help to further understand the mechanisms of behaviour change reported. Another limitation is the small sample selected based on their weight change and the lack of data from the two control groups. Participants who did not complete the study were also not interviewed.

Future studies should consider additional telephone support as requested by participants in this sample. Although participants were invited to contact the research team with any questions, including a formal telephone consultation was suggested to offer more formalised contact and support. While reviews of telehealth for interventions have reported modest impact on weight loss, combining telehealth with other digital services may further increase engagement and impact (Wylie-Rosett, 2014;Perri, 2020).

Conclusion

Participants receiving tailored feedback on objective measures of diet and PA report increased capability and motivation for behaviour change, independent of weight loss. Weight loss was associated with high engagement with the digital self-monitoring tools and personal goals for increasing PA behaviours and fruit and vegetable intake.

Chapter 9 Discussion

Overview of these findings

This thesis makes a significant contribution to the field by examining how technology can be used to improve dietary behaviours. The results present new evidence on the experiences, knowledge and beliefs of Western Australian adults relating to digital interventions and behavioural strategies for weight loss. The method used to develop the intervention was novel, using hypothetical scenarios to capture participant's views on how to approach weight loss. To our knowledge, ToDAy is the first intervention to provide dietary feedback using annotated images of the participant's meals. This novel contribution to the field enables future researchers to develop the use of technology further to deliver tailored, evidence-based, dietary advice. In order to develop the science of tailoring using digital tools, it is essential to ensure tailored feedback is informed by high-quality data and strives to meet clinical guidelines rather than focus on weight loss.

This thesis describes a series of studies employing multiple methods to investigate the use of technology to improve dietary behaviours. Earlier chapters examined the use of technology in digital tailored weight loss interventions: dietary assessment methods used to inform tailored feedback, acceptability of intervention features and participants experiences of using these features to manage their weight. As findings are discussed at the end of each chapter, this section will highlight overarching issues from the body of work conducted during this thesis, outline how objectives have been addressed, novel contributions to the literature, limitations and new questions arising from this research.

(Objective 1) Systematically review the protocols for DA methods used to inform tailored feedback in digital weight loss interventions, examining the digital platforms used for data collection, type of DA and duration of the assessment

The systematic review (Chapter 3) is unique in that it examined the method, duration and platform used to assess diet and how this information was then used to inform tailored dietary feedback. The review identified a range of methods (n=5) used to collect dietary information in the 13 interventions examined, ranging from robust dietary assessments methods (e.g. dietary records) to brief assessment methods, often poorly described. The effectiveness of tailored feedback and hence the intervention is somewhat dependent on the quality of the dietary assessment and how well this information is used. Detailed dietary assessment is more able to prove more personalised feedback, potentially leading to improvements in dietary behaviours. A recommendation of this thesis is that future dietary behavioural interventions include standardised dietary assessment methods, fully describe the dietary assessment method used and detail how the dietary data informed tailored feedback.

Most tailored dietary feedback interventions focussed on reducing energy intake, rather than improving diet quality. This is inconsistent with clinical guidelines for weight management which specifically recommends creating an energy deficit by replacing discretionary foods with vegetables, fruits, whole grains and nuts/seeds (New Zealand, 2017;National Health and Medical Research Council (Australia), 2013;Yumuk, 2015). This advice is based on sound evidence that improving diet quality has significant health benefits, independent of weight loss (Afshin et al., 2019; Aune et al., 2017).

This systematic review found that most studies did not provide sufficient detail on the dietary assessment method used or the protocol for how this data was used to inform tailored feedback. This may be because the digital interventions reviewed were designed to evaluate the implementation method and explore a new technology (mobile app or specially developed website) or a novel combination of technology (combing email support with a website) rather than the efficacy of dietary assessment. In addition, studies were designed to assess behaviour change techniques, participant engagement and physical activity. Even so, publishing a detailed account of the protocol used to formulate dietary feedback is needed to enable replication of studies and advance the science of behaviour change using technology and tailoring. A limitation of this review is that it only included studies with participants with overweight or obesity; as a result some digital dietary assessments that have been used in general populations studies were not reported. For example, this systematic review did not include image-based dietary assessment methods (Kerr et al., 2016) or food frequency questionnaires using photographs to quantify the portion size of each food (Celis-Morales, 2016) as the sample in these studies were not overweight. A broader review is recommended to identify all DA methods used in digital interventions providing tailored dietary feedback.

Objective (2) Report on young adults' experiences of receiving the dietary feedback in the CHAT study and determine whether those experiences were associated with positive improvements in dietary intake.

Chapter 4 addressed objective 2 with a mixed method process evaluation of the connecting health and technology study (CHAT). A major strength of this study was that dietary behaviours were assessed using a 4-day mFR which enabled an evaluation of whether young adults' experiences of receiving the dietary feedback was associated in improvements in dietary intake. Contemplation about vegetable and EDNP food intake appears to be an important mediator of dietary change in young adults. Participants who agreed that the text messages made them think about how much EDNP food they ate, were twice as likely to decrease their intake by over half a serve (OR = 2.39, 95% CI: 1.2 to 5.25) compared with those who disagreed. The results of this study highlight a gap between how participants viewed their diet and what was recorded from the mFR. Other studies have also reported over-optimistic perception of their diet (Xue, 2020 ;Jongenelis, 2018). Findings from this study suggest a lack of nutrition knowledge, may be a barrier and hindering their efforts to improve their diet as they believe their diet is healthier than it is. Participants report being 'surprised' or 'shocked' about their dietary feedback. Again, this was specifically about which foods were classified as EDNP, for example participants questions whether a meat pie, cereal bars and biscuits were correctly coded as EDNP serves. The qualitative studies in this thesis and elsewhere support this with participants expressing confusion on what constitutes a portion, which foods are classified as EDNP problems with interpreting the dietary guidelines (Rooney, 2017;Lambert, 2019 ;Kothe, 2011). Findings from this study suggested that future interventions need to help individuals identify EDNP items in their own diet.

While nutrition knowledge alone does not create behaviour change, higher levels of nutrition knowledge are associated with consuming more fruit and vegetables and less EDNP (Hendrie, 2008;Pollard, 2008). Using a validated measure of nutrition knowledge to determine change in knowledge may further our understanding of the mediators of tailored feedback. The Australian version of the General Nutrition Knowledge Questionnaire for Australia includes questions on current dietary recommendations, nutrients in foods, food choice and diet disease relationships (Thompson, 2019). Further investigations using this tool at baseline and follow up may help to understand and quantify how dietary feedback impacts nutrition knowledge. In addition, it would be helpful to see how different levels of nutrition knowledge at baseline impact the users experience and behaviour change.

One concern with digital tailored interventions is that those who benefit the most are those who are already attempting to follow a healthy diet. This explore was explored in a previous published paper from this study. At baseline, participants were asked “How important is eating a healthy diet?” Responses were categorised as high (6–10) and low (0–5) scores (Fig. 4). Compared to men scored high, low scoring men in both intervention arms were more likely to reduce their daily serves of EDNP at follow up (P= .04) No effect was observed in women.

The process evaluation using qualitative and quantitative methods in Chapter 4, examined how the user’s experience of tailored dietary feedback was associated with positive improvements in dietary intake and provided the foundation for identifying potential behaviour change techniques to be used in ToDAy. Findings suggest that tailored feedback may work by prompting individuals to think about their vegetable intake (Shoneye, 2019). As expected this was associated with increased vegetable intake but a unique finding is the association with a decrease in EDNP. A national survey of almost 8,000 Australian adults also reported this adverse relationship between vegetables and EDNP, findings reveal high intakes of EDNP food and beverages were associated with lower intake of vegetables and fruit (Sui, 2016).This further reinforces the need for weight loss interventions to address diet quality rather than focus on weight loss.

Results from the process evaluation in chapter 4 point to several mediators for behaviour change, making it difficult to identify a single theoretical model or framework. Tailored feedback influenced a decline in discretionary food consumption by making users think about discretionary food, increasing their awareness of their food choices and prompting more conscious eating. This explains the link with intrinsic motivation – engaging in the behaviour because it is something of importance or valued (McSpadden et al., 2016). Interventions that support this type of autonomy and intrinsic motivations are associated with greater and more sustained behaviour change (Mata, 2011;Ryan, 2000). A limitation of the study were that measures of autonomy and self-regulation were not measured. To understand motivations towards changing dietary behaviours, future interventions should consider the inclusion of these measures.

Objective (3) Conduct a formative focus group study to inform the development of a digital, tailored weight loss intervention and identify behaviour change techniques for weight loss.

There is limited evidence or guidance on how to design behaviour change interventions that are delivered across multiple digital platforms. Conducting the focus group and interviews to the development of ToDAy shows the benefit of including consumers in an iterative process (Chapter 5). Ideas and feedback from participants were integral to the design and acceptability can be tested before the intervention is finalised. The results of this study were instrumental in the design of tailored feedback which included annotated images of the participant's meal. This approach has the potential to make tailored feedback available to those with limited literacy and enhance participants understanding of how to apply the dietary advice to their own meals.

A significant strength of the publication to address objective 4 and 5 is the iterative involvement of the end users and the person-centred approach. Users provided unique insights into the acceptability of the content, language, tone, protocols for recruitment, and usability of the proposed digital intervention features. This study explored ideas for intervention features with the users at an early stage of intervention development when it was still feasible to respond to feedback. Importantly, the combined ideas were further tested to ensure they met the user's expectations. This led to a design that merged the preferences of the user with the evidence and theory base required for scientific research. A unique feature of this publication comprising chapter 5 is the transparency which details examples of the original intervention ideas and then how this evolved, based on participants feedback.

The process of identifying behaviour change techniques, translating them into digital intervention features and testing these with the users revealed several strengths of this method. First, it aided a clear documentation of the complex relationship between the clinical aims (e.g. weight) and the behaviour goals (e.g. reduced EDNP). There is still much debate about which theoretical approach is bested suited to weight loss interventions and how this theory is linked to specific behaviour change techniques. By documenting the source and rationale for each behaviour change technique this study uses consistent and comparable methods that add to our knowledge about the drivers of behaviour change. A second important strength was use of the client-centred approach which ensured that the scientific approach to designing the interventions included the user's needs for features that were also engaging, informative and easy to use.

The iterative process used to develop the intervention included qualitative studies with health professionals working with LiveLighter® materials, and members from the LiveLighter® mailing list as detailed in Chapter 5. However, some learning from this process were not published in the final paper but influenced the development of the ToDAy intervention. For example, health professionals from a range of geographical areas and professions were engaged to get a broad perspective of potential challenges to implementing a digital intervention – access to a smartphone, access to the internet and digital literacy were some of the factors discussed. Examples were given of local health education programs that had been successful in raising awareness about the link between discretionary food and health; Swap It Don't Stop It (O'Hara, 2016)and Measure Up (Grunseit, 2015). This highlighted environmental barriers to purchasing fruit and vegetables: lack of transport and shopping at local stores with high-cost and low-quality produce. While ToDAy focussed on supporting individual behaviour, the economic, social and environmental drivers are acknowledged as essential strategies to reduce excess weight gain at a population level.

Objective (4) Explore preferences for digital intervention features that are proven to be effective in changing dietary behaviours.

The original research design planned to use computer-tailored software to generate the feedback, informed by questionnaire responses from participants as well as data from the mFR. Participants in the focus groups and interviews were clear in their preference for using the mFR, regarding this a more acceptable than traditional methods requiring questionnaires or selecting foods or beverages from a list. This is supported by a study examining factors relating to attrition in a digital lifestyle intervention (N= 549) where attrition levels were highest at the stage of completing questionnaires on self-monitoring, such as those used to inform tailored feedback (Van der Mispel et al., 2017). Using an image-based DA was viewed as having a significant advantage over the written questionnaire-based system for providing feedback. Likewise, participants had a strong preference for their images to be included in the tailored feedback. The iterative nature of the qualitative process to develop ToDAy allowed the users' preferences to reflect the intervention design, resulting in a novel approach and a true engagement between consumers and researchers. As a result, ToDAy is unique in providing dietary feedback using annotated images of the participant's meals.

In line with recommendations on the reporting of complex digital interventions, an increasing number of studies have published a detailed protocol of how potential users were engaged in the development of the intervention (Phelan, 2015 ;Quested, 2018;Celis-Morales, 2015). A unique feature of this study is the transparency of the draft intervention features with a rationale for how they were developed and refined in response to qualitative studies.

The process of exploring the preferences of the end user, through the lens of a theoretical framework have been described previously. For example, focus groups with users were employed in the design of a culturally sensitive self-management program for African Caribbean communities with type 2 diabetes (Moore, 2019). Similarly, in the Chapter 5 study the results were analysed in the COM-B framework, revealing culturally specific barriers to implementing healthful behaviours, which were then linked to appropriate intervention functions and behaviour change techniques in the final intervention (Michie, van Stralen, et al., 2011). However, the qualitative studies to develop ToDAy asked users to provide feedback to hypothetical participants. This revealed misinformation and significant gaps in their knowledge about weight management and nutrition which are likely hindering their efforts to change their behaviour. The data from this study supports the use of intervention features that build participant's capacity to change behaviour by supporting their knowledge and skills.

The final intervention included similar features to those reported as important and effective in previous research, behaviour change techniques associated with self-regulation (Alley et al., 2016; Doumit et al., 2016; Eckerstorfer et al., 2018; Jakicic et al., 2016; Pirotta et al., 2019). These include self-monitoring of behaviour, goal setting and are supported by a number of systematic reviews (Burke, 2011 ;Cavero-Redondo, 2020;Lau, 2020;Patel, 2019)

Objective (5) Develop an evidence-based and person-centred weight loss intervention: ToDAy.

The process of developing the intervention was scientific and systematic, allowing future researchers to access the procedures, rationale and evidence base. The intervention content was based on the best available evidence at the time. Since, then, the clinical guidelines for weight management in Australia have been rescinded and it is not clear when new guidelines will be developed. However, the candidate also accessed clinical guidelines for weight management from Canada, New Zealand, Europe and the United Kingdom (Durrer Schutz, 2019 ;New Zealand, 2017). These updated guidelines reflect the latest issues in weight management, of most relevance to lifestyle interventions is the use of very local calorie diets and a low carbohydrate diet. While the newer guidelines summarise the emerging evidence for these approaches, the advice remains in line with the reduced energy diet and adherence to the Australian dietary guidelines described in ToDAy. As a result, the science behind the dietary content of ToDAy remains evidence based.

The ToDAy protocol followed the guidelines for conducting and reporting tailored interventions to ensure consistency in terminology, reporting of tailored interventions, the tailoring approaches to be used and the algorithms used to determine who gets which message (Harrington & Noar, 2012). Table 9.1 details how the intervention development process for ToDAy aligns with guidance on how to implement the Medical Research Council guidance on the development of complex interventions, with iterative input from stakeholders (Cathain, 2019). While ToDAy was developed to be consistent with these guidelines, there were some practical issues in implementing them. Firstly, the interventions protocol used the behavioural intervention technology model (BIT), which acknowledges that digital interventions may be adapted or varied from the protocol before or during the intervention (Mohr et al., 2014). For instance, the initial protocol was designed to send participants feedback within two weeks of the baseline assessment. At the start of the study, this was delayed as the assessment and composition of feedback took longer than expected. The published protocol allows the intervention to be replicated and the procedures to be examined by future researchers.

Table 9-1 Mapping the research activities to the Medical Research Council framework for developing and evaluating complex interventions

Development	**Chapter**	
Identify evidence base	1	Background to poor diet and excess weight in adults
	2	Evidence base on the effectiveness of clinical treatment, digital interventions and tailored interventions
	2	Identify existing systematic reviews and RCTs using technology to deliver tailored interventions for weight loss in adults with overweight and obesity
Identifying appropriate theory	2	Explore potential theory and behaviour change techniques (COM-B, self-determination theory, motivational interviewing)
	2	Explore potential frameworks for developing interventions; Person-centred, MRC framework for developing complex interventions, BIT model)
Modelling	3	Systematically review existing literature and theory to explore how the digital tailored interventions might alter behaviour, intervention effectiveness and outcomes
Feasibility		
Acceptability	4	Report on young adults' experience of using technology to access their diet and receiving tailored feedback via SMS

	5	Engage users and consumer representatives to understand the user and incorporate their needs into digital intervention features
	5	Testing of intervention features to determine their usability and acceptability with potential users in the target group
Recruitment	5	Review existing literature and consult with local health professionals to identify potential avenues for recruiting and retaining equal numbers of eligible male and female users
	6	Use evidence from previous studies to identify sample size, intervention content and protocol for assessing behaviour to inform tailored feedback
Evaluation		
Assess effectiveness	6	Design of a 3 arm, 2 stage randomised clinical trial. Primary outcome measures at 6 and 12 months are changes in body mass, EDNP food and beverage consumption. Secondary outcomes include change in fruit and vegetable consumption
Understand the change process	8	Exit interviews conducted to explore the experiences, capability and motivation of those who lost weight, maintained weight and gained weight during the 6-month intervention phase
Assess cost-effectiveness	n/a	An economic evaluation is described in the protocol (chapter 6) but this analysis is beyond the scope of this thesis

As participants were screened and images analysed, new challenges arose which were not described in the protocol. These included how to respond to participants with incomplete food records, how to decide which images would be annotated for the feedback and how to include forgotten food. The software and format to be used for the email feedback were not detailed in the protocol, but this information is integral for the study to be replicated. Initially, the layout and text for the templates were developed in Microsoft Word. The images were saved and edited in Microsoft PowerPoint before being added to the Word template. At the start, this process was time-consuming, and some participants reported trouble viewing the images. Input from a professional marketing team was sought to design a stable email template. These logistical issues are often not reported in published protocols but have implications on the cost and scalability of the intervention.

An important strength of the protocol for the ToDAy intervention is the multiple tailored feedback strategies used. Hawkins et al describe three levels of tailoring; descriptive, comparative and evaluative and the ToDAy intervention utilised all three (Hawkins et al., 2008). In addition, there is further evidence that the more personalised and unique the tailoring, the more persuasive the feedback is to the user (Lustria et al., 2009). Benefits of using an image-based dietary assessment include improved accuracy in estimating portion size and identifying food types (Ahmad et al., 2016; Boushey et al., 2015). By using images of the participant's meals and snacks, the feedback also takes advantage of these benefits, receiving tailored feedback on the specific foods they eat, ensuring that the information is familiar, acceptable and relevant. To the candidate's knowledge, this is the first intervention to tailor feedback using images of participant's food. This novel contribution to the science of tailoring enables future exploration of image based approaches and how they may influence engagement, nutrition knowledge and the potential to engage people with limited literacy.

Objective 6 Investigate whether a tailored intervention using mobile technology can improve dietary behaviours in adults with overweight and obesity

A significant strength of this evaluation is the inclusion of quantitative and qualitative assessment methods, designed alongside the protocol. Advanced planning of the evaluation measures provides the opportunity to collect the relevant data at each time point. One-fifth of participants in ToDAy achieved clinically significant weight loss (5%) at 6-months, similar to the Fit For Life (FFL) lifestyle intervention to prevent diabetes. FFL delivered face-to-face weekly group education for 90 minutes, over 12 weeks (McKnight, 2018). In FFL, the average weight loss was 2.7 kg (3%), and 20% of participants lost more than 5% of baseline weight at 12-months. In comparison, the intervention group participants in ToDAy received tailored feedback over 12-months via email on 7 occasions (2, 4, 6, 12, 18, 24 and 52 weeks). The intensity or dose of intervention may not have been not have been sufficient to bring about the anticipated behaviour change but the results are comparable with this example of a face-to-face clinical intervention (FFL).

A review of clinical data in the United States concluded that intensive lifestyle interventions should include at least 14 visits in six months (Cardiology, 2014 ;Heymsfield, 2017). However, the impact of this intense approach has not yet been explored on a digital platform. ToDAy provided half of this with seven tailored feedback emails over twelve months.

As the mFR images taken by participants include a time and date stamp, there is potential to assess frequency and timing of eating which could enable more tailored messaging. The systematic review in chapter 3 reveals that most dietary interventions provide instant, quantitative feedback on energy consumed and expended (N=10) (M. Carter et al., 2013; Teixeira et al., 2018). A practical framework for designing tailored feedback identified four key features; personalisation, just-in-time, actionable and founded on a behavioural assessment (Schembre et al., 2018). This type of instant just-in-time feedback is more easily provided on physical activity behaviours but more challenging when providing more detailed dietary feedback, as undertaken in this study. In addition, it does not address the elements of being actionable or founded on a behavioural assessment. In contrast, the tailored feedback used in the ToDAy study was actionable, using images to demonstrate specific change, and included a behavioural assessments. Just-in-time feedback considers the timing of the feedback in relation to the participants opportunity or receptiveness to the feedback; for example, if the goal is to eat five serves of vegetables per day, feedback would be provided before the last meal to prompt an opportunity for the goal to be achieved (Schembre et al., 2018). Future studies to explore timing of tailored feedback with the mFR and the ToDAy protocol would need to consider a different platform, instead of email. Existing interventions sending time specific tailored feedback use alerts on a mobile application or text messages which are more likely to prompt an instant response (Mummah, 2017;Lim, 2016;Choi, 2016).

A limitation of the tailoring approach used in the ToDAy study is the delay of approximately two weeks between completing the dietary assessment with the mFR and receiving the tailored feedback by email. This process requires a trained professional to conduct the dietary assessment and construct the tailored feedback, rather than an automated systems, that provide instant tailored feedback informed by an algorithm of responses (Morgan et al., 2013; Wang et al., 2018). While this instant feedback is preferred by participants seeking digital weight loss support (Tang et al., 2015), it does not provide specific instructions on when, where, and how to perform the desired behaviour, a crucial aspect of effective tailored feedback (Michie et al., 2013; Schembre et al., 2018).

As detailed in Chapter 7, objective assessment of diet conducted at baseline and 6 months, shows no significant difference in dietary intake between the groups receiving tailored feedback and monitoring only. There are several possible reasons for this. First, all participants expressed a desire and motivation for weight loss by volunteering to take part in the intervention. This means that the weight change observed in the control groups is not likely to reflect the weight trend among the general population. This is supported by results from a meta-analysis of control arms in 30 RCTs, showing weight loss of about one kg at 12 months (Johns et al., 2016). Secondly, assessment for the active control group in ToDAy included elements of effective interventions for weight loss: being weighed, wearing an accelerometer and face-to-face contacts at baseline, 6 and 12 months with research staff. These data collection activities may have increased awareness of both dietary and physical activity behaviours in this control group. It is also possible that misreporting of diet occurred though this unlikely to account for the lack of between group differences as it appears both groups changed their dietary intake over time. Likewise, there is a plethora of evidence linking self-monitoring of dietary intake with improved dietary intake, increased awareness of dietary choices and weight loss (Turk et al., 2013; Wang et al., 2018; Yu et al., 2015). This may account for dietary improvements and weight loss in the active control group.

An observational study of over 500 adults with overweight and obesity found regular weighing was associated with more vigorous PA and better diet quality (Houston et al., 2019). In this study, weight was taken in a university laboratory by a health professional. While efforts were made to be supportive, this may have had an impact on participants’ motivation or placed implicit pressure to lose weight

(Johns et al., 2016). Most participants in this study had a tertiary education and were overweight or moderately obese so the findings are not generalizable to other populations, for example, those with a BMI between 35 and 40 or those with less formal education.

Evidence explored in Chapter 2 and Chapter 3 reveals that self-monitoring of diet and dietary assessment prompts improved diet quality, reduced portion sizes and modest weight loss; this may account for some of the weight loss observed in the active control participants (AC). Informed by this relationship, the RCT to evaluate the impact of ToDAy included three parallel arms, two groups using the mFR and completing face-to-face assessments but the active control (AC) receiving no feedback and the tailored feedback (TF) group receiving email feedback. Another reason for weight loss in the AC group could be that participants already had some capability and opportunity for weight loss, and the study provided further motivation. Motivation was identified as a barrier to dietary improvements in Chapter 5; participants were aware of the dietary recommendations for weight loss but their efforts were hindered by their belief that these were not achievable or necessary. The COM-B model describes this type of motivation as reflective, self-conscious beliefs about the behaviour. Another study using the COM-B model to examine change in dietary behaviour, reports that reflective motivation is more likely to be a facilitator of positive behaviour change, rather than a barrier (Timlin, 2020). Exit interviews with those in the AC group may have offered insight to explain what changes this group made, the source of this information and their motivation.

A notable strength of the study is the high retention rate in the intervention group (91.5% at 6-months). A review of digital weight loss interventions found that 7 of the 11 studies reported attrition ≥ 20% (Sherrington, 2016). Another review identified factors that may help reduce attrition such as financial incentives, self-monitoring technology and combining behavioural guidance with personalised dietary advice; strategies employed in the ToDAY protocol (Pirotta, 2019).

Objective 7 Conduct a qualitative study to identify intervention features influencing participants' motivation, capability and opportunity to change their dietary and activity behaviours

Exit interviews reveal that self-monitoring worked in a loop system with tailored feedback, as described in the theoretical frameworks in Chapter 2. Weight change is multifactorial with medication, age, hormones and biological factors interacting with lifestyle choices like diet and PA (Mullan et al., 2017). Using weight loss as the sole indicator of behaviour change limits our understanding of what worked, why and for whom. Those who were able to implement the feedback and lose weight expressed a sense of confidence, reinforcing the belief that their weight is, in fact, related to their behaviour.

The idea to select participants for interview based on their change in weight was designed to identify correlations with the participant's perceived experience of behaviour change and achieving a weight loss goal. Understanding the participants perception of how changes to their motivation, capability and behaviour have impacted their weight are also important. Participants who lost weight reported this was mainly due to increasing their physical activity. However, data from their tailored feedback suggests the greatest energy deficit could be achieved from dietary changes. Evidence from other studies support the role of dietary change as the driver of weight loss which is enhanced and sustained with PA (Fayh, 2013 ;Jakicic, 2016;Ostendorf, 2019). These participants also indicated that they used strategies such as regular self-monitoring and planning ahead to facilitate adherence to their diet and PA goals. As the Fitbit, provided instant and ongoing feedback on progress, this may have influenced their perception that PA was the main driver of their weight change.

Objective 8 Explore participants' preferences for intervention features and how the intervention might be improved

Interviews undertaken with intervention participants in this study, show a preference for image-based easy to understand feedback. While there was some preference for more detailed, written information, most were happy if given the option to access links to other sources of information. Likewise, the mobile food record was viewed positively, with participants reporting a preference for taking an image, as apposed to “scrolling through a long list”. Participant burden is a major problem with self-reported dietary assessment requiring high levels of motivation, literacy and food knowledge (Dao et al., 2019). The results of the exit interviews are encouraging and confirm the earlier studies on the acceptability of the mFR in young adults (Bathgate et al., 2017; Boushey et al., 2015). Data presented in this thesis supports the use of the mFR in adults living with overweight and obesity. This is an important finding as adults aged 40 to 59 years are most likely to experience excess weight and the associated chronic conditions (Australian Institute of Health and Welfare, 2016).

Results from the exit interviews suggest a telephone consultation may improve engagement and offer needed support for participants in the ToDAy intervention. Some participants referred to the exit interview as useful in helping them to interpret their results and viewed the phone call as a brief consultation. Evidence for telehealth interventions have reported low to modest impact on weight loss, but some reports suggest that they may work better in combinations with a comprehensive digital intervention (Perri et al., 2020; Wylie-Rosett, 2014). For example, a commercial tailored weight loss intervention included telephone calls from trained consultants to provide social support for weight loss, weight maintenance and reminders to complete self-monitoring tools (Collins, 2015). The results suggest that the additional support offered was associated with greater retention and usage of the online weight loss tools that may benefit behaviour change and weight loss (Collins et al., 2012). While the difference observed was modest, it supports other studies which suggest supplementing digital interventions with brief human support leads to better engagement and improved outcomes (Partridge, 2016 ;Wylie-Rosett, 2014;Dennison, 2014). Future studies could build of this by investigating the impact of the ToDAy protocol with additional telephone consultations following email dietary feedback.

Strengths and limitations

A major strength of this thesis is that three of the key chapter have already been published in high quality academic journals. Through the peer review process, these studies were examined and refined allowing the intervention to benefit from a broad range of expert input.

Chapter 4 adds important knowledge to the understanding of how these digital tools work in a real-world setting. The combination of qualitative data and think aloud style exploration of the intervention is unique and insightful. Few studies have used an iterative process on such a large scale to refine intervention features and content. It was especially important to see results highlighting a lack of knowledge about weight loss behaviours, and widespread misinformation about the effects of alcohol and carbohydrates on body weight. As a health professional working in weight management, exploring misinformation is an important aspect of client centred practice. This study explores weight loss beliefs among the broader population and helps us to understand the impact this has on their behaviour.

While previous studies have used an image based dietary assessment, this is the first intervention to use image based dietary feedback. Annotating images of participant's own meals is the ultimate form of tailoring, increasing the relevance and impact of the feedback message. The qualitative interviews in Chapter 8 highlight the importance of the images being specific to each participant and helping to simplify what can be complex, nutrition education.

There are important limitations to this body of work that need to be acknowledged. Participants taking part in the focus groups (Chapter 5) and intervention (Chapter 7) studies were recruited online and required to have use of a smartphone so that they were able to use the mFR app for dietary recording. Those who did not have access to this technology could not participate and data from the exclusion criteria shows this accounted for very few (1.5%). A concern about digital interventions is the potential of excluding vulnerable groups such as those who are aged over 65 years, unemployed, low levels of education and people from low-income households

(Michie et al., 2017; van Velthoven et al., 2018; World Health Organization, 2016). A 2020 report on the Australian Digital Inclusion Index shows a consistent economical, geographical and social divide in online participation (Afshar Ali, 2020). In Australia, these vulnerable groups also experience other barriers to health such a low literacy, difficulties with English language and cultural specific barriers to health information (Afshar Ali, 2020; Jones, 2017). Further research is needed to determine whether and to what extent the image-based content of ToDAy may assist in addressing these barriers.

Both control groups in ToDAy suffered a loss to follow-up, with six-months attrition in the active control and online groups, 65.4% and 22.2%, respectively. This highlights the lack of engagement with the online group, contrasting the engagement with participants who were in the active control group. A survey of 6,352 online participants reports that half would not have taken part if the study was not online, this was more pronounced for men and people with obesity (Mejean et al., 2014). It is possible that those who gained weight were less willing to attend follow-up, and those who succeeded in losing weight were more willing to participate in follow-up, thus skewing the results. The lack of complete data for all interventions poses a number of problems: (1) statistical power is reduced; (2) missing data is not random but pertinent in the online control group, reducing the internal validity of the remaining data; and (3) it is unclear how best to analyse the missing data. A meta-analysis of 121 RCTs for weight loss found numerous approaches to manage missing data: the majority of studies (59%) used data from the last observation carried forward; 14% analysed completers only; and 11% used a mixed model analysis to account for potential bias in the missing data (Elobeid et al., 2009). While this discussion acknowledges there are several approaches to manage missing data, they found it was unlikely to make a significant impact in a heterogeneous sample with high rates of missing data (McCoy, 2017; Elobeid, 2009).

A further limitation was that cost-effectiveness of the intervention has not been undertaken. According to modelling on cost benefits of obesity interventions in Australia, 5% weight loss among 2–3% of people with obesity would result in AUD $14.1 million of savings per year (Pricewaterhouse Cooper, 2015). As detailed in

Chapter 6, the ToDAy protocol includes a cost-effectiveness analysis to be undertaken. While the results are beyond the scope of this thesis, the findings presented suggest that ToDAy has the potential to achieve cost-effective and clinically significant outcomes.

Implications and recommendations

- Findings from this body of work indicate there may be overlap between dietary assessment and self-monitoring of diet, suggesting that both involve the same behavioural processes that increase awareness of intake and improve diet quality (Cavero-Redondo, 2020). Although the mFR is based on participants taking an image of their food and beverage, the process of doing this and the idea that it will be evaluated results in reactivity and seems to trigger an increased awareness of food choices, leading to improvements in dietary choice.

- The dietary assessment used to inform tailored feedback should be based on validated and evidence based methods. The full methodology and the protocol for how this data was used to inform dietary feedback should be published.

- Most digital weight loss interventions provide tailored feedback that is limited to numerical information on dietary energy. This thesis demonstrated the value of using annotated images from the individual's mFR data in the provision of tailored feedback. Future interventions should provide image-based tailored dietary feedback focused on improving diet quality.

- This research substantiates the role of the mFR to assess dietary intake and inform tailored dietary feedback in digital interventions. A key strength of the mFR is that this method can capture multiple elements of dietary behaviour (content, portion size, time of eating). As demonstrated in this thesis the mFR is method that participants in this study found to be acceptable and easy to use.

- Tailored feedback informed by the mFR, prompts reflection of dietary intake and is associated with both an increase in vegetable intake and a decrease in discretionary food and beverages.

- A lack of knowledge, confidence, and susceptibility to misinformation about weight management has shown to be a barrier to engaging in weight loss behaviours. Using hypothetical scenarios is a useful strategies when assessing weight management beliefs among people with overweight and obesity.

- The findings suggest that a theory-based?? digital weight management intervention using a mobile food record to inform tailored feedback is an acceptable, feasible, and engaging strategy. Further studies are needed to determine the optimum dose and frequency of tailored feedback.

- Participants receiving tailored feedback on objective measures of diet report increased capability and motivation for behaviour change, independent of weight loss. Provide additional human support, possibly via telephone counselling may provide additional benefits and enhance engagement.

Chapter 10 Implications and conclusion

Implications for digital dietary interventions

Findings from this body of work indicate there may be an overlap between dietary assessment and self-monitoring of diet, suggesting that both involve the same behavioural processes that increase awareness of intake and improve diet quality (Cavero-Redondo et al., 2020). Although the mFR is based on participants taking an image of their food and beverage, the process of doing this and the idea that it will be evaluated results in reactivity and seems to trigger an increased awareness of food choices, leading to improvements in dietary choice.

Implications for future research

Tailoring

The level of personalisation in ToDAy was well received by participants, however it proved to be time consuming to undertake and not sustainable for future interventions without modifications. One of the most time consuming activities was the preparation of the dietary assessment and feedback. With improvements in automated methods of dietary assessment this may reduce the analysis time. It is also noted that the inclusion of participant images in the dietary feedback was identified significant in making the content easy to understand and actionable. The next steps for personalised would likely focus on feedback which can be automatically generated based on participants responses to questionnaires and dietary intake. While the image based method is preferred, the addition of written feedback is a more sustainable approach to expand the tailoring parameters and increasing the capacity for the intervention to be up-scaled.

Psychological factors

Other factors that could be tailored automatically include psychological factors that are known to impact efforts to change eating behaviours and weight management. For example, dietary restraint, dieting history, body dissatisfaction and perceived weight stigma (Mullan et. Al, 2017). In the early stages of the intervention, this was trialled with feedback at 12 months drafted in response to the 3-factor eating questionnaire assessing dietary restraint. Our behavioural psychologist and consumer representatives reviewed the content of this feedback. While the feedback was accurate, the research team, had reservations about approaching dietary restraint by email as the management in complicated and depends on other factors. For example, dietary restraint is often seen alongside depression, body dissatisfaction and a long history of dieting (Capperelli et al. 2009). Future interventions have the potential trial the impact and acceptable of tailored feedback to address these psychological factors.

Social support

Peer-led support groups represent a novel and potentially effective form of weight loss support, especially when the intervention successfully creates a sense of shared community among its members. Evidence suggests that peer support provides the most benefits for those with limited support in their own lives and vulnerable groups, such as those support a specific ethnic group, gender or diagnosis (Holt et al, 2014, and Aschbrenner et al. 2019 and Ufholz, 2020). The utility of online peer support as an adjunct to in-person peer support may not greatly improve short-term study outcomes but is positively perceived by participants and may improve long-term adherence to new weight management behaviours (Ufholz, 2020). The most effective online support seems to stem from face to face interventions which were followed by digital peer support (Kwasnicka, 2020 and Wyke, 2015). The potential platforms for digital remote support (social media platforms, text messaging, telephone calls) improve access, provide accountability and contact to a wider network warrant further research. Despite these benefits, t social media and online sources are also a source of misinformation and harmful norms (Wang et al, 2019). Future digital intervention should consider the feasibility for developing an online support system that include guidance from healthcare professionals or trained peer coaches may be necessary safeguards.

Future research should progress this body of work by including these learnings:

- The dietary assessment used to inform tailored feedback should be based on validated and evidence based methods. The full methodology and the protocol for how this data was used to inform dietary feedback should be published.

- Most digital weight loss interventions provide tailored feedback that is limited to numerical information on dietary energy. This thesis demonstrated the value of using annotated images from the individual's mFR in the provision of tailored feedback. Future interventions should provide image-based tailored dietary feedback focussed on improving diet quality.

  - This research substantiates the role of the mFR to assess dietary intake and inform tailored dietary feedback in digital interventions. A key strength of the mFR is that this method can capture multiple elements of dietary behaviour (content, portion size, time of eating). As demonstrated in this thesis, using the mFR for dietary assessment is a method that participants in this study find acceptable and easy to use.

  - Tailored feedback informed by the mFR, prompts reflection of dietary intake and is associated with both an increase in vegetable intake and a decrease in discretionary food and beverages.

  - Findings from this body of work highlight the value in conducting qualitative research prior to the intervention. Using hypothetical scenarios is a useful strategies when assessing the capability, opportunity and motivation for weight management behaviours among people with overweight and obesity.

  - The level of personalisation in ToDAy was well received by participants, however it proved to be time consuming to undertake. and not sustainable for future interventions without modifications. One of the most time consuming activities was the preparation of the dietary assessment and feedback. With improvements in automated methods of dietary assessment this may reduce the analysis time. It is also noted that the inclusion of participant images in the dietary feedback was identified significant in making the content easy to understand and actionable. The next steps for personalised would likely focus on feedback which can be automatically generated based on participants responses to questionnaires and dietary intake. While the image based method is preferred, the addition of written feedback is a more sustainable approach to expand the tailoring parameters and increasing the capacity for the intervention to be up-scaled.

Implication for improving the impact of digital interventions for weight management

- The findings suggest that a theory-based digital weight management intervention using a mobile food record to inform tailored feedback is an acceptable, feasible, and engaging strategy. Further studies are needed to determine the optimum dose and frequency of tailored feedback.

- The level of personalisation in ToDAy was well received by participants, however it proved to be time consuming to undertakeand not sustainable for future interventions without modifications. One of the most time consuming activities was the preparation of the dietary assessment and feedback. With improvements in automated methods of dietary assessment this may reduce the analysis time. It is also noted that the inclusion of participant images in the dietary feedback was identified significant in making the content easy to understand and actionable. The next steps for personalised would likely focus on feedback which can be automatically generated based on participants responses to questionnaires and dietary intake. While the image based method is preferred, the addition of written feedback is a more sustainable approach to expand the tailoring parameters and increasing the capacity for the intervention to be up-scaled.

Implications for policy

- Evaluation of clinical weight loss services and health promotion interventions require broad and robust evaluation tools where outcomes are not limited to weight change.

- Consider including tools and support for assessing dietary intake in the next clinical practice guidelines for the management of overweight and obesity in adults and children. This should include advice on methods to include images of participants foods to aid communication of the type and volume of food consumed.

The WA Healthy Action Plan 2019-2024 Western Australia Department of Health, 2019) includes a framework of seven factors required to build a community that supports a healthy weight. I believe that the rests of this thesis can contribute to three of these key areas.

1. Innovation: Using digital images of food for dietary assessment and dietary feedback. The results from this thesis suggest that participants are happy taking images of their meals and find this approach less burdensome than other digital methods. Further work is requires to determine how health professionals (dietitians) may be supported to implement image based dietary assessment and feedback into their practice.

2. Build workforce capability and confidence: Individual dietetic management includes a diet history to identify dietary habits inconsistent with dietary recommendations. As described in this thesis, dietary self-monitoring and tailored feedback are key behaviour change techniques for improving diet quality and supporting weight management. The systematic review of the dietary assessment methods used in weight loss interventions reveals that these platforms are still burdensome and generally only provide feedback on kilojoule or macronutrient intake which is confusing to patients who eat food not nutrients.

Digital food records using the mFR with time and date stamp data, have the potential to:

1. provide individualised patient feedback on eating frequency

2. Prompt greater awareness of the food choices and volumes of food being consumed and recorded.

3. Reduce the time for dietitians to assess the eating behaviours of individuals seeking weight management support.

The mFR could be adapted to provide a suitable digital platform that community dietitians can access for their patients.

Conclusion

This thesis makes a significant contribution to the field by examining how technology can be used to improve dietary behaviours. The results present new evidence on the experiences, knowledge and beliefs of Western Australian adults relating to digital interventions and behavioural strategies for weight loss. The method used to develop the intervention was novel, using hypothetical scenarios to capture participant's views on how to approach weight loss. To our knowledge, ToDAy is the first intervention to provide dietary feedback using annotated images of the participant's meals. This novel contribution to the field enables future researchers to develop the use of technology further to deliver tailored, evidence-based, dietary advice. In order to develop the science of tailoring using digital tools, it is essential to ensure tailored feedback is informed by high-quality data and strives to meet clinical guidelines rather than focus on weight loss.

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Appendices

Appendix A Ethical approval

MEMORANDUM

Curtin University

Office of Research and Development
Human Research Ethics Office

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

To: CC:	A/Prof Deborah Kerr School of Public Health
From	Professor Peter O'Leary, Chair HREC
Subject	Ethics approval Approval number: HR61/2016
Date	06-Apr-16

Thank you for your application submitted to the Human Research Ethics Office for the project: 6539

Computer-tailoring to change overweight adults' diet and physical activity

Your application was reviewed by Human Research Ethics Committee at Curtin University at their meeting on the 02/02/2016

Thankyou for providing the additional information requested by the Human Research Ethics Committee. The information you provided was satisfactory and your proposal is now approved.

Please note the following conditions of approval:

1. Approval is granted for a period of four years fror **07-Apr-16** to **07-Apr-20**
2. Research must be conducted as stated in the approved protocol.
3. Any amendments to the approved protocol must be approved by the Ethics Office.
4. An annual progress report must be submitted to the Ethics Office annually, on the anniversary of approval.
5. All adverse events must be reported to the Ethics Office.
6. A completion report must be submitted to the Ethics Office on completion of the project.
7. Data must be stored in accordance with WAUSDA and Curtin University policy.
8. The Ethics Office may conduct a randomly identified audit of a proportion of research projects approved by the HREC.

Should you have any queries about the consideration of your project please contact the Ethics Support Officer for your faculty, or the Ethics Office at hrec@curtin.edu.au or on 9266 2784. All human research ethics forms and guidelines are available on the ethics website.

Yours sincerely,

Professor_Peter O'Leary
Chair HREC Research Ethics Committee

Appendix B Research integrity training

Curtin University

ORGANISATIONAL
DEVELOPMENT UNIT
CERTIFICATE OF COMPLETION

This is to certify that
Charlene Shoneye

Completed the
SOL Research Integrity Professional Development Program

Professor Deborah Terry
Vice-Chancellor

Date: 30/07/2017

Appendix C Research integrity training

Curtin University

RESEARCH OFFICE AT CURTIN

CERTIFICATE OF COMPLETION

This is to certify that

Charlene Shoneye

Completed the

Research Integrity Concise - Human Subjects Protections

Professor Deborah Terry
Vice-Chancellor

Date: 21/10/2019

Appendix D Data management plan

Curtin University

Research Data Management Plan

Qualitative focus group study to inform the development of a computer-tailored weight management intervention

Principal Investigator	Deborah Kerr
Data Management Plan Edited by	Deborah Kerr
Modified Date	16/06/2016
Data Management Plan ID	KERR0D-HS02306
Faculty	Health Sciences
Script project number	RES-HEA-SPH-DK-54568-1

1 Research Project Details

1.1 Research project title

Qualitative focus group study to inform the development of a computer-tailored weight management intervention

1.2 Research project summary

Current guidelines recommend new online programs are tested with the target audience before any formal trials. This is to ensure the program is user friendly and meets the needs of the users. Focus groups are commonly used to generate discussion and explore ideas of groups of people. In this study we want to know what the group thinks about our ideas, images and intervention design.

This study aims to explore the attitudes, experiences and beliefs of overweight adults in regards to online weight management. We also want to include their ideas and views about what makes an online weight loss intervention effective and popular.

1.3 Keywords
nutrition, health promotion, focus group methdology

2 Research Project Data Details

2.1 Research project data summary

Source of data: The focus group discussions will be recorded and transcribed verbatim by a professional transcription service.

content/ subject matter: factors that may support or hinder engagement with an online weight loss intervention

Data analysis: The transcriptions will be analysed through an inductive approach to determine the most important themes.The analysis will be conducted by the doctoral student and the researchers concurrently. They will each review the transcripts to identify text that relates to the study objectives, labelling each of the segments of text to create themes or categories. They will review the segments to reduce overlap among the themes or categories, and then review the other person's work for consistency. If there is general consistency in the themes that have been identified, the final model that incorporates the most important themes or categories will be created. If there is general lack of consistency, or the number of themes or categories remains too great, the process of reviewing the transcripts will recommence. The final list of important themes will be discussed and agreed among all of the research team.

2.2 Will the data be identifiable

- Non-identifiable — data which has never been labelled with individual identifiers

Appendix E Example of the 4-week tailored diet and activity feedback to a participant.

TODAY
Tailored Online Diet and Activity studY

Hi John,

It's the **LiveLighter TODAY** team with your diet and activity feedback.

Your diet summary

Decide on a weight loss goal and aim to lose up to 10% of your body weight in six months. **This table** can help you to work out how much this is for you.

1. Fruit and veg summary

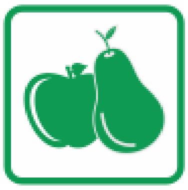
What's the goal? 2 fruit & 5 veg every day.

1. Vegetables

Your average daily serves of vegetables was 0.75. Ranging from 0 to 1.25 serves.

What's the goal again? 5 serves of veg every day.

You can only go up from here!



2. Fruit

Your average daily serves of fruit was 0.

What's the goal again? 2 serves of fruit every day.

You can only go up from here!

What is a serve of vegetables?

A standard serve is about 75g (100-350kJ) or

1/2 cup cooked green or orange vegetable

1/2 cup canned beans or lentils

1/2 cup sweetcorn

1/2 medium potato

1 medium tomato

What is a serve of fruit?

A standard serve is about 150g (350kJ) or

1 medium apple, banana or orange

2 small apricots, kiwi fruits or plums

1 cup canned fruit (no added sugar)

Or only occasionally:

125ml (1/2 cup) pure fruit juice

4 dried apricot halves

1 1/2 tablespoons of sultanas

To lose weight **reduce your daily energy intake** by at least 2,500 kJ per day (or 600 calories).

For most people this means:

Avoid or limit junk food, sugary drinks and/or alcohol

Eat less at meals or snacks (except for fruit and vegetables)

Eat less often (e.g. limit snacking)

Time to set some healthy eating goals

To lose weight **reduce your daily energy intake** by at least **2,500 kJ per day**.

Could you try to add a serve of vegetables in at least one meal each day? Head to the Livelighter Salad Builder fact sheet for some ideas on creating interesting salads to have with your meals.

Appendix F Exit interview script

Participants' perceptions of a digital, tailored, weight loss intervention
LiveLighter TODAY exit interview objectives:
1. Explore participants' preferences for intervention features
2. Identify participants' views on how the intervention might be improved
3. Identify intervention features influencing participants' motivation, capability and opportunity to change their eating and activity behaviours

	Men (n=12)	Women (n=12)
Under 40 years	≥ 10% weight loss over 1 year (n=3)	≥ 10% weight loss over 1 year (n=3)
	< 5% or no weight loss over 1 year (n=3)	< 5% or no weight loss over 1 year (n=3)
Over 40 years	≥ 10% weight loss over 1 year (n=3)	≥ 10% weight loss over 1 year (n=3)
	< 5% or no weight loss over 1 year (n=3)	< 5% or no weight loss over 1 year (n=3)

Script
Hi [participant], my name is [researcher]
I am from LiveLighter TODAY diet and activity study that you signed up for about 12-months ago. Thank you for taking the time to chat with me today. I would like to ask you some questions over the next 30-45 minutes about your involvement in the study.
I'm sure you remember coming in to Curtin University to visit us on three occasions: at the start of the study, and again at 6 and 12 months. During these visits we took some physical measurements and asked you to complete a few surveys beforehand about yourself, your diet and activity. We also gave you a Fitbit watch to wear (and keep) to monitor your activity and asked you to take images of your food and drink to monitor you diet. For the first 6 months we emailed you feedback about your diet and activity.
Does that all sound familiar?
Now, we would like you to help us understand what parts of the study you found helpful or not helpful. Your views are really important to help to improve future research. We understand that not everything we do works for everybody so please feel free to give us your honest opinion.
A few important points to remember are:

- There are no right and wrong answers – we would just like to know what *you* think.
- You do not have to answer any questions that make you feel uncomfortable or would prefer not to answer.
- If anything is not clear or you have anything further to add - please stop me at any time.

OK before we start, would you mind if I record your answers so that we don't miss any details? (Phone recording turned on with permission).
Motivation

- Could you tell me why you signed up to the study?
- Was there anything you were hoping to get out of the study?

- Can you tell me what you thought about the study in general?

I am now going to ask about any changes you made to your diet or activity during the study.

- Were there any changes that you noticed as a result of being in the study?
- Can you think of anything that helped you to make these changes? (prompt planning ahead, emails from TODAY, taking photos of your food, wearing the Fitbit, Fitbit app, new knowledge about veg/junk food serves or movement goals – step count, active minutes, hourly movement)

Social support

- Thinking about the people around you, friends family and work mates. Can you tell me if anyone influenced your efforts during the study?
- As a result of being in the study, do you think you may have influenced anyone else around you to make changes to their diet and activity?
- Can you think of anything else that we could have provided that might have helped you achieve your goals?

Knowledge

- As a result of the study, did you learn anything new about your daily activity – how much, how hard and how often you move?
- Your diet and what you eat?

Opportunity

The feedback on your diet gave suggestions to reduce your daily energy intake (or calories) by avoiding junk food, sugary drinks and alcohol and increasing fruit and vegetable serves; Eating less at meals or snacks and eating less often

- With these suggestions in mind, was there parts that you found easier to do?
- Was there parts that you found more challenging?
- Was there any particular parts that you found stuck in your mind / helpful/ not so helpful?

The activity feedback gave suggestions on moving more (step count), moving harder (active minutes) and moving more often (hourly activity).

- Was there parts of this feedback that you found easier to do?
- Was there parts that you found more challenging?
- Was there any particular parts that you found stuck in your mind / helpful/ not so helpful?

I would now like to ask some questions about your habits. That is things you do automatically, without even thinking. Like locking the door when you leave the house.

- As a result of being in the study have you formed any new habits? (prompt physical activity and eating)
- Can you tell me more about this? (what *helped/could help* you develop habits)?

Finally, we would like to know your thoughts on how you think the study could be improved for future research.

- Have you got any ideas on how the study could be improved to help people to be more active?
- Have you got any ideas on how the study could be improved to help people to make better food choices?

That's the end of the interview. We have a $50 voucher to Myer or Bunnings (you can choose) to thank you for your valuable time.

	Eating	Physical activity
Capability		
Knowledge e.g. able to identify serve of veg	Can you think of anything that helped you to make these changes? (prompt for planning ahead, emails from TODAY, taking photos of your food, wearing the Fitbit, Fitbit app, new knowledge about veg/junk food serves or sitting time and active minutes)	
Physical .e.g. ease at which task can be performed	How easy was it for you to make these changes? (no food in the home, no lunch break at work) or (Move more? Move harder? Spend less time sitting?)	
Opportunity		
Physical e.g. environment	The feedback on your diet gave suggestions to avoid or limit junk food, sugary drinks and/or alcohol. How easy was it for you to make these changes? Was there parts of this feedback that you found easier/more challenging to do?	The activity feedback gave suggestions on moving more, moving harder and moving more often. How easy was it for you to make these changes? (gym at work, walk dog/kids to school, lack of time). Was there parts of this feedback that you found easier to do?
Social e.g. cultural norms	As a result of being in the study, do you think you may have influenced anyone else around you to make changes to their diet and activity levels?	
Motivation		
Reflective e.g. plan and beliefs	Thinking about the feedback on your diet, was there any particular parts that you found stuck in your mind / helpful/ not so helpful?	Thinking about the feedback on your activity, was there any particular parts that you found stuck in your mind / helpful/ not so helpful?
Automatic e.g. desires and impulses	As a result of being in the study, have you formed any new habits?	
	Yes – what has helped you develop that?	
	No – what would help you to develop that?	

Appendix G Author contribution statements

I, Charlene Shoneye, contributed (study design, data analysis, first draft manuscript, contributed amendments as per external reviewer comments and approved the final draft) to the manuscript entitled: Design and Development of a Digital Weight Management Intervention (ToDAy): Qualitative Study

Shoneye, C. L., Mullan, B., Begley, A., Pollard, C. M., Jancey, J., & Kerr, D. A. (2020). Design and Development of a Digital Weight Management Intervention (ToDAy): Qualitative Study. *JMIR mHealth and uHealth*, *8*(9), e17919.

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