Using social media and mobile gaming to improve the vegetable intake of young adults

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Abstract

Adequate consumption of vegetables is linked to a reduction in chronic disease risk, particularly cardiovascular disease, stroke and some cancers. Young adults aged 18-34 years are the poorest consumers of vegetables among the Australian adult population with less than 6% meeting the recommended five serves per day (375 grams). The overall quality of their diets is poor, with excessive consumption of energy dense discretionary foods and drinks. This age group is gaining weight more than other adults, with a significant increase in the percentage with obesity from 1995 to 2011/12 as demonstrated by the National Nutrition and Physical Activity Survey (NNPAS). Vegetables have been shown to mediate weight loss among young adults, and research has demonstrated their role in satiety and lowering the energy density of the diet. Thus designing and testing interventions targeted at improving the vegetable intake of young adults to improve their diet quality; reduce their future risk of chronic disease; and assist in managing the obesity epidemic is warranted.

The objective of thesis was to develop and test the feasibility of a behaviour change program for improving vegetable intake of young adults aged 18-30 years. Modern and age-appropriate communication strategies such as social media and mobile applications were selected as delivery platforms to maximise reach and engagement. This is especially important since young adults do not visit primary care practitioners frequently, and may not have adequate exposure to public health campaigns typically targeted at middle-aged adults.

The first chapter of this dissertation is a summary of the current evidence surrounding the health benefits of vegetable consumption and the factors known to influence intake. An

overview of the unique characteristics of young adults that should be considered in any health promotion program targeted at this age group are outlined. The overall aim and an outline of the thesis are specified.

Chapter Two presents the findings from an analysis of the most recent National Nutrition and Physical Activity Survey data (NNPAS 2011-12) to explore the current patterns of vegetable intake among Australian young adults according to sociodemographic characteristics including, age, gender, BMI, socioeconomic index for areas (SEIFA) and geographical location. The variety of vegetables eaten and timing of consumption (by meal occasion) was also examined. The research highlighted that while the mean intake of vegetables is well below the recommendations for all young adults; 18-24-year-old males are the poorest consumers. Furthermore, an opportunity exists to encourage young adults to consume a wider variety of vegetables especially green and brassica varieties and to incorporate vegetables in all meal occasions, particularly breakfast and snacks for which intake was lowest.

Chapter Three presents the protocol for a systematic review of existing randomised controlled trials (RCTs) using electronic and mobile phone based (e/mHealth) strategies to improve fruit and vegetable intake of young adults. This review aimed to assess the efficacy and external validity of these interventions. External validity refers to the degree to which the effects observed in the studies can be generalized to the broader young adult population.

The fourth chapter is the review which summarises the results and identifies characteristics of effective programs that might be used in designing interventions in the future. A majority of studies had combined the measure of fruit and vegetables. My meta-analysis of the four studies that measured vegetable intake alone, revealed a pooled effect size of 0.15, which is small. But the mean change across studies was 0.5 serves of vegetables per day. Overall, the preliminary evidence suggested that e/mHealth strategies such as texting, phone coaching and online education platforms may be effective for improving vegetable consumption among young adults; however, better-quality interventions, using valid measures of vegetable intake are needed. Improved reporting on external validity components is indicated. Studies need to investigate both the internal and external validity if they are to be translated and scaled up in the community. This will ensure that research extends beyond effectiveness testing and considers applicability of study designs for broader dissemination. An opportunity was identified to specifically test the impact of more modern platforms such as social media and smartphone apps.

Chapter Five explored the efficacy of more modern platforms through a narrative review of social media and gaming interventions designed to improve nutrition outcomes in young adults. While the body of evidence indicated that use of social media and gaming for nutrition promotion was in its infancy, these strategies have been shown to have positive implications on nutrition knowledge and attitudes. There was limited research to confirm they were effective in increasing vegetable intake specifically or other dietary behaviours and most of the published studies were of low quality. Thus, an opportunity presented to test the impact of these strategies for improving vegetable intake using high-quality study designs.

Chapter Six provides an overview of the theoretical framework which informed the proposed program components. This framework is based on The Behaviour Change Wheel by Professor Susan Michie and Colleagues. Using Michie's model, the target behaviour (B) (vegetable consumption) was broken down into its components; Capability (C), Opportunity

(O) and Motivation (M) (COM-B). Appropriate behaviour change techniques that address these components were integrated into the program design.

Chapter Seven describes the formative research conducted to examine the acceptability of the proposed program material presented in a focus group setting. This chapter summarises the perspectives, preferences and feedback gathered from young adults. The formative research revealed positive support among young adults for the use of a smartphone app for goal setting and self-monitoring of vegetable intake and indicated that further instructional guidance around meal planning and cooking is required. Focus groups were also used to gather feedback on a series of short cooking videos that address the commonly reported barriers to vegetable intake. Details of the design and testing of the videos is provided in Chapter Eight. In summary, the short cooking videos were well received and effectively reduced the perception of time, cooking skills and cost as a barriers to cooking with vegetables.

Chapter Nine describes the outcomes of a feasibility study which aimed to test effectiveness of social media and mobile-gaming as platforms for improving the vegetable intake of young adults over four weeks. The study was conducted using a 2x2 factorial design to compare effects of different behavioural components delivered via a standard app (goal setting and self-monitoring) or a gamified app (standard app with gaming components to incentivise participants), with our without the addition of social support (social media). The feasibility of delivering the intervention through the apps and social media was established. The additional components of incentives and social support may not improve vegetable intake beyond what is achievable through the process of goal setting and self-monitoring. However, these outcomes were only short term, in a small sample of young adults and were underpowered to detect changes. Thus further research is needed to assess the impact of these strategies on longer-term habit formation. Process evaluation revealed that the program components were acceptable and easy to use. Further, participants reported learning key skills in meal planning and recipe modification for the inclusion of vegetables across all meals in the day. This thesis then concludes with Chapter Ten, which discusses the overall findings of this research, its implications, directions for future research and the potential translation and scale up of this program to the broader young adult community.

Declaration

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Monica Marina Nour

2nd July 2018

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Ethical approval

Methods and materials of the four week vegetable program and process evaluation presented in Chapter eight were approved by the Human Research Ethics Committee at The University of Sydney in July 2017 (Approval Number 2017/306).

Methods and materials of the formative research projects detailed in Chapters six and seven were approved by the Human Research Ethics Committee at The University of Sydney in October 2016 (Approval Number 2016/705) and April 2016 (Approval Number 2016/304) respectively.

Note on authorship attribution

I Monica Marina Nour (the candidate) hereby declare that no part of this thesis has been submitted for a degree at the University of Sydney or at any other tertiary institution. The research presented in this thesis was conducted by the candidate under the guidance of primary supervisor Professor Margaret Allman-Farinelli and auxiliary supervisor Professor Robyn McConchie. Contributions were made by these supervisors as well as co-authors Dr. Kevin McGeechan, Associate Professor Anna Rangan, Dr. Zhixian Sui, Dr. Stephanie R Partridge, Ms. Juliana Chen, Ms. Amanda L Grech, Ms. Anika S Rouf, Ms. Sin Hang Yeung, Ms .Zilvia G. Y. Cheng and Ms. Jessica L Farrow. All work presented in this thesis is the original work of the candidate and the aforementioned supervisors and co-authors.

I Monica Marina Nour (the candidate), under the guidance of my primary supervisor Professor Margaret Allman-Farinelli developed the research question presented in Chapter Two and analysed the data under the guidance of Dr. Kevin McGeechan and Dr. Zhixian Sui. I also devised the protocol for and conducted the systematic literature review and meta-analysis described in Chapter Three and Four. I was the primary researcher involved in developing the research question and producing the final manuscript for the narrative review presented in Chapter Five. Ms. Yeung assisted with screening studies and summarizing the information for the draft manuscript. The findings of the reviews presented in Chapter Four and Five, in part, informed the design of the four week vegetable program described in Chapter Nine. With the guidance of my supervisor Professor Margaret Allman-Farinelli I designed the protocol and materials for this program, and independently coordinated and carried out the feasibility testing and process evaluation described in Chapter Nine. Co-author Juliana Chen assisted with participant randomisation in this study. The data presented in this thesis was analysed by the candidate, under the guidance of Dr Kevin McGeechan. I designed the protocol for and coordinated the focus group studies presented in Chapters Seven and Eight. I guided two Masters of Nutrition and Dietetics students (Ms Zilvia Cheng and Ms Jessica Farrow) through the process of producing the cooking videos reported on in Chapter Eight. A chapter specific author contribution statement is detailed at the start of each chapter.

Authorship attribution statement

As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

Margaret Allman-Farinelli

2nd July 2018

Publications

The following peer-reviewed publications arose directly from research conducted as part of the PhD candidature:

Manuscripts published or accepted for publication (first author):

1. **Nour, M. M**., Chen, J., & Allman-Farinelli, M. (2015). Efficacy and external validity of electronic and mobile phone-based interventions promoting vegetable intake in young adults: A systematic review protocol. *JMIR research protocols*, 4(3), e92.

2. **Nour, M**., Chen, J., & Allman-Farinelli, M. (2016). Efficacy and External Validity of Electronic and Mobile Phone-Based Interventions Promoting Vegetable Intake in Young Adults: Systematic Review and Meta-Analysis. *Journal of medical Internet research*, 18(4).

3. **Nour, M**., Yeung, S. H., Partridge, S., & Allman-Farinelli, M. (2017). A Narrative Review of Social Media and Game-Based Nutrition Interventions Targeted at Young Adults. *Journal of the Academy of Nutrition and Dietetics*, 117(5), 735-752.

4. **Nour M,** Grech A, Sui Z, McGeechan K, Rangan A, Allman-Farinelli M. (2017). The fruit and vegetable intake of young Australian adults: a population perspective. *Public health nutrition*, 20(14), 2499-2512.

5. **Nour, M**. M., Rouf, A. S., & Allman-Farinelli, M. (2018). Exploring young adult perspectives on the use of gamification and social media in a smartphone platform for improving vegetable intake. *Appetite*, 120, 547-556.

6. **Nour, M**., Cheng, Z. G. Y., Farrow, J. L., & Allman-Farinelli, M. (2018). Short Videos Addressing Barriers to Cooking with Vegetables in Young Adults: Pilot Testing. *Journal of the American College of Nutrition*, 1-7.

Manuscripts in preparation for journal submission:

7. **Nour, M**., Lutze S, Grech A, Allman-Farinelli M. The relationship between vegetable intake and weight outcomes: a systematic review of cohort studies.

8. **Nour, M**., Chen, J.,McGeechan, K.,& Allman-Farinelli, M. A factorial study to evaluate intervention components delivered via social media and mobile gaming to improve the vegetable intake of young adults

Other manuscripts that the candidate contributed to during her candidature are listed below:

Other manuscripts published (non-first author):

9. Allman-Farinelli, M., Partridge, S.R., Nour, M.,& Roy R. Dietary behaviours of young adults born into an obesogenic environment. *The Global Fruit and Veg Newsletter*, November 2016: no. 15

10. Jung J, **Nour M**, Allman-Farinelli M, Kay J. FIT: lock-screen ultra-lite logging an important food target. *Technical Report* 702. 2016;ISBN: 978-1-74210-384-6.

11. Hayba, N., Partridge, S. R., **Nour, M**. M., Grech, A., & Allman Farinelli, M. (2018). Effectiveness of lifestyle interventions for preventing harmful weight gain among young adults from lower socioeconomic status and ethnically diverse backgrounds: a systematic review. *Obesity Reviews*, 19(3), 333-346.

Conference presentations

The following abstracts arose directly from research conducted as part of the PhD candidature:

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1. **Nour, M**., Sui, Z., Grech, A., & Allman-farinelli, M. Evaluation Of Fruit And Vegetable Intake Among Australian Young Adults: Analysis Of The 2011/2012 National Nutrition And Physical Activity Survey. *33rd National Conference of the Dietitians Association of Australia*, Melbourne, Australia 19-21st May 2016

2. **Nour M,** & Allman-Farinelli M. Using social media and mobile gaming to improve vegetable intake in young adults. *2nd annual Charles Perkins Centre EMCR Symposium 'Celebrating Our Diversity'* 22-23 September 2016

3. **Nour M**, Kay J, Allman-Farinelli M. Design and rationale of an innovative intervention addressing inadequate vegetable intake among young adults using social media and mobile gaming for the *3rd UCL Centre for Behaviour Change Digital Health Conference* 2017*: Harnessing digital technology for behaviour change*. London, UK 22nd – 23rd February 2017

4. **Nour, M.**, Kay,J., Allman-Farinelli, M. Addressing inadequate vegetable intake among young adults using social media and mobile gaming. *15th World Congress on Public Health*.

Melbourne, Australia 3rd-7th April 2017

5. **Nour M,** Rouf A, Allman-Farinelli M. Understanding enablers to vegetable intake in young adults to inform the development of a socially connected smart-phone based intervention: A mixed methods approach. In the proceedings of the *34th National Conference of the Dietitians Association of Australia*, Hobart, Australia 18-20th May 2017

Poster presentations:

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2. **Nour et al**., The development of a theory-based gamified smartphone application to promote vegetable intake in young adults. *International Society of Behavioural Nutrition and Physical Activity*, 2016, Cape Town, South Africa

3. **Nour et al**., A systematic review of social media and game-based nutrition interventions targeted at young adults. *International Society of Behavioural Nutrition and Physical Activity*, 2016, Cape Town, South Africa

4. **Nour et al**., Testing of a smart-phone platform using social media and gamification to improve vegetable intake in young adults: Focus group findings. *International Society of Behavioural Nutrition and Physical Activity*, 2017, Victoria, Canada

5. **Nour et al**., Exploring the link between vegetable intake and weight outcomes: a systematic review of cohort studies. In the proceedings of the *35th National Conference of the Dietitians Association of Australia*, Sydney, Australia 17-19th May 2018

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Abbreviations

EPHPP	Effective Public Health Practice Project
ABS	Australian Bureau of Statistics
APEASE	Acceptability, Practicability, Effectiveness, Affordability, Safety and Equity
Apps	applications
AUD	Australian Dollar
AUSNUT	Australian Food and Nutrient Database
BCT	Behaviour change techniques
BMI	Body Mass Index
C	control
COM-B	Capability Opportunity Motivation and Behaviour
CT	control theory
eHealth	Electronic health
F&V	fruit and vegetables
FAO	Food and Agriculture Organization
FG	focus group
GRADE	Grading of Recommendations Assessment, Development and Evaluation
I	intervention
IQR	interquartile range

kJ	kilojoules
MeSH	Medline thesaurus Medical Subject Headings
mHealth	Mobile health
MOST	Multiphase Optimisation Strategies
N/A	not available
NGT	nominal group technique
NHS	National Health Survey
NNPAS	National Nutrition and Physical Activity Survey
NR	Not reported
OC	operant conditioning
PA	physical activity
PICOS	participants, interventions, comparisons, outcomes and study designs
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
RCT	randomized controlled trial
SCT	social cognitive theory
SEIFA	socioeconomic index for areas
SES	socio-economic status
SRBAI	Self-Report Behavioural Automaticity index
TTM	transtheoretical model
UK	United Kingdom

USA	United States of America
WCRF	World Cancer Research Fund
WEL	Weight Efficacy Lifestyle
WHO	World Health Organisation
Wks	weeks

Chapter One: Introduction

1.1 Introduction to chapter

This thesis aims to explore the potential of modern communication technologies in the delivery of nutrition promotion to young adults. More specifically, their potential for improving vegetable intake when integrated into a program based on the Behaviour Change Wheel is explored. **Chapter One** contextualises this thesis within the existing evidence base (Section 1.2 to Section 1.3), defines the thesis aims (Section 1.4) and provides an outline describing how each chapter meets the thesis objectives (Section 1.5).[1]

[1] Six chapters of this thesis have been published. Thus, layout (containing identical text), terminology and English language per chapter is in accordance with journal requirements. Unpublished chapters (Chapter 1, 6, 9 Chapter 10) use English (Australian). Reference lists appear after each chapter to match the published work. All referencing in each chapter is maintained in the journal referencing style.

1.2 Problem definition

1.2.1 Global recommendations and population intakes of fruits and vegetables

In 2013, it was estimated that 4.9 million deaths worldwide were directly attributable to poor fruit and vegetable intake (1). As a result, The World Health Organization (WHO) labelled fruit and vegetable consumption as a significant modifiable risk factor that should be improved in order to reduce the burden of chronic diseases globally (2).

The WHO panel on diet and nutrition recommends a minimum intake of 400-500 g of fruits and non-starchy vegetables per day for the prevention of chronic diseases (equivalent to five 80 g servings). Countries such as the United Kingdom (UK) uphold this “5 a day” recommendation within their national dietary guidelines (2016) (3). It has been estimated that approximately 25% of adults residing in the UK meet this “5 a day” recommendation (4). In Australia, the Dietary Guidelines (2013) recommend a total of seven serves per day; two 150 gram servings of fruit (350 kJ per serving) and five 75 gram servings of vegetables (equivalent to 675 g, 100-350 kJ per serving). Starchy vegetables are included in these recommendations, where half a medium potato is considered a standard serving (5). The Dietary Guidelines for Americans 2015-2020 also recommend intake to the equivalence of seven servings per day, including starchy vegetables (6). Both Australians and Americans are falling short of their national recommendations. In 2015, only 12% of American adults met the daily fruit recommendation and 9% met the guidelines for vegetables (7). In Australia, data collected by the Australian Bureau of Statistics (ABS) in 2014/15 revealed 49.8% of adults met the fruit guidelines, while only 7% consumed the recommended amount of vegetables(8). The average intake of fruit and vegetables per day was 3.9 servings (1.6 servings of fruit (250 g) and 2.3 servings of vegetables (172.5 g)). Overall, only 5.1% of Australian adults met both fruit and vegetable recommendations (8).

Similar inadequacies are observed globally. In a prospective study of 18 countries, the mean fruit and vegetable intake was 3.76 servings. Variations were observed by income strata with low-income countries (e.g. India) consuming on average 2.14 servings, lower-middle-income countries (e.g. China) consuming 3.17 servings, and upper-middle (e.g. Brazil) and high income countries (e.g. Canada) reporting a mean of 4.31 and 5.42 servings per day respectively (9). Thus, the pertinent issue at hand is a population wide inadequacy of fruit and vegetable intake.

1.2.2 Fruit and vegetable intakes of Australian young adults

The most recent Australian data on fruit and vegetable intake was collected in the National Health Survey (NHS 2014/15). This survey used self-report short questions to quantify intake. It should be noted that while the short questions were found to be valid measures for detecting inadequate intake when assessing diets at a population level, vegetable intakes were more difficult to accurately classify (10). The NHS data revealed that at a population level, young adults were the poorest consumers of fruits and vegetables among Australian adults. It was also found that older people were more likely to meet the recommendations than younger people (8). Among the older adults (aged 65-74 years), 8.1% consumed the recommended amounts of fruit and vegetables, while only 3.2% of 18-24 year olds met these guidelines. Although both fruit and vegetable intake was inadequate in young adults, a greater proportion met fruit recommendations at the time of the survey. On average, only 5.3% of 18-34 year olds met the vegetable recommendations compared to 44.2% who met the guidelines for fruit. There were also differences observed by gender, with lower reported vegetable intakes in men (Figure 1.1) (8).

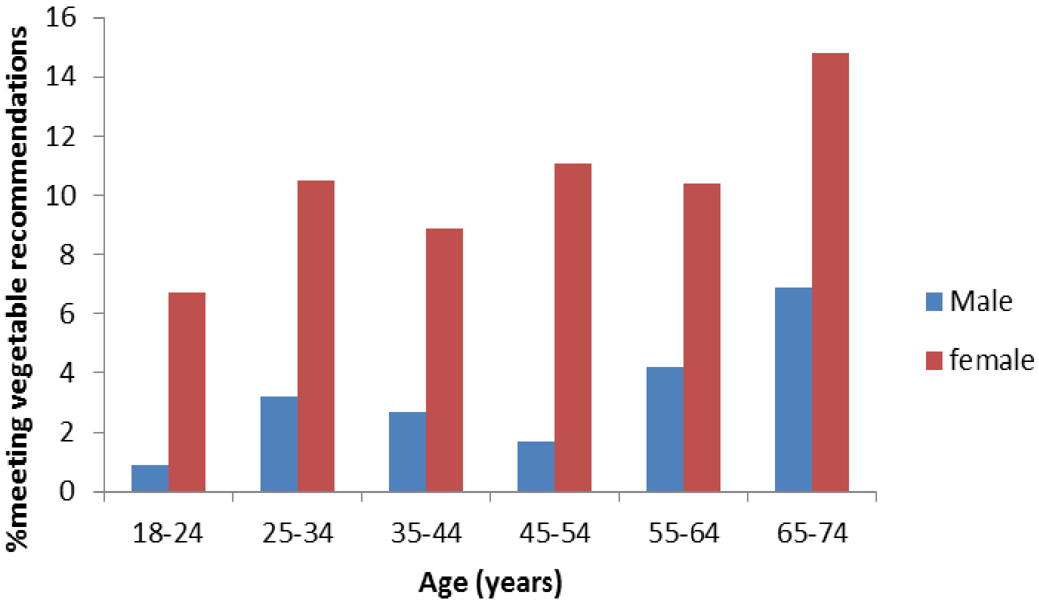

Figure 1.1: Percentage of Australian males and females meeting the recommendations for vegetable intake by age category as reported 2014/15 National Health Survey (reproduced from Australian Bureau of Statistics)

1.2.3 Closing the gap between current intakes and national recommendations

It is evident that a large proportion of Australians are consuming fruit and vegetable quantities far from the recommendations. Research has confirmed a dose-response relationship between increasing intakes and health benefits (11). Thus, even small improvements that do not necessarily meet the recommendations for fruit and vegetable consumption would be beneficial. The approach of using simple public health messages which focus on achievable/actionable targets has been used in campaigns to empower improvements. For example, in the USA, the message ‘Fruit and Veggies—More Matters’ was launched in 2007 by the Produce For Better Health Foundation (PBH) in partnership with the Center for Disease Prevention and Control (CDC). This campaign continues with a focus on encouraging Americans to eat “more” fruits and vegetables to improve their health and has an actionable message as the campaign slogan; “Eat More! Fill half your plate with fruit & veggies” (12).

The literature has indicated that people have poor knowledge of what counts as “5 a day” (13) and surveys have suggested that people perceive their intakes as already adequate (14). In addition, even when people know the recommendations they think near enough is good enough (15). Shifting away from the “5 a day” message and empowering people to eat a little “more” for improved health, may be the key to closing the gap between current intakes and the national recommendations. It would be beneficial on a population level if intakes were improved even by one quarter of a vegetable serve. A recent analysis estimated that increasing population wide intakes of vegetables by just 10% would reduce the Australian government’s health expenditure by $99.9 million (in 2015-16 dollars) (16). A 10% increase from the current mean intake is approximately equivalent to one quarter of a vegetable serving or a quarter cup of salad.

1.2.4 A focus on vegetables

As highlighted (section 1.2.2), fewer Australians are meeting vegetable recommendations in comparison to fruit. This is likely related to the additional barriers to consuming vegetables compared with fruit. Fruit has a more desirable sweet flavour, and many have a soft texture that allows it to be consumed conveniently in its raw form as a snack or dessert. In contrast, vegetables may be bitter and are usually consumed as part of a meal where time is required to plan, prepare and cook the ingredients (17, 18). Thus, interventions addressing the specific barriers to vegetable intake are indicated (19). However, as presented in Chapter Four, very few programs have targeted vegetable intake independently of fruit. The majority aimed to increase fruit and vegetable consumption collectively making it difficult to decipher the impact of these interventions on vegetable intake specifically. As fruit can be incorporated into the diet with greater ease (17) and is generally more palatable, it is possible that participants would adopt the habit more easily than they would for vegetables. Australian public health researchers in the area of public health have argued the value of separating fruit and vegetable recommendations and educational messages to encourage more specific increases in vegetable intake, for which knowledge of serves and intake is poorest (20). Given the limited evidence on the impact of interventions on improving the vegetable intake of young adults specifically (21, 22) (Chapter Four), this thesis focuses on developing an intervention to improve the vegetable intake of young adults, who overall are the poorest consumers of vegetables among the adult population (8) (See Chapter Two).

1.2.4 The health benefits of vegetables

Beyond the essential vitamins and minerals that vegetables provide, when consumed in adequate amounts, vegetables confer many positive health benefits, including reductions in the risk of stroke, cardiovascular disease and some cancers (11). More specifically, it has been demonstrated through meta-analyses that an increase in vegetable intake by approximately one serving reduces the risk of stroke and cardiovascular disease mortality by 11% and 4%, respectively(23, 24). A more recent meta-analysis showed a dose-response relationship where every 200 g increase in vegetable intake resulted in a reduced risk of coronary heart disease, stroke and cardiovascular disease by 16%, 13% and 10% respectively (11). Vegetables contain bioactive components and nutrients that have antioxidant and anti-inflammatory effects which provide protection against reactive oxygen species and this is suspected to be one mechanism by which vegetables improve cardiovascular outcomes (25). It has also been proposed that the fibre found within vegetables can serve as a modulator of lipid absorption (26). The implications of vegetable consumption on cardiovascular outcomes have been examined more closely by researchers by assessing the impact of this food group on parameters of cardiovascular heath, such as blood pressure and the concentration of lipids within the blood. A 2018 study of adolescents showed that intake of green vegetables and beans were inversely related to total cholesterol and LDL cholesterol, while overall vegetable intake was inversely associated with systolic blood pressure (27).

It is also hypothesized that the phytochemical components of vegetables have protective effects against cancer. Research suggests that the indoles within Brassica vegetables such as cabbage, broccoli and cauliflower influence chemical carcinogenesis (28-31). There is also some epidemiological evidence to suggest Allium vegetables (e.g. onion and garlic) protect against cancers of the gastrointestinal tract (32). In 2018, the World Cancer Research Fund (WCRF) reviewed all the available evidence on vegetables and cancer and concluded that there is limited evidence indicating that non-starchy vegetables are protective against cancers of the mouth, oesophagus, colorectum, breast, lung, pharynx and larynx. More specifically, there is limited evidence which suggests that carotenoid containing vegetables (and other foods) might protect against lung and breast cancer. Furthermore, Vitamin C containing vegetables (and other foods) may protect against lung cancer (in current smokers) and colon cancer (33). While the evidence base is limited, a recent meta-analysis of 19 studies concluded that increasing vegetable intake by 200 g per day is linked to a 3% reduction in cancer incidence/ mortality (11).

The other proposed health benefits of vegetables relate specifically to the risk of becoming overweight or obese. It is well understood that increasing vegetables decrease the energy density of the diet and increase dietary fiber which reduces overall energy intake and may assist with maintaining a healthy weight (34, 35). Clinical trials have supported this theory, with evidence from a recent 12 week randomised controlled trial (RCT) conducted on Australian young adults showing that vegetables mediated 40% of the weight loss observed (36).

Overall, it is evident that vegetables are an essential part of a healthy diet and critical for chronic disease prevention. A recent meta-analysis of prospective studies summarised these benefits as a reduction in all-cause mortality by 13% with every 200 g of vegetables consumed (11). Apart from improving life expectancy, there is also emerging evidence linking vegetable consumption to other more immediate health outcomes. For example, studies have shown that higher intakes of vegetables (and fruit) are predictive of life satisfaction, happiness and overall well-being (37). Another recent study found that even in the short term (14 days), increasing intake can improve the psychological well-being of young adults, including their self-reported feelings of vitality, flourishing, and motivation (38). An Australian study measuring the attractiveness of male body odour found that young adult females preferred scents from young adult males who had higher carotenoid concentrations (linked to greater consumption of fruits and vegetables) (39). It has been reported elsewhere that carotenoids are present in sweat and thus diet quality (particularly fruit and vegetable intake) can impact the attractiveness of sweat odor (40). The effect of vegetables on bodily attractiveness also extends to skin tone. In a single-blind randomised crossover trial conducted over four weeks, fruit and vegetable consumption was shown to positively impact skin appearance. The study showed that higher intakes are linked to greater skin yellowness and fasting plasma carotenoid concentrations (41).

Developing messages to help consumers understand these health benefits is one important step in improving vegetable intakes of the population. Motivating change in people's behaviours however is multifaceted and complex, and should take into consideration the determinants of vegetable intake which are discussed below.

1.2.5 Determinants of vegetable intake

Researchers have proposed various factors that may contribute to inadequate vegetable consumption. One potential reason may be a poor understanding of recommended intakes. An Australian survey revealed that less than 15% of the population correctly identified a serving size as half a cup of cooked vegetables (20). Similarly, a recent survey in the UK found that while population knowledge of the "5 a day" message was adequate, understanding of which foods were included was poor and people had difficulty conceptualising the amount which constituted a serving. Survey respondents also indicated a lack of clarity around the message of consuming a variety of fruit and vegetables (13). As such, it has been highlighted that strategies aiming to increase consumption should address the gap in knowledge regarding what constitutes a serve of vegetables, and the types and varieties that should be consumed (42).

Preference for other more palatable foods is another barrier to vegetable consumption reported by Australian adults (15). A cross-sectional survey of Australian young adults aged 26–36 years revealed that energy-dense takeaway meals were a favoured convenience food consumed by 17.7% of females and 37.9% of males two or more times per week (43). Not only has regular consumption of take-away meals been associated with a higher prevalence of abdominal obesity(43), but evidence also suggests that low intake of home-cooked meals is linked to poorer diet quality and lower vegetable intake(44). Given that taste is a highly ranked determinant of vegetable intake among young adults (45), and is a strong correlate of intake in the transition from adolescence to young adulthood (46), it is important that young adults are shown appetising ways to add vegetables to the diet. Providing guidance on meal planning, selection of ingredients and methods of preparation in order to improve food literacy (47), may encourage greater home cooking, improve diet quality and increase vegetable intake.

Successful behaviour change also requires self-regulatory skills. Self-regulation is multifaceted and not only involves having the motivation and capability to initiate change, but also the ability to sustain that change over time. Drive for self-regulation of vegetable intake has been recognised in the literature as a key determinant of vegetable purchasing and consumption (48). Part of this self-regulatory behaviour is the ability to plan, shop for, and make time to prepare healthy dishes containing vegetables, which young adults are lacking (49). As such, the development of autonomous motivation for consuming healthy foods such as vegetables, and the presence of self-regulatory skills including planning, automaticity and habit formation, have been recognised as key enablers (49).

Addressing these determinants of vegetable consumption, including knowledge, skills and ability to self-regulate ones behaviour may equip young adults with the confidence to improve vegetable intake. A recent healthy lifestyle program run with young adults demonstrated that self-efficacy (confidence) for consuming vegetables mediated the change in intake after the intervention (50).

1.2.6 Young adults as a unique population who require tailored interventions

Evidence demonstrates that tailoring interventions, whereby participants received personally relevant feedback, may lead to improved outcomes (51, 52). Young adulthood is a life stage characterised by change and transition. Effective nutrition interventions should take into consideration the unique idiosyncrasies of this period of life and the impact these have on eating habits. These include juggling study and work commitments, adjusting to increased independence, changing employment and living conditions and an increased requirement to self-manage time whilst also keeping up with potentially new social circles and norms (53-56). During this period of transition, young adults report that eating healthy is a significant challenge (57), and many have irregular meal patterns (58).

There is a unique opportunity to positively influence the nutrition habits of young adults during this life-stage where they are malleable to change (59). Yet this population are largely understudied; with most fruit and vegetable interventions and programs targeted at middle-aged adults and school-aged children (21, 60). Young adults are likely to become parents in the near future, thus influencing their eating habits may also have positive implications on the diets of future generations. A recent meta-analysis confirmed the strong association between the food behaviours modelled by parents and the consumption patterns of their offspring (61). The provision of direct support to build self-efficacy and confidence for incorporating healthy foods such as vegetables into their diet is one key step in the process of improving their nutrition habits (62).

The aforementioned life circumstances and challenges that influence young adults limit the applicability of generic messages from social marketing campaigns for increasing fruit and vegetable intake. Thus, interventions designed for young adults that use tailored messages, relevant resources and age appropriate delivery channels should be designed to address the specific motivators and barriers of young adults. The intervention should be theory-based so that the key components of behaviour change are addressed. An overview of previous strategies used to improve vegetable intakes is discussed in section 1.3 which follows.

1.3 Solution generation

1.3.1 Global programs aiming to improve vegetable intake

In Australia, the last fruit and vegetable specific social marketing campaign was titled “Go for 2&5”. It was managed by the Commonwealth Department of Health in 2005 and targeted adults, encouraging increased fruit and vegetable intake (63). Although multiple strategies such as mass media (radio, television, point-of-sale), school and community activities and press and publications were used for promotion, it is unknown whether younger adults engaged with the messages. The key goal of this program was to support intention formation for the consumption of two servings of fruit and five servings of vegetables daily among adults. The Western Australian “Go for 2&5” campaign, used short positive and motivational messages targeted the primary caregiver within the household who was responsible for shopping and meal preparation (64). Key messages aimed to educate on the recommended daily servings of fruit and vegetables, and address barriers to intake by framing the ease of the process of preparing and eating vegetables. Evaluation revealed a significant increase in vegetable intake by 0.6 serves over a three year period (64).

The United States have also targeted caregivers in their latest campaign launched in 2007, titled “Fruits & Veggies – More Matters” (12). Rather than focusing on promoting the consumption of five servings a day, this campaign promoted small steps to help increase consumption such as adding beans to salads and soups, or processing vegetables to be added to pasta sauces. The messages also focused on inspiring consumers by promoting the benefits of fruit and vegetable intake, including their role in improving health and energy levels. The latest evaluation has revealed that consumption levels have not improved, however, the campaign has been successful in increasing motivation with close to 50% of mothers surveyed very/extremely motivated by the messages promoted (double the percentage since 2007) (12).

A national Danish campaign called “6 Om Dagen” which translates to “6 a day” has been very successful in increasing fruit and vegetable intakes. The number six, which in Danish is pronounced as “sex”, was selected as it was predicted to be a notable and effective way to engage consumers, particularly men. The campaign commenced in 1995 and in the period between its launch and 2004, consumption of vegetables increased by 41% in 11-75 year olds (21). The campaign remains effective more than two decades later, with vegetable intakes increasing by 29% between 2008-2011. The most recent national data from Denmark (2011-2013) indicates that vegetable intake has increased from a mean daily intake of 162 g per day to 191 g among 18-75 year olds (21, 65). Given the positive impact “6 Om Dagen” has had on population consumption levels, the campaign continues to be promoted in Denmark and suggests that catchy messages which make the process of eating more vegetables appear “sexy” may be a successful approach to behaviour change.

Aside from population wide marketing campaigns, there have been research-based interventions for improving fruit and vegetable intake in the general population. A review of 34 studies concluded an average increase in fruit and vegetable intake by +0.8 servings per day. The proportion of this change as vegetables alone was not reported. This review found that among the effective studies, self-efficacy generally promoted greater intake (66).

In 2016, a review of programs solely targeting vegetable intake found a total of 140 interventions (60). However, 81% were conducted with children and only three with young adults. The authors noted that while strategies which may be successful in one population group might also be effective in others, a “one size fits all” approach should not be employed (60). This is particularly important when addressing the underlying motivators of young adults who, as discussed in section 1.2.6, have unique challenges that should be considered.

1.3.2 Interventions for young adults

There are a number of interventions in young adults to improve their lifestyle habits which date back to 1976 (67). A large proportion of the literature in this area is related to weight management for 18-25 year olds, where fruit and vegetable intake is targeted as one lifestyle behaviour for improvement. While the literature has revealed that providing support, encouragement and feedback are important components for health behaviour change in young adults (67), the evidence from interventions which target fruit and vegetable intake as the primary outcome are limited (68-72). Furthermore, the majority have been delivered within university/college courses within the United States (US) using regular face-to-face contact with facilitators. Living arrangements of college students in the US and Australia differ. Most US students live on campus with meal provisions from the college food service provider. In

Australia, only a minority of students have pre-prepared meals supplied. This limits the applicability of the US programs within the Australian population and in settings beyond the university/college environment. Furthermore, as these interventions are designed for individual behaviour change, there is a need for the development of interventions that appeal to individuals but are applicable to young adults within the wider population.

Researchers have suggested testing modern approaches to program delivery such as use of social marketing strategies and technology-based modes of communication to deliver individualized theory-based interventions but at scale to the community-at-large (66). This approach may be particularly useful for younger generations where modern platforms including apps and social media are their primary information sharing resources.

The technological advancements which have occurred in the last couple of decades have encouraged greater interconnectedness and information sharing, particularly through smartphones and social media platforms. While these technologies have been shown to enhance maintenance of behavioural changes (73), little is known about the effectiveness of digital platforms such as social media and smartphones for improving vegetable intake in young adults specifically. Therefore, the research in this thesis aims to explore the impact of using these platforms to deliver a theory-based behavioural intervention in a controlled setting.

1.3.2 Mobile technologies and their use among young adults

The current generation of young adults (GEN Y) are technologically savvy, using platforms such as social media and smartphones for communication more than any other age group

(74). In 2016 95% of Australian young adults aged 18-34 years owned a smartphone and 91% used their device for social networking (74, 75). In 2015 it was reported that 75% of this age group also used their smartphone to obtain health-related information (76).

This high penetration of smartphone ownership and usage increases accessibility to smartphone applications (apps) and digital media which have been harnessed by researchers for the delivery of behaviour change interventions. The WHO has termed the use of smartphones in the public health setting as ‘mobile health’ (mHealth) (73). ‘Electronic Health’ or eHealth describes use of the internet to aid with public health practice. It is proposed that capitalising on e/mHealth for interventions can increase efficiency and expand delivery beyond the conventional boundaries (77). The functionalities of smartphone communication technologies such as dietary assessment and tracking apps (78), short messaging service (SMS), and access to the internet and social networking platforms would likely be more appealing to young adults than traditional modes of intervention such as face-to-face or group education.

Another modern approach for behaviour change is the use of gaming elements such as points and rewards in a non-game context to enhance motivation. This has formally been defined as gamification (79, 80). Gamification has been shown to have implications on the degree of engagement in digital behaviour change interventions (81). Gamification elements serve as affordances to increase intrinsic motivation. Particular elements such as rewards can generate excitement and satisfaction when engaging in the target behaviour (82). This investment of emotion and value towards the activity can result in greater cognitive absorption of the required behaviour and may support “immersion” with the task or goal (81). Furthermore, rewards can reinforce positive behaviours enabling change (83), habit formation and maintenance of new behaviours (84).

The effectiveness of e/mHealth interventions for improving the vegetable intake of young adults and the impact of gamification and social networks on nutrition behaviours of this age group have not yet been documented. As such, Chapters Four and Five aimed to review the existing literature and determine directions for future research in this area.

1.4 Thesis aims and summary

From the available evidence, it is clear that young adults are a unique population who, during the transition to adulthood, require tailored support to help them improve their alarmingly poor vegetable intake. This age group has been labelled as the “young invincibles”, and are a particularly challenging population to engage in health behaviour change due to their higher risk taking tendencies and lack of motivation by the longer term implications of risky behaviours, such as consuming a poor quality diet (85). The pressing issue at hand is finding appealing and motivating ways to promote the benefits of eating more vegetables to this at-risk age group while building their skills and confidence in carrying out the behaviour. Current and past public health campaigns have used generic messages about increasing fruit and vegetable intake delivered via conventional communication platforms and aimed at primary carers that are unlikely to effectively engage the young adult population. Furthermore, the majority of the interventions run with young adults have been delivered in the tertiary education setting in the US and their impact on the broader population of young adults has not yet been established.

The research in this thesis aims to explore the potential for use of modern communication platforms, namely social media and a mobile gaming as platforms for the delivery of a theory-based vegetable intervention for young adults aged 18 to 30 years. Prior to the design of these platforms, a comprehensive investigation into the current patterns of fruit and vegetable intake among Australian young adults, by demographic variables will be undertaken to inform intervention design. The varieties consumed will be examined and intake patterns will be explored by meal occasion to determine specific opportunities for increasing intakes to be applied to the intervention. The outcomes of this analysis are presented in Chapter Two.

A systematic literature review and meta-analysis of randomised controlled trials (RCTs) using e/mHealth strategies to improve the fruit and/or vegetable intake of young adults will be conducted to identify the effectiveness of these modern communication platforms for improving the vegetable intake of young adults and specific characteristics related to effectiveness (Chapter Three and Four). Furthermore, the external validity of these studies will be explored to determine the generalisability of the interventions and if there is sufficient evidence to enable the translation and potential scaling-up of these interventions. Due to the limited number of studies using social media and gaming components to improve the vegetable intake of young adults specifically, a second review was conducted and synthesised in narrative style (presented in Chapter 5). The scope of intervention outcomes includes all nutrition-related behaviours and/or weight-related outcomes. This body of work establishes the potential impact of these emerging technologies on nutrition behavior change and whether further evidence is necessary to support their effectiveness.

Characteristics of the effective intervention programs reported in Chapter Four and Five, as well as the opportunities identified for further effectiveness testing will be used to guide the development of a behavioural program for delivery by social media and mobile-gaming program for young adults (Chapter Six). Outcomes from a series of focus groups present the perceptions young adults have toward the use of these technologies for improving vegetable intake. Feedback on samples of the proposed program material was also collected via the nominal group technique (Chapter Seven and Eight). Findings from this formative research will inform the intervention. The feasibility of delivering the intervention will be tested and outcomes related to vegetable intake and vegetable knowledge, habit formation, self-efficacy and motivation will be reported in Chapter Nine.

1.5 Thesis outline

In summary, the research in this thesis will:

1. Comprehensively examine patterns of fruit and vegetable intake in the Australian young adult population by sociodemographic variables and establish the varieties consumed and how intake varies across meal occasions to gain insight into intervention points. **(Chapter 2)**
2. Systematically investigate the effectiveness of RCTs that use e/mHealth strategies to improve fruit and/or vegetable intake of young adults and determine the generalisability and applicability of these studies by exploring external validity components to determine current practice and knowledge. **(Chapters 3 and 4)**
3. Summarise the current evidence supporting the use of emerging technologies, namely social media and electronic games for improving nutrition outcomes in young adults

to help inform program design for delivery of behaviour change techniques. **(Chapter 5)**

4. Develop a theory-based program that uses social media and mobile-gaming to improve the vegetable intake of young adults; ensuring the insights gained through Aims 1 and 2 inform the design process, with particular consideration given to scalability. **(Chapter 6)**
5. Conduct formative research with a sample of the target audience to gather feedback on the relevance and appropriateness of pilot intervention materials and use these findings to refine the design of the program and its components. **(Chapter 7 and 8)**
6. Conduct a four week pilot feasibility study using a factorial study design to determine which behaviour change components delivered via different apps and social media is most effective for improving vegetable intake and change in the determinants; knowledge, self-efficacy, motivation and habit formation. **(Chapter 9)**
7. Report on the effectiveness of the program for improving the vegetable intake of young adults. **(Chapter 9)**
8. Establish the key research findings, their implications for this area of research and provide practical recommendations for future work in this area. **(Chapter 10)**

   Figure 1.2 presents a diagrammatic summary of the research aims and an outline of the components of each thesis chapter.

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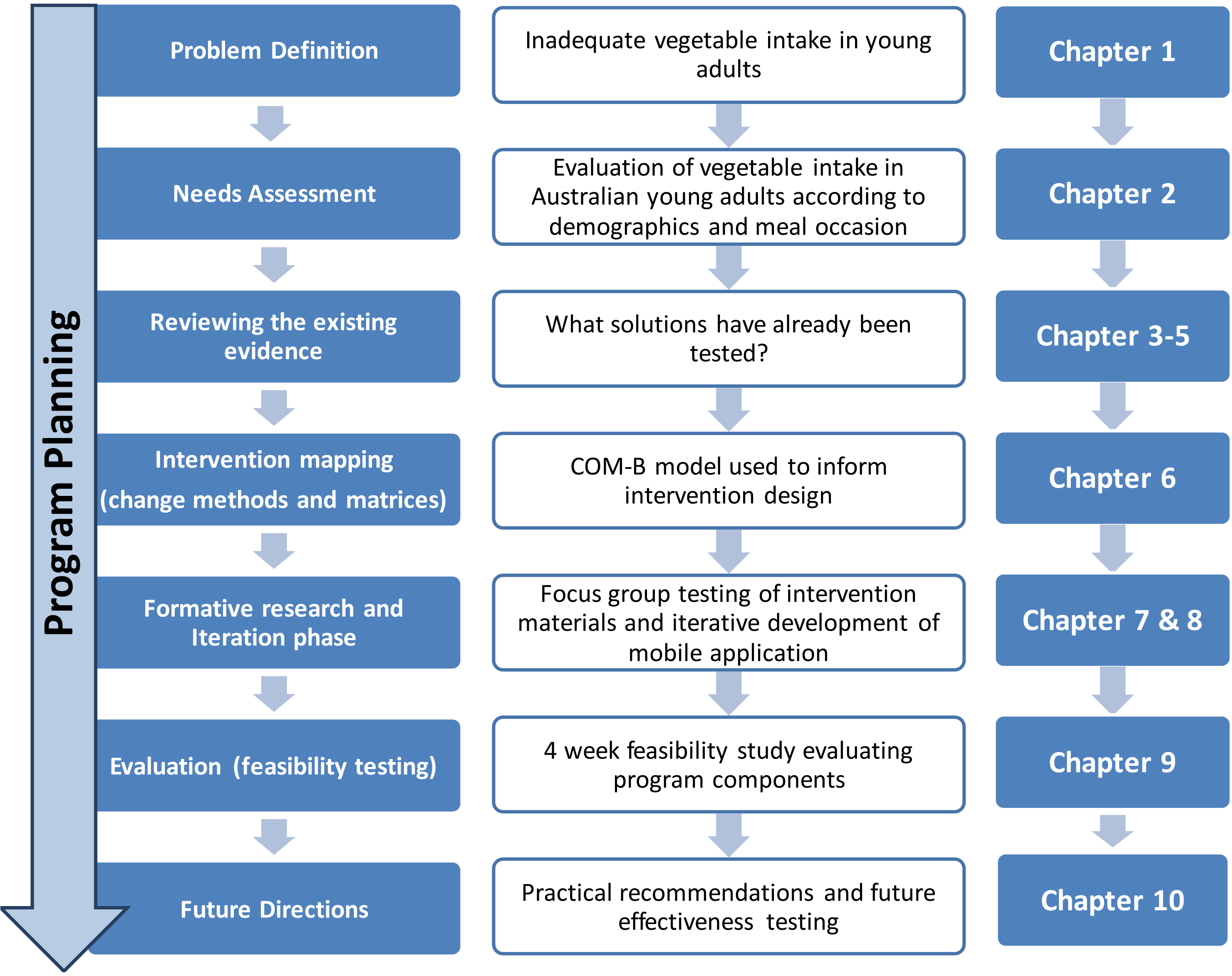

Figure 1.2 Diagrammatic summary of the research aims and an outline of the components of each thesis chapter.

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1.7 Conclusion to chapter

Australian young adults are the poorest consumers of vegetables among the adult population. This will result in detrimental impacts on their health. During this period of transition and change, they experience unique challenges that impact vegetable intake. These barriers need to be addressed in tailored programs that use messages that are appealing and motivating. The use of innovative and modern communication platforms could potentially maximise engagement and reach, but theory-informed programs delivered using these delivery channels must be tested for their effectiveness.

Chapter 2: The fruit and vegetable intake of young Australian adults: a population perspective

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2.1 Publication details

This chapter presents the manuscript titled 'The fruit and vegetable intake of young Australian adults: a population perspective.' published in *Public Health Nutrition*, 2017, Volume 20, Issue 14 pg 2499–2512, doi: doi:10.1017/S1368980017001124 (see *Appendix 2*). It has been reformatted but contains exactly the same text.

2.2 Author contribution

I Monica Marina Nour (the candidate) was the primary researcher involved in developing the research question and analysing the data. The secondary author Dr Sui assisted with disaggregation of the food data for analysis. Dr McGeechan and Dr Sui provided statistical support and all authors contributed to the interpretation of the results. I summarised the information and wrote the first draft of the manuscript. All co-authors provided input to the content of the final published manuscript.

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2.3 Introduction to chapter

The most recent assessment of the dietary intakes of Australians was conducted in 2011/12 by the Australian Bureau of Statistics (National Nutrition and Physical Activity Survey (NNPAS)). Unlike the short questions used in the Health Surveys, the dietary assessment method used in the NNPAS collected detailed data on quantities consumed as discrete foods and in mixed dishes by meal occasion. This chapter aims to use the data from the 24 hour dietary recalls to explore patterns of fruit and vegetable intakes in Australian young adults and the varieties eaten. The analysis examines consumption according to sociodemographic variables including age, sex, geographical location, SEIFA (socio-economic index for areas) and BMI. Intakes were also studied according to meal occasions (main meals vs. snacks) to identify opportunities for increasing intakes to be applied to an intervention. Understanding national level baseline data on intakes of specific vegetables by sex, geography and SEIFA has provided insight into the design of the intervention materials.

2.4 Abstract

Objective

To examine intakes and variety of fruit and vegetables consumed by Australian young adults, also assessing differences by meal occasion and sociodemographic characteristics.

Design

Secondary analysis of cross-sectional 24 h recall data collected through the 2011–12 National Nutrition and Physical Activity Survey. Crude means and proportions consuming fruits and vegetables were calculated. Pearson $\chi 2$ tests, Kruskal–Wallis analyses and linear regression models were used to assess differences in mean intakes by age, BMI and sociodemographic variables. The variety eaten was determined based on the number of fruit and vegetable subgroups consumed.

Setting

Representative sample of metropolitan and rural areas across Australia.

Subjects

Respondents aged 18–34 years were included (n 2397).

Results

Mean daily intake of fruit (128 g/0.9 servings) and vegetables (205 g/2.7 servings) was lower than the minimum recommended intake set at 2 and 5 servings, respectively. Age was positively associated with fruit and vegetable intake ($P=0 \cdot 002$, $P<0 \cdot 001$), with 18–24-year-olds reporting the poorest vegetable variety compared with 25–29- and 30–34-year-olds ($P=0.002$). When controlling for total energy, males consumed less vegetables than females ($P=0.002$). A large proportion of the 15 % of respondents who consumed adequate amounts

of fruits and vegetables on the day prior to the survey reported intake across all meal occasions ($P<0.001$).

Conclusions

Fruit and vegetable intake is suboptimal among Australian young adults. An age-appropriate campaign is recommended to target increased consumption, particularly for those aged 18–24 years, with opportunity to promote increased variety and consumption across the day.

2.5 Introduction

Fruits and vegetables are nutrient-dense foods, rich in fibre, vitamins, minerals and phytochemicals while being relatively low in energy. This makes them important components of a healthy diet. Regular consumption of an adequate intake is associated with lower risks of obesity (1), cancers (2-4), CVD (5-7), stroke (8), hypertension (9, 10) and all-cause mortality (11). Guidelines vary by country, although most are consistent with the WHO's minimum recommendation of 400–500 g of fruits and vegetables daily (excluding potatoes and other starchy tubers) to reduce the risk of chronic disease (12-14). In the UK, five daily portions of fruits and vegetables (combined weight of 400 g) are recommended for health. This does not include starchy vegetables such as potatoes (14). In Australia, two servings of fruits (150 g/serving) and five servings of vegetables (75 g/serving) are the minimum recommended daily intake for adults and include non-fried potatoes (15). As these recommendations are based on gender-specific energy and nutrient requirements, adult males are recommended six servings of vegetables daily (total weight of 450 g). Variety is also encouraged to maximise dietary diversity and the bioavailability of nutrients and other beneficial phytochemicals (15-18).

Fruit and vegetable consumption levels are inadequate in many countries (19-23). Internationally, the intake among young adults is particularly low (24, 25). Researchers and practitioners have made efforts to encourage intake and most recently the Australian government led the population-wide Go For 2&5® campaign which resulted in a combined increase in consumption by 0·8 servings/d (26). Despite these efforts the latest statistics indicate that 19–30-year-old Australians are the poorest consumers of fruits and vegetables among adults (27).

While formative research with young adults suggests that fruit and vegetable consumption is likely to increase during the transition to parenthood (28, 29), if the pattern of suboptimal intake tracks into middle adulthood, it increases the risk of diet-related diseases among these adults and their offspring are likely to inherit these poor dietary patterns (30). Thus, innovative interventions and campaigns are needed to positively influence fruit and vegetable intake of future generations of adults. For maximum effect, interventions should be tailored to the target population (31). This requires an in-depth understanding of the current patterns of intake and determinants of consumption.

The determinants of fruit and vegetable intake have been well documented in the literature, with gender, socio-economic status (SES), personal preferences, availability and accessibility, and parental intake influencing consumption (32). Australian-wide studies specifically evaluating fruit and vegetable intake according to demographic associations are limited and more than 10 years old(33-35), although there have been attempts to estimate intake at the state level such as the Western Australian report on intakes following the Go For 2&5 campaign (26). Prior to the most recent nutrition survey measuring food and dietary patterns (the 2011–12 National Nutrition and Physical Activity Survey (NNPAS)), the last national survey was conducted in 1995 (36). Preliminary results of the recent national survey show that fruit and vegetable intake remains inadequate (27). However, this analysis does not account for all sources of fruits and vegetables in the diet. Detailed secondary analysis including mixed dishes where fruits and vegetables make a minor contribution might yield more complete results.

In 1995, Australians living in areas of lower SES with low incomes had the lowest fruit and vegetable intakes (35). Previous literature has also demonstrated that access to fresh fruits and vegetables varies with geographical location (37-39). Other research has shown that increased vegetable intake can mediate weight loss in young adults (40). To provide context for interventions, current relationships between intake, sociodemographic variables, and factors such as BMI should be examined.

Dietary guidelines based on epidemiological evidence recommend consumption of a variety of fruits and vegetables to maximise bioavailability of nutrients including phytochemicals and the unique health benefits they confer (15-17). Thus, variety should be considered when planning interventions. Lastly, with recommendations set at five vegetable servings daily, it is unlikely that an individual will meet his/her requirements if vegetable consumption occurs in a single eating occasion. Thus, assessing distribution of intake across meal occasions is also of interest to discern opportunities for increased consumption.

Evaluating fruit and vegetable intake according to group characteristics and demographics can inform policy and health promotion practice to improve consumption levels. Thus, the present study aimed to conduct secondary analyses on the NNPAS data from 2011–12 in order to: (i) determine the intakes of fruits and vegetables among young adults (18–34-year-olds); (ii) evaluate variety of fruits and vegetables in the diets of young adults; (iii) investigate fruit and vegetable intakes by meal occasion (main meals v. snacks); and (iv) examine intakes according to sociodemographic variables such as age, gender, BMI, Socio-Economic Index for Areas (SEIFA) and geographical location.

2.6 Methods

Participants and dietary data methodology

The data analysed in the present study were collected as part of the 2011–12 Australian NNPAS by the Australian Bureau of Statistics (ABS). A detailed description of the survey methods including data collection and handling is available from the ABS (41). Briefly, the 2011–12 NNPAS was conducted using nationally representative sub-samples of the Australian Health Survey 2011–13. Trained ABS technicians collected dietary data on foods and beverages consumed using a computer-assisted personal interview, multiple-pass 24 h dietary recall. This method captured intakes of foods and beverages consumed by respondents on the day prior to the interview. To account for variations in intakes across seasons and days of the week, surveys were conducted over 12 months covering weekdays and weekends. Portion sizes were assessed by quantifying the amount of food the respondent consumed at one meal occasion. Rulers, rings, a grid, a wedge, various meat cuts and Australian-sourced drawings and photographs of actual-size food and drink containers in different shapes and sizes were provided in a food model booklet to help respondents estimate portion sizes, which were converted to grams by multiplying the volume specified by the food density (41). A second 24 h recall was conducted with all participants asked to participate on a voluntary basis. Data from the second interview (computer-assisted telephone interview) was not included as only 64 % of respondents participated in the second dietary recall. The survey included a representative sample of city, metropolitan, rural and remote areas across the Australian States and Territories. In the present paper, secondary analyses were conducted on fruit and vegetable intake data of young adults aged 18–34 years. This age range was chosen to reflect definitions of young adulthood according to national health institutes in the USA and Australia (42, 43). However, as emerging adults may have quite different lifestyles from those aged 30–35 years (44), we further grouped into the following age categories: 18–24 years, 25–29 years and 30–34 years. Data were extracted from the Confidentialised Unit Record Files provided by the ABS (permission granted for use) (45).

Classification of fruits and vegetables

The Confidentialised Unit Record Files group food data for all respondents into categories. Further grouping was conducted to classify fruits and vegetables according to categories based on the foundation and total diet food models developed for dietary guidelines (18). Fruits were categorised as citrus, pome, tropical, berries, stone or other; with a separate fruit juice category. Vegetables were grouped as green and brassica, orange, starchy, root/tubular/bulb or other, excluding fried potatoes. Legumes, fresh, canned, frozen and dried varieties of fruits and vegetables, as well as fruits and vegetables within mixed dishes were included in the analyses (see Appendix 2.1, Table S1). All fruits and vegetables in mixed dishes were included. The proportions of fruits and vegetables within all mixed dishes were determined based on ingredient weights reported within the 2011–13 AUSNUT food recipe file (46) and assigned to the appropriate fruit or vegetable category. Consumption of fruit juice exceeding 125 ml and fried potatoes were excluded from analyses in accordance with the Australian Guide to Healthy Eating recommendations which classify them as discretionary (non-core) items (15). Fried potato intake was assessed and reported separately.

Assessment of fruit and vegetable intake

The total weight of fruits and vegetables consumed by each respondent was calculated as the sum of the fruit and vegetable categories, which included both individual fruits and vegetables and those from mixed dishes. Consumers and non-consumers were identified and proportions were established. The mean intakes of fruits and vegetables (grams) were calculated and converted to servings. Internationally there is variation in the definition of a serving. For example, in the UK, a serving of fruit or vegetables is equivalent to 80 g (47). We used the Australian Guide to Healthy Eating (15) definition which specifies that a standard serving of fruit is equivalent to 150 g, while a serving of vegetables equates to 75 g, with a minimum of two servings of fruit and five servings of vegetables recommended daily for adults. These recommendations are based on gender-specific energy and nutrients requirements, such that adult males are recommended six servings of vegetables daily.

Variety and intake by meal occasion

The variety of fruits and vegetables eaten was calculated as the number of the fruit and vegetable categories consumed as defined in Table S1 (Appendix 2.1). Variety was assessed using a modified version of the scoring system developed by Magarey et al. (34). Scoring was as follows: low variety (one type of fruit, one or two types of vegetable), medium variety (two types of fruit, three or four types of vegetable) and high variety (three or more types of fruit, five or more types of vegetable). For this analysis, consuming ≥50 % of a serving of a category of fruit or vegetable as defined in Table S1 (Appendix 2.1) (i.e. ≥75 g of fruit or ≥37·5 g of vegetables) was counted as consuming one type of fruit or vegetable. The number of different types consumed by each participant was summed to give his/her total variety score. Fruit juice was excluded from variety scoring as the type of fruit within these products was not differentiated as part of the current analyses. Dried fruit was also excluded as only a small proportion of the population reported consumption on the day prior to the dietary recall. Data were also categorised by meal occasion as breakfast, lunch, dinner or snacks, where snacks included brunch, morning tea, afternoon tea, snack, extended consumption and other. The mean fruit and vegetable intake at each meal occasion was determined. Further analyses were conducted to explore patterns in number of servings consumed across the day and proportions consuming fruits and vegetables per meal occasion.

Associations between fruit and vegetable intake and lifestyle, anthropometry and sociodemographic variables

To explore factors that may influence fruit and vegetable consumption, we evaluated the relationship between age, BMI, sociodemographic variables (SEIFA and geographical location), lifestyle factors and mean intakes. BMI was derived from the height and weight measurements taken objectively by the interviewer and categorised as underweight (≤18·5 kg/m2), healthy weight (18·5–24·99 kg/m2), overweight (25·0–29·99 kg/m2) or obese (≥30·0 kg/m2) based on the National Institutes of Health's cut-offs (48). Respondents with no BMI recording (n 317) were coded as 'missing values' and omitted from BMI analyses. The SEIFA takes into consideration the impact of the area of residence, rather than an individual's income, occupation or level of education, on intake. Quintile 1 includes the most disadvantaged areas, while quintile 5 represents the least disadvantaged areas. Geographical location was categorised as inner regional Australia, city/metropolitan (capital cities and surrounds) and other (outer regional Australia, remote and very remote Australia). Data on smoking (smoker v. non-smoker) and alcohol consumption (grams per day) were also evaluated as potential confounders in regression models.

Statistics

Statistical analyses were conducted using the statistical software package IBM SPSS Statistics for Windows version 22.0. Data for those aged 18–34 years inclusive were extracted from the Confidentialised Unit Record Files. Subject weighting factors supplied by the ABS were applied to the data before analyses, to ensure they were more representative of the population by age, gender, area of residence and seasonal effect (41). Under-reporters were identified as those with a ratio of energy intake to BMR of <0·87 based on the Goldberg cut-off (49), which has been used for identification of misreporting in previous national Australian surveys (50) and validated for use with 24 h recall data (51). Results are reported including under-reporters unless stated otherwise. Descriptive statistics were used to report fruit and vegetable intake. The mean intake per capita and median intake per consumer were determined and percentage consuming calculated. Differences in proportions of young adults consuming fruits and vegetables according gender, age, BMI, SEIFA and geographical location were assessed using Pearson's χ^2 tests. Differences in variety scores and proportions of persons consuming vegetables at each meal occasion according to categories of servings consumed were also determined by Pearson χ^2tests. As data were not normally distributed, Kruskal–Wallis tests were applied to assess trends in intakes across categories and by age and gender, and to compare differences in intakes between meal occasions. Linear regression models were used to determine the relationship between fruit and vegetable intake and age, gender, BMI and sociodemographic variables (SEIFA and geographical location), controlling for energy intake and lifestyle factors (smoking status and alcohol intake). Statistical significance was set at $P<0.05$ for all tests.

2.7 Results

Characteristics

Table 2.1 summarises the characteristics of the sample of young adults included within the analyses (n 2397). The sample was evenly distributed across genders, age and SEIFA. Close to half the population were classed as overweight or obese (Table 2.1). Approximately 16 % of respondents were classed as under-reporters (n 386).

Table 2.1 Characteristics of the sample of Australian young adults from the National Nutrition and Physical Activity Survey 2011–12 (n 2397)

Characteristics	**Percentage % (n)**
Sex	
Male	46.7 (1120)
Female	53.3 (1277)
Age	
18-24 years	32.5 (780)
25-29 years	30.7 (736)
30-34 years	36.8 (881)
Socio-economic index for areas (SEIFA)	
Lowest 20%	18.8 (451)
Second quintile	20.8 (499)
Third quintile	20.4 (490)
Fourth quintile	17.5 (419)
Highest 20%	22.4 (538)
Geographical location	
City	69.0 (1654)
Inner regional	17.0 (408)
Outer regional/remote	14.0 (335)
Body Mass Index (BMI) [†]	
Underweight (<18.5 kg/m^2)	3.2 (67)
Healthy weight (18.5-24.99 kg/m^2)	47.1 (979)
Overweight (25-29.99 kg/m^2)	32.2 (669)
Obese (≥30 kg/m^2)	17.5 (365)
Whether currently smoking	
Yes	22.7 (554)
No	77.3 (1854)
Whether consumed alcohol on the day surveyed	
Yes	26.2 (629)
No	73.8 (1768)

* n 2080, 317 measurements not obtained.

Proportions of young adults consuming fruits and vegetables

Proportions of young adults consuming fruits and vegetables, and the amounts consumed, according to age, gender, BMI, SEIFA and geographical location, are presented in Tables 2.2–2.5. Fifty-six per cent of respondents consumed fruit (48 % when excluding fruit juice) and 93 %

consumed vegetables. A small percentage of respondents (4.3 %) did not consume any fruit or vegetables. A greater proportion of females consumed fruits than males (males, 40·6 %; females, 53.8 %; $P<0.001$). No significant differences were observed between genders for vegetable consumption (Table 2.2). Fewer young adults aged 18–24 years reported consuming fruits (Table 2.4), and the largest percentage of consumers was observed in the young adults of the highest SEIFA category for fruit when including juice (Table 2.5) and for vegetables (Table 2.3). The proportion consuming legumes on the day prior to the dietary recall was relatively low at 12.3 %. Pome fruit and fruit juice were the most popular fruit categories consumed (Table 2.4).

Table 2.2 Proportions (%) of Australian young adults aged 18–34 years consuming vegetables, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to age, gender and BMI, National Nutrition and Physical Activity Survey 2011–12 (n 2397)

	Gender					**Age group (years)**						
	Male		**Female**			**18-24**		**25-29**		**30-34**		
	%	**Median (IQR)**[‡]	**%**	**Median (IQR)**	***P***	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Veg[‖]	92.5	159 (79-299)	93.8	160 (86.4-284)	.95	92.1	151 (70.8-270)	95.0	166 (91.7-308)	92.7	163 (89.6-306)	**.002**
Green Veg	72.9	28.9 (12.3-73.8)	72.6	30.0 (12.5-70.3)	.97	69.9	26.7 (8.3-65.0)	75.8	33.0 (15.0-74.0)	72.8	31.0 (12.5-74.0)	**.002**
Legumes	12.5	44.8 (8.5-148)	12.1	38.6 (6.8-137)	.70	10.6	26.4 (4.5-120)	13.0	50.0 (8.7-138)	13.1	44.0 (13.4-140)	.24
Orange Veg	33.8	30.0 (14.0-66.6)	36.3	37.2 (17.8-70.4)	.09	33.1	33.6 (15.0-62.8)	37.8	35.9 (20.0-72.5)	34.7	32.3 (14.0-68.8)	.07
Root Veg	69.4	21.4 (9.3-40.8)	66.2	19.8 (9.2-37.5)	**.004**	66.9	19.5 (8.4-39.9)	69.4	21.6 (9.4-39.0)	67.0	19.8 (9.4-39.8)	.61
Other Veg	72.6	72.0 (30.6-125)	75.3	62.4 (29.4-123)	.82	71.2	61.8 (29.0-115)	76.9	67.4 (31.7-132)	74.2	74.0 (30.0-128)	**.004**
Starchy Veg	27.5	89.1 (26.2-203)	34.1	89.1 (32.9-156)	**.001**	28.5	103 (40.7-172)	32.5	78.0 (21.5-193)	32.1	82.5 (26.2-190)	.27

	BMI[†] **(kg/m^2)**								
	<18.5		**18.5-24.9**		**25-29.9**		**≥30**		
	%	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Veg[‖]	95.5	155 (110-241)	94.2	161 (82.2-306)	93.0	158 (90.6-304)	91.2	159 (68.1-304)	.36
Green Veg	67.2	21.2 (7.6-60.1)	73.0	28.9 (12.3-63.3)	74.0	32.5 (13.0-80.2)	70.7	28.8 (15.0-73.4)	.80
Legumes	14.9	46.4 (13.4-740)	13.6	46.0 (14.8-100)	11.2	38.7 (7.9-138)	8.8	8.5 (5.1-37.9)	.06
Orange Veg	31.3	45.4 (25-71.9)	35.1	34.1 (16.7-75)	35.1	34.5 (16.7-70.0)	36.2	28.5 (14.0-70.2)	.97
Root Veg	68.7	16.7 (10.7-57.9)	68.1	24.1 (10.0-41.6)	66.8	17.7 (8.0-40.0)	67.9	16.3 (7.5-36.5)	.27
Other Veg	71.6	70.0 (39.4-110)	76.0	64.5 (31.3-131)	72.9	74.9 (34.8-124)	72.9	58.5 (26-115)	.11
Starchy Veg	31.3	97.3 (43.4-137)	31.2	96.8 (28.3-187)	30.5	92.5 (24.2-203)	31.8	82.5 (19.2-203)	.92

P from Kruskal–Wallis test on per capita intakes; significant P values indicated in bold font; [†] n= 2080 as 317 participants did not have a measured weight and height for calculation of BMI values; [‡] IQR= interquartile range with 25th-75th percentile per consumer [‖]Excluding fried potatoes

Table 2.3, Proportions (%) of Australian young adults aged 18–34 years consuming vegetables, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to Socio-Economic Index for Areas (SEIFA) and geographical location, National Nutrition and Physical Activity Survey 2011–12 (n 2397)

	SEIFA										
	Lowest 20%		**2nd Quintile**		**3rd Quintile**		**4th Quintile**		**Highest 20%**		
	%	**Median (IQR)‡**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Veg‖	90.0	152 (71.8-270)	93.6	153 (73.0-301)	92.2	174 (95.2-308)	94.3	166 (84.5-280)	95.5	152 (86.1-310)	.06
Green Veg	68.1	28.1 (12.5-70.0)	73.5	28.9 (12.3-71.4)	71.0	30.7 (12.5-72.2)	75.9	29.6 (12.3-76.9)	75.1	31.0 (12.3-63.3)	.12
Legumes	10.4	48.0 (13.8-201)	13.0	50.0 5.6-149)	11.0	46.0 (15.1-84)	12.6	28.0 (7.6-66.0)	13.9	26.2 (13.4-140)	.41
Orange Veg	32.4	37.1 (24.8-77.5)	38.3	32.4 (16.7-58.5)	35.9	35.9 (15-76.8)	31.5	33.1 (12.8-71.9)	36.6	30.0 (15.0-57.7)	.39
Root Veg	64.1	24.4 (9.4-38.1)	70.1	17.9 (7.6-39.3)	66.5	21.6 (10.0-41.8)	68.5	19.2 (8.3-39.8)	69.0	22.8 (10.7-40.8)	.41
Other Veg	64.7	68.5 (29-124)	73.1	59.5 (31.7-115.9)	73.9	61.9 (27.0-118)	78.5	65.6 (34.4-130)	79.4	74.0 (35.0-130)	**<.001**
Starchy Veg	29.0	103 (20.2-203)	28.1	83.5 (28.0-183)	33.9	92.5 (44.5-183)	33.2	70.0 (19.2-148)	31.2	92.5 (38.5-207)	.29

	Geographical location						
	City		**Inner Regional**		**Outer regional/remote**		
	%	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Veg‖	93.5	158 (82.4-279)	92.9	188 (92-330)	92.2	133 (73-294)	.15
Green Veg	73.8	28.7 (12.3-70.8)	71.1	31.8 (15.0-76.3)	69.6	38.4 (17.0-70.0)	.75
Legumes	12.6	44.8 (13.4-140)	12.0	22.0 (4.2-120)	11.0	49.7 (6.8-138)	.71
Orange Veg	34.2	32.8 (15.5-67.0)	37.0	40.5 (26.0-70.2)	37.3	26.0 (14.0-68.8)	.30
Root Veg	68.6	20.5 (9.4-40.8)	66.7	20.4 (7.1-35.0)	64.8	16.3 (8.3-34.6)	.31
Other Veg	75.8	67.1 (30.6-126)	68.9	62.4 (29.0-124)	71.9	61.8 (29.0-107)	**.045**
Starchy Veg	30.1	80.8 (25.7-168)	38.2	110 (51.9-196)	26.9	107 (46.6-193)	**<.001**

P from Kruskal–Wallis test on per capita intakes; significant P values indicated in bold font; †n= 2080 as 317 participants did not have a measured weight and height for calculation of BMI values; ‡ IQR= interquartile range with 25th-75th percentile per consumer ‖Excluding fried potatoes

Table 2.4. Proportions (%) of Australian young adults aged 18–34 years consuming fruit, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to age, gender and BMI, National Nutrition and Physical Activity Survey 2011–12 (n 2397)

	Gender					Age group (years)						
	Male		Female			18-24		25-29		30-34		
	%	**Median (IQR)[‡]**	**%**	**Median (IQR)**	***P***	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Fruit without Juice	40.6	188 (114-359)	53.8	175 (103-262)	**<.001**	41.8	184 (114-309)	49.0	175 (90-263)	51.6	184 (131-300)	**.002**
Total Fruit including Juice§	50.8	164 (150-314)	59.4	178 (139-298)	**<.001**	49.6	166 (150-310)	57.3	167 (150-295)	58.3	175 (150-304)	**.002**
Citrus Fruit	10.3	131 (75.0-193)	12.0	93.0 (75.0-150)	.21	9.7	131 (65.5-193)	12.4	75.0 (75.0-150)	11.5	131 (75.0-150)	.23
Pome Fruit	20.8	173 (164-196)	25.1	164 (143-188)	**.045**	21.3	164 (143-188)	23.0	164 (158-188)	24.7	164 (164-188)	.23
Tropical Fruit	7.2	55.5 (18.0-245)	9.2	45.0 (18.5-112)	.08	9.6	51.0 (21.2-184)	7.6	45.0 (10.5-159)	7.7	44.3 (18.0-184)	.27
Berries	4.7	44.3 (24.0-124)	9.8	38.5 (24.0-70.1)	**.001**	6.4	35.2 (19.0-110)	7.2	57.7 (24.0-135)	8.5	41.9 (24.0-80.0)	.28
Stone Fruit	5.2	151 (66.0-295)	7.4	145 (54.0-151)	**.03**	5.8	140 (23.3-166)	5.7	145 (47.3-175)	7.5	151 (109-288)	.23
Other Fruit	9.3	85.8 (27.0-156)	16.1	78.0 (40.0-175)	**<.001**	11.4	85.8 (40.0-175)	11.5	78.0 (23.3-170)	15.4	78.0 (44.5-170)	**.02**
Dried Fruit	8.0	24.1 (8.9-50.0)	8.3	18.8 (10.8-32.0)	.87	5.1	13.8 (7.8-26.8)	9.1	23.0 (15.3-46.9)	10.1	21.2 (9.4-46.9)	**<.001**
Fruit Juice[‖]	19.3	150 (150-150)	17.3	150 (150-150)	.17	16.7	150 (150-150)	19.4	150 (150-150)	18.6	150 (150-150)	.41

	BMI[†] (kg/m^2)								
	<18.5		18.5-24.9		25-29.9		≥30		
	%	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Fruit without Juice	37.3	219 (164-343)	51.5	170 (81.0-290)	45.6	188 (150-315)	42.2	164 (75.0-262)	**.02**
Total Fruit including Juice§	41.8	179 (152-384)	59.9	169 (143-296)	53.7	174 (150-315)	51.0	162 (94.0-274)	**.01**
Citrus Fruit	9.0	15.7 (15.7-131)	10.7	92.8 (75.0-150)	10.6	131 (75.0-193)	11.8	99.0 (75.0-193)	.10
Pome Fruit	14.9	164 (37.9-164)	23.2	164 (153-188)	24.4	164 (164-188)	19.7	164 (153-188)	.06
Tropical Fruit	7.5	51.0 (51.0-190)	9.9	41.9 (18.0-159)	7.3	73.5 (23.1-367)	6.3	83.3 (25.1-367)	.54
Berries	13.4	36.0 (27.4-139)	8.8	38.8 (24.0-110)	6.7	36.8 (19.0-88.0)	3.0	83.3 (24.0-159.2)	.06
Stone Fruit	7.5	145 (18.3-165)	6.6	145 (60.0-217)	4.9	145 (75.0-176)	7.1	151 (83.3-210)	.52
Other Fruit	17.9	68.8 (13.9-100)	13.9	85.0 (27.0-175)	12.3	136 (33.3-160)	10.7	78.0 (44.0-170)	.44
Dried Fruit	4.5	50.0 (50.0-150)	10.2	18.8 (12.7-40.2)	8.2	24.1 (9.4-46.9)	4.1	8.5 (4.2-24.0)	**.02**
Fruit Juice[‖]	13.4	150 (150-150)	20.0	150 (150-150)	17.3	150 (150-150)	15.3	150 (150-150)	.42

p Kruskal–Wallis test on per capita intakes; significant P values indicated in bold font. [†]n= 2080 as 317 participants did not have a measured weight and height for calculation of BMI values [‡] IQR= interquartile range with 25th-75th percentile per consumer,[§] Including fruit juice, up to one serve (125mls or ½ a cup), [‖] up to one serve (125mls or ½ a cup).

Table 2.5. Proportions (%) of Australian young adults aged 18–34 years consuming fruit, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to Socio-Economic Index for Areas (SEIFA) and geographical location, National Nutrition and Physical Activity Survey 2011–12 (n 2397)

	SEIFA										
	Lowest 20%		**2nd Quintile**		**3rd Quintile**		**4th Quintile**		**Highest 20%**		
	%	**Median (IQR)‡**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Fruit without Juice	37.3	184(131-303)	51.5	175(107-334)	45.6	188(125-280)	42.2	185(105-333)	51.1	184(102-276)	**.001**
Total Fruit including Juice§	41.8	166(143-295)	59.9	164(150-314)	53.7	186(150-304)	51.0	181(150-303)	62.1	164(143-306)	**<.001**
Citrus Fruit	9.0	75.0(58.0-225)	10.7	131(75.0-193)	10.6	131(75.0-193)	11.8	75.0(75.0-150)	12.3	91.9(75-150)	.14
Pome Fruit	14.9	164(153-188)	23.2	164(153-188)	24.4	164(153-188)	19.7	173(153-188)	22.3	164(153-188)	.10
Tropical Fruit	7.5	73.5(10.8-294)	9.9	72.0(9.8-190)	7.3	40.0(23.3-73.9)	6.3	62.9(19.2-367)	9.7	51.0(16.4-159)	**.04**
Berries	13.4	36.0(20.8-83.3)	8.8	96.0(44.3-139)	6.7	38.5(23.3-72)	3.0	43.4(24.0-110)	11.2	30.7(18.0-66.0)	**.003**
Stone Fruit	7.5	151(83.3-165.4)	6.6	145(40.0-201)	4.9	145(75.0-151)	7.1	151(60.0-210)	7.1	118(46.4-290)	.23
Other Fruit	17.9	121(44.0-218)	13.9	78.0(26.0-156)	12.3	75.0(21.8-160)	10.7	126(62.9-170)	16.5	78.0(44.0-204)	**.02**
Dried Fruit	4.5	8(3.5-13.5)	10.2	26.8(10.8-50)	8.2	20.1(6.7-35)	4.1	21.6(16.3-50.0)	8.7	26.1(12.7-41.7)	**.02**
Fruit Juice‖	13.4	150(150-150)	20.0	150(150-150)	17.3	150(150-150)	15.3	150(150-150)	24.7	150(150-150)	**<.001**

	Geographical location						
	City		**Inner Regional**		**Outer regional/remote**		
	%	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	***P***
Total Fruit without Juice	49.1	188(128-307)	44.1	160(75-215)	44.8	188(102-294)	**.02**
Total Fruit including Juice§	57.9	170(150-304)	51.0	164(113-285)	51.9	187(150-309)	**.01**
Citrus Fruit	11.9	131(75.0-193)	8.3	93.0(75.0-150)	11.0	131(65.5-262)	.10
Pome Fruit	24.3	164(153-188)	20.1	164(135-188)	20.6	164(153-188)	.06
Tropical Fruit	8.0	51.0(16.4-190)	8.1	23.1(14.3-73.5)	9.9	56.6(40.0-193)	.54
Berries	7.6	38.5(24.0-101)	5.1	24.0(19.0-114)	9.6	56.6(24.0-80.2)	.06
Stone Fruit	6.5	151(60.0-217)	5.1	145(40.0-210)	7.2	145(66.0-151)	.52
Other Fruit	13.3	85.0(40.0-170)	11.0	78.0(26.4-156)	13.4	62.9(20.8-221)	.44
Dried Fruit	8.5	19.2(9.4-40.2)	9.8	16.7(13.4-51.2)	4.5	20.0(17.8-35.6)	**.02**
Fruit Juice‖	18.6	150(150-150)	15.9	150(150-150)	19.1	150(150-150)	.42

p for Kruskal–Wallis test on per capita intakes; significant P values indicated in bold font; †n= 2080 as 317 participants did not have a measured weight and height for calculation of BMI values ‡ IQR= interquartile range with 25th-75th percentile per consumer ,§ Including fruit juice, up to one serve (125mls or ½ a cup), ‖ up to one serve (125mls or ½ a cup).

Amounts of fruits and vegetables consumed

Median intake among consumers was 181.5 and 159.5 g for fruit and vegetables, respectively. This is equivalent to 1.2 servings of fruit and 2.1 servings of vegetables using Australian standard serving sizes. The median (interquartile range; 25th–75th percentile) intake of fried potatoes among 18–34-year-olds was 88.5 (55.0–134.3) g, which, if included, would bring the median servings of vegetables consumed to 3.3 servings. Intake of vegetables was lowest for 18–24-year-olds (P=0.002; Table 2.2). Fruit intake (including juice) was highest for the 30–34-year-olds (P=0.002), with females consuming more than males (P<0.001; Table 2.4). Those within the obese category reported the lowest intake of fruits (P=0.02; Table 2.4). While no significant differences were found between SEIFA quintiles for vegetable intake, consumption patterns were trending towards significance (P=0.06). Geographical location had no significant effect on vegetable intake. However, those within regional locations reported consuming more starchy vegetables (P<0.001) and less of the 'others' category (P=0.045; Table 2.3).

Comparison of per capita intake with Australian Guide to Healthy Eating recommendations

On average, 18–34-year-olds consumed 128 g (0.9 servings) of fruit, which was below the 300 g (2 servings) minimum daily recommendation. The mean vegetable intake was 205 g (2.7 servings), also below the 375 g (5 servings) minimum recommended daily intake. Approximately 15 % of the young adults consumed ≥5 servings of vegetables and ≥2 servings of fruit on the day prior to recall.

Fruit and vegetable variety

The variety of fruits and vegetables consumed by the respondents is presented in Table 2.6. Less than a quarter of population surveyed reported consuming 3–4 different vegetable categories on the day prior to the dietary recall. Among those who consumed vegetables, intake of starchy vegetables was high (approximately 1.2 servings) but consumption of the green and brassica group was less than half a serving (Table 2.2). A large proportion of the young adults consumed <1 type of fruit, with citrus, pome and stone fruits eaten the most among fruit consumers (Table 2.4). There were no differences in fruit variety (consuming ≥2 categories) by age or gender. However, those aged 18–24 years had the lowest vegetable variety score (P=0.01), with no differences by gender.

Table 2.6. Proportions of Australian young adults aged 18–34 years consuming a low, medium and high variety of vegetable and fruit sub-categories, National Nutrition and Physical Activity Survey 2011–12 (n 2397)

Number of subcategories consumed*	**18-24 year olds (n=780)**	**25-29 year olds (n=736)**	**30-34 year olds (n=881)**
VEGETABLES†		**Proportion (%) (n)**	
<1	26.9 (210)	19.8 (146)	21.3 (188)
1-2 (Low)	57.4 (448)	59.2 (436)	57.9 (510)
3-4 (Medium)	15.0 (117)§	18.9 (139)	19.6 (173)
≥5 (High)	0.6 (5)	2.0 (15)	1.1 (10)
FRUIT‡		**Proportion (%) (n)**	
<1	67.4 (526)	62.6 (461)	59.8 (527)
1 (Low)	24.2 (189)	28.0 (206)	29.7 (262)
2 (Medium)	6.7 (52)	8.4 (62)	8.7 (77)
≥3 (High)	1.7 (13)	1.0 (7)	1.7 (15)

*Consumption of a category defined as eating at least half a serving of fruit or vegetable within the category (≥37·5 g of vegetables or ≥75 g of fruit).
†Excluding fried potatoes.
‡Excluding fruit juice and dried fruit.
§Significant difference in proportion scoring ≥3 for vegetable variety score by age using post hoc χ2 analysis (z=3·0, P<0·008, Bonferroni-corrected P value).

Analysis by meal occasion

Differences in fruit and vegetable intake were observed across meal occasions ($P<0.001$). The highest mean intake of vegetables occurred at dinner (131 (SD 212) g, 1.75 servings), followed by lunch (64.7 (SD 101) g). Less than a quarter of a serving of vegetables was reported at

breakfast (12.5 (SD 52.2) g) and as snacks (15.5 (SD 64.5) g). Fruit consumption was highest between main meals with almost half a serving consumed as snacks (68.9 (SD 128) g). Table 2.7 demonstrates the differences in proportions consuming fruits and vegetables per meal occasion grouped according to the number of servings consumed throughout the day. Those consuming >5 vegetable servings daily had the highest proportion of consumers across all meals ($P<0.001$). Additionally, a larger proportion of respondents who consumed >2 fruit servings/d reported intake of fruit as a snack and at lunch compared with those consuming ≤1 serving/d ($P<0.001$; Table 2.7).

Table 2.7. Proportions (%) of Australian young adults aged 18–34 years consuming vegetables and fruits per meal occasion (breakfast, lunch, dinner and snacks), grouped according to the number of servings consumed throughout the day, National Nutrition and Physical Activity Survey 2011–12 (n 2397)

Vegetables							
Meal Occasion	**≤ 75 g/day ≤ 1 serve/day (n=490)**	**76-150g/day ≤ 2 serves/day (n=565)**	**151-225g/day ≤ 3 serves/day (n=305)**	**226-300g/day ≤ 4 serves/day (n=283)**	**301-375g/day ≤ 5 serves/day (n=182)**	**>375g/day > 5 serves/day (n=360)**	**p***
Breakfast	3.5	6.0	10.8	11.7	11.5	19.7	**<.001**
Lunch	47.8	58.9	64.9	67.5	78.6	71.1	**<.001**
Dinner	67.8	83.2	90.2	91.2	93.4	95.8	**<.001**
Snacks‡	12.2	12.4	15.4	20.1	19.8	25.3	**<.001**

Fruit†				
Meal Occasion	**≤150 g/day ≤ 1 serve/day (n=402)**	**151-300g/day ≤ 2 serves/day (n=479)**	**>300g/day > 2 serves/day (n=261)**	**p***
Breakfast	31.1	22.5	31.8	**.01**
Lunch	16.4	15.2	27.6	**<.001**
Dinner	18.2	10.9	15.3	**.01**
Snacks‡	46.3	78.7	81.2	**<.001**

*From $\chi2$ analysis of differences in proportions of persons consuming vegetables/fruits at each meal according to categories of servings consumed; significant P values indicated in bold font. †Excluding fruit juice. ‡Snacks included all foods consumed between main meals.

Associations between fruit and vegetable intake and lifestyle, anthropometry and sociodemographic variables: linear modelling

Table 2.8 shows the associations between fruit and vegetable intake and sociodemographic and lifestyle factors. A positive association was observed between age and fruit and vegetable intake (P=0.002, excluding juice; P=0.003 including juice; P<0.001, vegetables). When controlling for energy males consumed less vegetables than females (P=0.002). There were no associations found between BMI and intake (Table 2.8). While the removal of under-reporters increased β values positively, the associations remained non-significant. Living in outer regional and remote areas was associated with the lowest fruit intake (P=0.01, excluding juice). No associations were found between intake and SEIFA categories.

Table 2.8. Linear regression results: factors associated with vegetable and fruit intake among Australian young adults aged 18–34 years, National Nutrition and Physical Activity Survey 2011–12 (n 2397)

Socio-demographic variables	Vegetables Beta coefficients †	Fruit (excluding juice) Beta coefficients †	Fruit (including juice) Beta coefficients †
Age groups	**F = 10.3 p<.001**	**F = 6.1 p=.002**	**F = 6.0 p=.003**
18-24 years [R]	0.0	0.0	0.0
25-29 years	49.0	9.4	11.9
30-34 years	38.5	27.0	28.3
Gender	**F = 9.3 p=.002**	**F = 1.2 p=.28**	**F = .003 p=.95**
Male [R]	0.0	0.0	0.0
Female	31.6	7.2	0.4
BMI (kg/m^2)‡	**F =0.7 p=0.5**	**F = 1.6 p=0.2**	**F = 2.3 p=.08**
<18.5 [R]	-0.3	-20.8	-27.3
18.5-24.9	0.0	0.0	0.0
25-29.9	-18.0	0.7	-4.2
≥30	-15.3	-24.0	-31.8
SEIFA	**F = 0.8 p=0.5**	**F = 0.4 p=.82**	**F = 2.0 p=.09**
Lowest 20% [R]	0.0	0.0	0.0
2nd Quintile	13.1	-0.3	-5.3
3rd Quintile	4.6	8.3	13.7
4th Quintile	14.9	8.8	19.8
Highest 20%	24.1	3.3	13.6
Geographical location	**F = 1.5 p=0.2**	**F = 4.4 p=.01**	**F = 2.6 p=.07**
City [R]	0.0	0.0	0.0
Inner regional	16.0	-26.4	-21.6
Outer regional/remote	-21.1	-0.1	-2.4

†Beta co-efficients represent the adjusted mean difference between each sub-group and the reference group (R), based on per capita intake in grams (n=2397), after controlling for confounders including age, gender, BMI, SEIFA, geographical location, smoking status and alcohol intake; ‡under-reporters (n=386) excluded.

2.8 Discussion

The present secondary analysis of the 2011–12 NNPAS data confirms that fruit and vegetable intakes of young adults aged 18–34 years are suboptimal. The combined mean fruit and vegetable intake of the surveyed sample (328 g/d) fell short of the WHO standard, which recommends 400–500 g of fruits and vegetables daily for prevention of chronic disease risk (12) and aligns with previous reports on the global inadequacy of population intakes (52). Most Australian young adults also failed to consume a variety of fruits and vegetables, with those in the youngest age group (18–24 years) reporting the lowest intakes and variety. Analyses by sociodemographic variables revealed that males may need more support than females to improve intake as well as those in regional areas who have less access to a variety of fresh vegetables. These findings can inform policy and health promotion practice to effectively close the gap between current consumption levels and recommended intake.

Young adults consumed a mean of 0.9 and 2.7 servings of fruits and vegetables daily, respectively. This is higher than the ABS analysis for 19–30-year-olds (0.7 and 2.2 servings of fruits and vegetables) (53), but includes all sources of fruits and vegetables using disaggregated data. Overall, vegetable intake of young adults may be slightly better than reported in previous analysis but is still well below recommendations, and therefore public health messages promoting fruit and vegetable consumption remain important.

Previous data collected in 1995 do not report intake of young adults separately; however, mean daily intake for those aged 19 years or over was 3.6 servings of vegetables and approximately 1 serving of fruit (36). While the food items, classification of fruits and vegetables and method of analyses differed between the surveys, it is evident that intake of fruits and vegetables remains poor and is worsening. Thus, immediate action is required to assist this generation of adults to improve their intake.

Despite literature indicating that access to a variety of fruits and vegetables is lower and costs are higher in regional areas of Australia (39, 54-56), no differences in intake were observed between geographical locations. However, those within regional locations reported consuming more starchy vegetables and less of the 'others' category. As fruits and vegetables are highly perishable, the costs of transportation to remote areas are high and with desert climates, water shortages and soil prohibiting local production in some areas (57), it is not surprising that young adults in isolated rural areas consume less perishable vegetables. To address this, social marketing campaigns could focus on the promotion of nutritionally equivalent frozen and low-sugar and low-sodium canned fruits and vegetables as a means of increasing variety at low cost, particularly in regional areas. Examples include frozen berries or canned beans, tomatoes and mushrooms.

Studies in Australia have explored differences in fruit and vegetable intake by SES. While Giskes et al. identified lower intakes among adolescents living lower-SES areas (35), and the New South Wales population health survey results (2014) showed that fewer people in disadvantaged areas met fruit and vegetable recommendations (58), no studies have specifically looked at young adults. The present analysis found no differences in mean vegetable intake of young adults by SEIFA quintile. However, among the higher SEIFA group there was a trend towards greater consumption of the 'other vegetables', such as mushrooms and avocado, which tend to be more expensive. It may be worthwhile to run local rather than national campaigns that address the specific barriers relevant to fruit and vegetable intake for the population within their area of residence. With the perceived cost of vegetables identified as a significant barrier to intake among young adults (28, 59), campaigns could focus on budgeting for the inclusion of fruits and vegetables, particularly for lower SEIFA groups. Furthermore, previous research has indicated that there are no significant differences in knowledge of fruit and vegetable recommendations between socio-economic groups; however, those from higher SES quintiles scored significantly higher in their ability to make healthier food choices (60). This suggests the lower-SES areas may need extra support in translating knowledge into behaviour.

The analysis of patterns of fruit intake by SEIFA group revealed that while the lowest intake was recorded for those in the lowest SEIFA quintile, the highest intake of fruit juice was among those of the top SEIFA group. These results contrast what is seen in the USA, where the highest juice consumption is reported among those of lower SES (61). Industry reports on the trend of commercial fruit juice consumption estimate an annual growth in revenue from juice sales of 9.8 % in Australia (62). This proliferation of juice sales through outlets that offer ‘designer’ juices may be contributing to a trend for juice consumption among young adults of higher SEIFA. Previous research in Australia highlighted that such juices were seen as a fashion accessory by young adults (63). Although fruit juice can assist in meeting the recommended two fruit servings daily, the higher sugar and lower fibre content of these beverages and ease of overconsumption indicate that intake should continue to be monitored and emphasis placed on increasing whole fruit consumption and replacing juice with water. This is particularly important considering fruit juice promotes weight gain over the long term (64).

Overall, variety was poor among the young adults. Fruit consumers mainly reported intake of pome, citrus and stone fruit with lower intakes of berries and tropical fruit. Among vegetable consumers, intake of starchy vegetables was high but consumption of the green and brassica group was less than half a serving. While starchy vegetables contain carbohydrates (which provide energy) and some vitamins, green leafy and brassica vegetables are rich in folate which has been postulated to reduce the risk of cancer (18) and neural tube defects (65). They are also a good source of phytochemicals, Fe and vitamin C. Our estimates of vegetable intake counted potatoes prepared without fat as a starchy vegetable but did not include fried potatoes as per the Australian dietary guidelines. Among consumers the median intake of fried potatoes (1.2 servings) was proportionally high compared with other vegetables.

Only 12 % of the young adults surveyed consumed legumes. The consumption of legumes is of value, as they are a relatively inexpensive source of protein, Fe, fibre and micronutrients. Thus, promoting intake of these protein- and nutrient-rich vegetables to young adults can help to improve vegetable intake while also reducing the total cost of meals. Additionally, with previous research highlighting the effect of exposure to fruits and vegetables in the early years of life on intake and variety consumed in adulthood (66), continued work is needed to promote consumption in younger children with initiatives such as the Stephanie Alexander Kitchen Garden Program (67).

To our knowledge, the current analysis is the first to examine fruit and vegetable intake by meal occasion. The findings demonstrated that vegetables are consumed mainly at dinner and lunch, with an opportunity to increase intake at breakfast and as snacks. Fruit consumption was highest between main meals with almost half a serving consumed as snack. Additionally, a greater proportion of respondents who met or exceeded the daily recommendations consumed fruits and vegetables throughout the day. Thus, public health practitioners should consider encouraging intake at all meals to increase the likelihood of reaching the recommended daily intake of fruits and vegetables.

Finally, the low level of fruit and vegetable intake within the young adult population is a concern considering the continued risk of overweight and obesity in this age group (68). Given the cross-sectional nature of these data, it is not surprising that there was no association observed between BMI category and intake. Previous longitudinal studies have confirmed, however, that increasing vegetable intake is associated with a reduction in weight (69), with a recent systematic review confirming that consumption of whole fruit can reduce the risk for long-term weight gain in middle-aged adults (64). Thus, promoting vegetable and whole fruit intake to young adults, especially those of higher BMI, may be beneficial to weight maintenance in their transition into adulthood. Furthermore, given the additional benefits of increased fruit and vegetable intake in reducing the risk of cancer, CVD and all-cause mortality (70), promoting increased intake in this young generation may reduce the future burden of chronic disease.

Strengths and limitations

As with most dietary assessment methods, the 24 h recall has some measurement error introduced by inaccurate recall or estimation of intake (71). It is also important to note that those classified as 'non-consumers' on the day of the interview may not typically be non-consumers. Thus, one day recalls may not be a reflection of usual intake among individuals, but provide a good estimation and snapshot of consumption at a population level, allowing public health researchers to assess how intake changes over time. We also looked at the effect of under-reporting, with no significant effect found on associations.

A significant strength of our secondary analysis was the use of detailed intake data including fruits and vegetables consumed as part of any mixed dish, providing a more comprehensive estimation of intake. Future analysis could explore the major mixed-meal sources of fruits and vegetables.

Conclusions

Fruit and vegetable intake remains suboptimal for Australian young adults aged 18–34 years, with poorer intakes among 18–24-year-olds and males. Therefore, intensive efforts are warranted to effectively promote fruits and vegetables to this at-risk population group to increase intake as they transition into adulthood. The analyses documented herein highlight the specific opportunities for improving intake, namely supporting younger adults aged 18–24 years, with a focus on engaging males to increase vegetable intake, promoting fruits and vegetables at all meal occasions, with inclusion in mixed dishes, to increase likelihood of meeting daily requirements. For those in regional areas with limited access to a variety of fresh fruits and vegetables, canned and frozen options can be explored.

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2.10 Conclusion to chapter

The secondary analysis of the dietary intake of vegetables using the validated 24 hour recall method shows that intakes of fruits and vegetables are insufficient at 0.9 and 2.7 serves per day respectively. The analysis also revealed that vegetables were mainly consumed at dinner and lunch, and an opportunity exists to promote intake at breakfast and as snacks in an intervention. Other learnings are that males consume fewer vegetables per total kilojoule than females and that those aged 18 to 24 years have the worst intakes. Overall, the variety of fruits and vegetables consumed by the young adults was poor, particularly the consumption of green and brassica vegetables. Encouraging intake of a variety of vegetables throughout the day will be a key strategy for inclusion in the intervention. The next two chapters will synthesise what is known about electronic and mobile interventions and diet in young adults.

Appendix 2

Appendix 2.1

Table S1: Fruit and Vegetable categories as defined by the Australian Dietary Guidelines and Foundation diets

Vegetable Categories					
Green & Brassica	**Orange**	**Root/tubular/bulb**	**Other**	**Starchy**	**Legumes/beans**
Asparagus	Carrot	Artichoke	Alfalfa	Potato	Black beans
Basil	Pumpkin	Bamboo shoot	Avocado	Sweet potato	Black-eyed beans
Broccoflower		Beetroot	Bean sprout	Sweet Corn	Borlotti beans
Broccoli		Celery	Broad bean	Cassava	Cannellini beans
Brussels		Fennel	Butter bean	Taro	Chickpeas
Brussels sprout		Garlic	Capsicum		Faba (Fava) beans
Cabbage		Ginger	Chilli		Lentils
Cauliflower		Leek	Choko		Lima beans
Chicory		Onion	Cucumber		Lupin beans
Chives		Parsnip	Eggplant		Pinto beans
Endive		Radish	Melon, bitter		Red kidney beans
Green bean		Shallot	Mixed vegetable		Split peas
Green peas		Spring onion	Mushroom		Soy beans
Kale		Swede	Okra		Tofu
Lettuce		Turnip	Snowpea sprout		
Parsley/cress			Sprout		
Salad cabbage			Squash		
Seaweed			Tomato		
Silverbeet			Zucchini/marrow		
Snowpea					
Spinach/Rocket					
Bok choy and other Asian greens					
Fruit Categories					
Citrus	**Pome**	**Tropical Fruit**	**Berries**	**Stone**	**Other**
Grapefruit	Apple	Banana	Blackberry	Apricot	Feijoa
Lemon	Loquat	Guava	Blueberry	Cherry	Fig
Lime	Pear	Mango	Loganberry	Nectarine	Grapes
Mandarin	Quince	Melon	Raspberry	Peach	Kiwifruit
Orange		Pineapple	Strawberry	Plum	Lychee
Tangerine		Pawpaw			Melons
		Rambutan			Passionfruit
					Pomegranate

Appendix 2.2

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The fruit and vegetable intake of young Australian adults: a population perspective

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Abstract
Objective: To examine intakes and variety of fruit and vegetables consumed by Australian young adults, also assessing differences by meal occasion and sociodemographic characteristics.
Design: Secondary analysis of cross-sectional 24 h recall data collected through the 2011–12 National Nutrition and Physical Activity Survey. Crude means and proportions consuming fruits and vegetables were calculated. Pearson χ^2 tests, Kruskal–Wallis analyses and linear regression models were used to assess differences in mean intakes by age, BMI and sociodemographic variables. The variety eaten was determined based on the number of fruit and vegetable subgroups consumed.
Setting: Representative sample of metropolitan and rural areas across Australia.
Subjects: Respondents aged 18–34 years were included (n 2397).
Results: Mean daily intake of fruit (128 g/0·9 servings) and vegetables (205 g/2·7 servings) was lower than the minimum recommended intake set at 2 and 5 servings, respectively. Age was positively associated with fruit and vegetable intake ($P=0{\cdot}002$, $P<0{\cdot}001$), with 18–24-year-olds reporting the poorest vegetable variety compared with 25–29- and 30–34-year-olds ($P=0{\cdot}002$). When controlling for total energy, males consumed less vegetables than females ($P=0{\cdot}002$). A large proportion of the 15 % of respondents who consumed adequate amounts of fruits and vegetables on the day prior to the survey reported intake across all meal occasions ($P<0{\cdot}001$).
Conclusions: Fruit and vegetable intake is suboptimal among Australian young adults. An age-appropriate campaign is recommended to target increased consumption, particularly for those aged 18–24 years, with opportunity to promote increased variety and consumption across the day.

Keywords
Fruits
Vegetables
Young adults
Population studies

Fruits and vegetables are nutrient-dense foods, rich in fibre, vitamins, minerals and phytochemicals while being relatively low in energy. This makes them important components of a healthy diet. Regular consumption of an adequate intake is associated with lower risks of obesity[1], cancers[2–4], CVD[5–7], stroke[8], hypertension[9,10] and all-cause mortality[11]. Guidelines vary by country, although most are consistent with the WHO's minimum recommendation of 400–500 g of fruits and vegetables daily (excluding potatoes and other starchy tubers) to reduce the risk of chronic disease[12–14]. In the UK, five daily portions of fruits and vegetables (combined weight of 400 g) are recommended for health. This does not include starchy vegetables such as potatoes[14]. In Australia, two servings of fruits (150 g/serving) and five servings of vegetables (75 g/serving) are the minimum recommended daily intake for adults and include non-fried potatoes[15]. As these recommendations are based on gender-specific energy and nutrient requirements, adult males are recommended six servings of vegetables daily (total weight of 450 g). Variety is also encouraged to maximise dietary diversity and the bioavailability of nutrients and other beneficial phytochemicals[15–18].

Fruit and vegetable consumption levels are inadequate in many countries[19–23]. Internationally, the intake among young adults is particularly low[24,25]. Researchers and practitioners have made efforts to encourage intake and most recently the Australian government led the population-wide Go For 2&5® campaign which resulted in a combined increase in consumption by 0·8 servings/d[26].

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Despite these efforts the latest statistics indicate that 19–30-year-old Australians are the poorest consumers of fruits and vegetables among adults[27].

While formative research with young adults suggests that fruit and vegetable consumption is likely to increase during the transition to parenthood[28,29], if the pattern of suboptimal intake tracks into middle adulthood, it increases the risk of diet-related diseases among these adults and their offspring are likely to inherit these poor dietary patterns[30]. Thus, innovative interventions and campaigns are needed to positively influence fruit and vegetable intake of future generations of adults. For maximum effect, interventions should be tailored to the target population[31]. This requires an in-depth understanding of the current patterns of intake and determinants of consumption.

The determinants of fruit and vegetable intake have been well documented in the literature, with gender, socio-economic status (SES), personal preferences, availability and accessibility, and parental intake influencing consumption[32]. Australian-wide studies specifically evaluating fruit and vegetable intake according to demographic associations are limited and more than 10 years old[33–35], although there have been attempts to estimate intake at the state level such as the Western Australian report on intakes following the Go For 2&5 campaign[26]. Prior to the most recent nutrition survey measuring food and dietary patterns (the 2011–12 National Nutrition and Physical Activity Survey (NNPAS)), the last national survey was conducted in 1995[36]. Preliminary results of the recent national survey show that fruit and vegetable intake remains inadequate[27]. However, this analysis does not account for all sources of fruits and vegetables in the diet. Detailed secondary analysis including mixed dishes where fruits and vegetables make a minor contribution might yield more complete results.

In 1995, Australians living in areas of lower SES with low incomes had the lowest fruit and vegetable intakes[35]. Previous literature has also demonstrated that access to fresh fruits and vegetables varies with geographical location[37–39]. Other research has shown that increased vegetable intake can mediate weight loss in young adults[40]. To provide context for interventions, current relationships between intake, sociodemographic variables, and factors such as BMI should be examined.

Dietary guidelines based on epidemiological evidence recommend consumption of a variety of fruits and vegetables to maximise bioavailability of nutrients including phytochemicals and the unique health benefits they confer[15–17]. Thus, variety should be considered when planning interventions. Lastly, with recommendations set at five vegetable servings daily, it is unlikely that an individual will meet his/her requirements if vegetable consumption occurs in a single eating occasion. Thus, assessing distribution of intake across meal occasions is also of interest to discern opportunities for increased consumption.

Evaluating fruit and vegetable intake according to group characteristics and demographics can inform policy and health promotion practice to improve consumption levels. Thus, the present study aimed to conduct secondary analyses on the NNPAS data from 2011–12 in order to: (i) determine the intakes of fruits and vegetables among young adults (18–34-year-olds); (ii) evaluate variety of fruits and vegetables in the diets of young adults; (iii) investigate fruit and vegetable intakes by meal occasion (main meals *v.* snacks); and (iv) examine intakes according to sociodemographic variables such as age, gender, BMI, Socio-Economic Index for Areas (SEIFA) and geographical location.

Methods

Participants and dietary data methodology

The data analysed in the present study were collected as part of the 2011–12 Australian NNPAS by the Australian Bureau of Statistics (ABS). A detailed description of the survey methods including data collection and handling is available from the ABS[41]. Briefly, the 2011–12 NNPAS was conducted using nationally representative subsamples of the Australian Health Survey 2011–13. Trained ABS technicians collected dietary data on foods and beverages consumed using a computer-assisted personal interview, multiple-pass 24 h dietary recall. This method captured intakes of foods and beverages consumed by respondents on the day prior to the interview. To account for variations in intakes across seasons and days of the week, surveys were conducted over 12 months covering weekdays and weekends. Portion sizes were assessed by quantifying the amount of food the respondent consumed at one meal occasion. Rulers, rings, a grid, a wedge, various meat cuts and Australian-sourced drawings and photographs of actual-size food and drink containers in different shapes and sizes were provided in a food model booklet to help respondents estimate portion sizes, which were converted to grams by multiplying the volume specified by the food density[41]. A second 24 h recall was conducted with all participants asked to participate on a voluntary basis. Data from the second interview (computer-assisted telephone interview) was not included as only 64 % of respondents participated in the second dietary recall. The survey included a representative sample of city, metropolitan, rural and remote areas across the Australian States and Territories. In the present paper, secondary analyses were conducted on fruit and vegetable intake data of young adults aged 18–34 years. This age range was chosen to reflect definitions of young adulthood according to national health institutes in the USA and Australia[42,43]. However, as emerging adults may have quite different lifestyles from those aged 30–35 years[44], we further grouped into the following age categories: 18–24 years, 25–29 years and 30–34 years. Data were extracted from the Confidentialised Unit Record Files provided by the ABS (permission granted for use)[45].

Classification of fruits and vegetables

The Confidentialised Unit Record Files group food data for all respondents into categories. Further grouping was conducted to classify fruits and vegetables according to categories based on the foundation and total diet food models developed for dietary guidelines[18]. Fruits were categorised as citrus, pome, tropical, berries, stone or other; with a separate fruit juice category. Vegetables were grouped as green and brassica, orange, starchy, root/tubular/bulb or other, excluding fried potatoes. Legumes, fresh, canned, frozen and dried varieties of fruits and vegetables, as well as fruits and vegetables within mixed dishes were included in the analyses (see online supplementary material, Table S1). All fruits and vegetables in mixed dishes were included. The proportions of fruits and vegetables within all mixed dishes were determined based on ingredient weights reported within the 2011–13 AUSNUT food recipe file[46] and assigned to the appropriate fruit or vegetable category. Consumption of fruit juice exceeding 125 ml and fried potatoes were excluded from analyses in accordance with the Australian Guide to Healthy Eating recommendations which classify them as discretionary (non-core) items[15]. Fried potato intake was assessed and reported separately.

Assessment of fruit and vegetable intake

The total weight of fruits and vegetables consumed by each respondent was calculated as the sum of the fruit and vegetable categories, which included both individual fruits and vegetables and those from mixed dishes. Consumers and non-consumers were identified and proportions were established. The mean intakes of fruits and vegetables (grams) were calculated and converted to servings. Internationally there is variation in the definition of a serving. For example, in the UK, a serving of fruit or vegetables is equivalent to 80 g[47]. We used the Australian Guide to Healthy Eating[15] definition which specifies that a standard serving of fruit is equivalent to 150 g, while a serving of vegetables equates to 75 g, with a minimum of two servings of fruit and five servings of vegetables recommended daily for adults. These recommendations are based on gender-specific energy and nutrients requirements, such that adult males are recommended six servings of vegetables daily.

Variety and intake by meal occasion

The variety of fruits and vegetables eaten was calculated as the number of the fruit and vegetable categories consumed as defined in the online supplementary material, Table S1. Variety was assessed using a modified version of the scoring system developed by Magarey *et al.*[34]. Scoring was as follows: low variety (one type of fruit, one or two types of vegetable), medium variety (two types of fruit, three or four types of vegetable) and high variety (three or more types of fruit, five or more types of vegetable). For this analysis, consuming ≥50 % of a serving of a category of fruit or vegetable as defined in Table S1 (i.e. ≥75 g of fruit or ≥37·5 g of vegetables) was counted as consuming one type of fruit or vegetable. The number of different types consumed by each participant was summed to give his/her total variety score. Fruit juice was excluded from variety scoring as the type of fruit within these products was not differentiated as part of the current analyses. Dried fruit was also excluded as only a small proportion of the population reported consumption on the day prior to the dietary recall. Data were also categorised by meal occasion as breakfast, lunch, dinner or snacks, where snacks included brunch, morning tea, afternoon tea, snack, extended consumption and other. The mean fruit and vegetable intake at each meal occasion was determined. Further analyses were conducted to explore patterns in number of servings consumed across the day and proportions consuming fruits and vegetables per meal occasion.

Associations between fruit and vegetable intake and lifestyle, anthropometry and sociodemographic variables

To explore factors that may influence fruit and vegetable consumption, we evaluated the relationship between age, BMI, sociodemographic variables (SEIFA and geographical location), lifestyle factors and mean intakes. BMI was derived from the height and weight measurements taken objectively by the interviewer and categorised as underweight (≤18·5 kg/m^2), healthy weight (18·5–24·99 kg/m^2), overweight (25·0–29·99 kg/m^2) or obese (≥30·0 kg/m^2) based on the National Institutes of Health's cut-offs[48]. Respondents with no BMI recording (n 317) were coded as 'missing values' and omitted from BMI analyses. The SEIFA takes into consideration the impact of the area of residence, rather than an individual's income, occupation or level of education, on intake. Quintile 1 includes the most disadvantaged areas, while quintile 5 represents the least disadvantaged areas. Geographical location was categorised as inner regional Australia, city/metropolitan (capital cities and surrounds) and other (outer regional Australia, remote and very remote Australia). Data on smoking (smoker *v.* non-smoker) and alcohol consumption (grams per day) were also evaluated as potential confounders in regression models.

Statistics

Statistical analyses were conducted using the statistical software package IBM SPSS Statistics for Windows version 22.0. Data for those aged 18–34 years inclusive were extracted from the Confidentialised Unit Record Files. Subject weighting factors supplied by the ABS were applied to the data before analyses, to ensure they were more representative of the population by age, gender, area of residence and seasonal effect[41]. Under-reporters were identified as those with a ratio of energy intake to BMR of <0·87 based on the Goldberg cut-off[49], which has been used for identification of misreporting in previous national Australian surveys(50) and validated for use with 24 h recall data(51). Results are reported including under-reporters unless stated otherwise. Descriptive statistics were used to report fruit and vegetable intake. The mean intake per capita and median intake per consumer were determined and percentage consuming calculated. Differences in proportions of young adults consuming fruits and vegetables according gender, age, BMI, SEIFA and geographical location were assessed using Pearson's χ^2 tests. Differences in variety scores and proportions of persons consuming vegetables at each meal occasion according to categories of servings consumed were also determined by Pearson χ^2 tests. As data were not normally distributed, Kruskal–Wallis tests were applied to assess trends in intakes across categories and by age and gender, and to compare differences in intakes between meal occasions. Linear regression models were used to determine the relationship between fruit and vegetable intake and age, gender, BMI and sociodemographic variables (SEIFA and geographical location), controlling for energy intake and lifestyle factors (smoking status and alcohol intake). Statistical significance was set at $P<0.05$ for all tests.

Results

Characteristics

Table 1 summarises the characteristics of the sample of young adults included within the analyses (n 2397). The sample was evenly distributed across genders, age and SEIFA. Close to half the population were classed as overweight or obese (Table 1). Approximately 16 % of respondents were classed as under-reporters (n 386).

Proportions of young adults consuming fruits and vegetables

Proportions of young adults consuming fruits and vegetables, and the amounts consumed, according to age, gender, BMI, SEIFA and geographical location, are presented in Tables 2–5. Fifty-six per cent of respondents consumed fruit (48 % when excluding fruit juice) and 93 % consumed vegetables. A small percentage of respondents (4·3 %) did not consume any fruit or vegetables. A greater proportion of females consumed fruits than males (males, 40·6 %; females, 53·8 %; $P<0.001$). No significant differences were observed between genders for vegetable consumption (Table 2). Fewer young adults aged 18–24 years reported consuming fruits (Table 4), and the largest percentage of consumers was observed in the young adults of the highest SEIFA category for fruit when including juice (Table 5) and for vegetables (Table 3). The proportion consuming legumes on the day prior to the dietary recall was relatively low at 12·3 %. Pome fruit and fruit juice were the most popular fruit categories consumed (Table 4).

Table 1 Characteristics of the sample of Australian young adults from the National Nutrition and Physical Activity Survey 2011–12 (n 2397)

Characteristic	%	n
Sex		
Male	46·7	1120
Female	53·3	1277
Age (years)		
18–24	32·5	780
25–29	30·7	736
30–34	36·8	881
Socio-Economic Index for Areas (SEIFA)		
Lowest 20 %	18·8	451
Second quintile	20·8	499
Third quintile	20·4	490
Fourth quintile	17·5	419
Highest 20 %	22·4	538
Geographical location		
City	69·0	1654
Inner regional	17·0	408
Outer regional/remote	14·0	335
BMI (kg/m^2)*		
Underweight (<18·5)	3·2	67
Healthy weight (18·5–24·99)	47·1	979
Overweight (25·0–29·99)	32·2	669
Obese (≥30·0)	17·5	365
Currently smoking		
Yes	22·7	554
No	77·3	1854
Consumed alcohol on the day surveyed		
Yes	26·2	629
No	73·8	1768

*n 2080, 317 measurements not obtained.

Amounts of fruits and vegetables consumed

Median intake among consumers was 181·5 and 159·5 g for fruit and vegetables, respectively. This is equivalent to 1·2 servings of fruit and 2·1 servings of vegetables using Australian standard serving sizes. The median (inter-quartile range; 25th–75th percentile) intake of fried potatoes among 18–34-year-olds was 88·5 (55·0–134·3) g, which, if included, would bring the median servings of vegetables consumed to 3·3 servings. Intake of vegetables was lowest for 18–24-year-olds ($P=0.002$; Table 2). Fruit intake (including juice) was highest for the 30–34-year-olds ($P=0.002$), with females consuming more than males ($P<0.001$; Table 4). Those within the obese category reported the lowest intake of fruits ($P=0.02$; Table 4). While no significant differences were found between SEIFA quintiles for vegetable intake, consumption patterns were trending towards significance ($P=0.06$). Geographical location had no significant effect on vegetable intake. However, those within regional locations reported consuming more starchy vegetables ($P<0.001$) and less of the 'others' category ($P=0.045$; Table 3).

Comparison of per capita intake with Australian Guide to Healthy Eating recommendations

On average, 18–34-year-olds consumed 128 g (0·9 servings) of fruit, which was below the 300 g (2 servings) minimum daily recommendation. The mean vegetable intake was 205 g (2·7 servings), also below the 375 g

Table 2 Proportions (%) of Australian young adults aged 18–34 years consuming vegetables, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to age, gender and BMI, National Nutrition and Physical Activity Survey 2011–12 (*n* 2397)

	Gender							Age group (years)										
	Male			Female				18–24			25–29			30–34			
	%	Median	IQR	%	Median	IQR	*P**	%	Median	IQR	%	Median	IQR	%	Median	IQR	*P**
Total Veg‡	92·5	159	79·0–299	93·8	160	86·4–284	0·95	92·1	151	70·8–270	95·0	166	91·7–308	92·7	163	89·6–306	**0·002**
Green Veg	72·9	28·9	12·3–73·8	72·6	30·0	12·5–70·3	0·97	69·9	26·7	8·3–65·0	75·8	33·0	15·0–74·0	72·8	31·0	12·5–74·0	**0·002**
Legumes	12·5	44·8	8·5–148	12·1	38·6	6·8–137	0·70	10·6	26·4	4·5–120	13·0	50·0	8·7–138	13·1	44·0	13·4–140	0·24
Orange Veg	33·8	30·0	14·0–66·6	36·3	37·2	17·8–70·4	0·09	33·1	33·6	15·0–62·8	37·8	35·9	20·0–72·5	34·7	32·3	14·0–68·8	0·07
Root Veg	69·4	21·4	9·3–40·8	66·2	19·8	9·2–37·5	**0·004**	66·9	19·5	8·4–39·9	69·4	21·6	9·4–39·0	67·0	19·8	9·4–39·8	0·61
Other Veg	72·6	72·0	30·6–125	75·3	62·4	29·4–123	0·82	71·2	61·8	29·0–115	76·9	67·4	31·7–132	74·2	74·0	30·0–128	**0·004**
Starchy Veg	27·5	89·1	26·2–203	34·1	89·1	32·9–156	**0·001**	28·5	103	40·7–172	32·5	78·0	21·5–193	32·1	82·5	26·2–190	0·27

	BMI (kg/m^2)†												
	<18·5			18·5–24·99			25·0–29·99			≥30·0			
	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	*P**
Total Veg‡	95·5	155	110–241	94·2	161	82·2–306	93·0	158	90·6–304	91·2	159	68·1–304	0·36
Green Veg	67·2	21·2	7·6–60·1	73·0	28·9	12·3–63·3	74·0	32·5	13·0–80·2	70·7	28·8	15·0–73·4	0·80
Legumes	14·9	46·4	13·4–740	13·6	46·0	14·8–100	11·2	38·7	7·9–138	8·8	8·5	5·1–37·9	0·06
Orange Veg	31·3	45·4	25·0–71·9	35·1	34·1	16·7–75·0	35·1	34·5	16·7–70·0	36·2	28·5	14·0–70·2	0·97
Root Veg	68·7	16·7	10·7–57·9	68·1	24·1	10·0–41·6	66·8	17·7	8·0–40·0	67·9	16·3	7·5–36·5	0·27
Other Veg	71·6	70·0	39·4–110	76·0	64·5	31·3–131	72·9	74·9	34·8–124	72·9	58·5	26·0–115	0·11
Starchy Veg	31·3	97·3	43·4–137	31·2	96·8	28·3–187	30·5	92·5	24·2–203	31·8	82·5	19·2–203	0·92

*From Kruskal–Wallis test on per capita intakes; significant *P* values indicated in bold font.
†*n* 2080, as 317 participants did not have a measured weight and height for calculation of BMI values.
‡Excluding fried potatoes.

Table 3 Proportions (%) of Australian young adults aged 18–34 years consuming vegetables, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to Socio-Economic Index for Areas (SEIFA) and geographical location, National Nutrition and Physical Activity Survey 2011–12 (*n* 2397)

	SEIFA															
	Lowest 20 %			Second quintile			Third quintile			Fourth quintile			Highest 20 %			
	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	*P**
Total Veg†	90·0	152	71·8–270	93·6	153	73·0–301	92·2	174	95·2–308	94·3	166	84·5–280	95·5	152	86·1–310	0·06
Green Veg	68·1	28·1	12·5–70·0	73·5	28·9	12·3–71·4	71·0	30·7	12·5–72·2	75·9	29·6	12·3–76·9	75·1	31·0	12·3–63·3	0·12
Legumes	10·4	48·0	13·8–201	13·0	50·0	5·6–149	11·0	46·0	15·1–84·0	12·6	28·0	7·6–66·0	13·9	26·2	13·4–140	0·41
Orange Veg	32·4	37·1	24·8–77·5	38·3	32·4	16·7–58·5	35·9	35·9	15·0–76·8	31·5	33·1	12·8–71·9	36·6	30·0	15·0–57·7	0·39
Root Veg	64·1	24·4	9·4–38·1	70·1	17·9	7·6–39·3	66·5	21·6	10·0–41·8	68·5	19·2	8·3–39·8	69·0	22·8	10·7–40·8	0·41
Other Veg	64·7	68·5	29·0–124	73·1	59·5	31·7–116	73·9	61·9	27·0–118	78·5	65·6	34·4–130	79·4	74·0	35·0–130	**<0·001**
Starchy Veg	29·0	103	20·2–203	28·1	83·5	28·0–183	33·9	92·5	44·5–183	33·2	70·0	19·2–148	31·2	92·5	38·5–207	0·29

	Geographical location									
	City			Inner Regional			Outer regional/remote			
	%	Median	IQR	%	Median	IQR	%	Median	IQR	*P**
Total Veg†	93·5	158	82·4–279	92·9	188	92·0–330	92·2	133	73·0–294	0·15
Green Veg	73·8	28·7	12·3–70·8	71·1	31·8	15·0–76·3	69·6	38·4	17·0–70·0	0·75
Legumes	12·6	44·8	13·4–140	12·0	22·0	4·2–120	11·0	49·7	6·8–138	0·71
Orange Veg	34·2	32·8	15·5–67·0	37·0	40·5	26·0–70·2	37·3	26·0	14·0–68·8	0·30
Root Veg	68·6	20·5	9·4–40·8	66·7	20·4	7·1–35·0	64·8	16·3	8·3–34·6	0·31
Other Veg	75·8	67·1	30·6–126	68·9	62·4	29·0–124	71·9	61·8	29·0–107	**0·045**
Starchy Veg	30·1	80·8	25·7–168	38·2	110	51·9–196	26·9	107	46·6–193	**<0·001**

*From Kruskal–Wallis test on per capita intakes; significant *P* values indicated in bold font.
†Excluding fried potatoes.

Table 4 Proportions (%) of Australian young adults aged 18–34 years consuming fruit, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to age, gender and BMI, National Nutrition and Physical Activity Survey 2011–12 (*n* 2397)

	Gender							Age group (years)									
	Male			Female				18–24			25–29			30–34			
	%	Median	IQR	%	Median	IQR	*P**	%	Median	IQR	%	Median	IQR	%	Median	IQR	*P**
Total Fruit without Juice	40·6	188	114–359	53·8	175	103–262	**<0·001**	41·8	184	114–309	49·0	175	90–263	51·6	184	131–300	**0·002**
Total Fruit including Juice‡	50·8	164	150–314	59·4	178	139–298	**<0·001**	49·6	166	150–310	57·3	167	150–295	58·3	175	150–304	**0·002**
Citrus Fruit	10·3	131	75·0–193	12·0	93·0	75·0–150	0·21	9·7	131	65·5–193	12·4	75·0	75·0–150	11·5	131	75·0–150	0·23
Pome Fruit	20·8	173	164–196	25·1	164	143–188	**0·045**	21·3	164	143–188	23·0	164	158–188	24·7	164	164–188	0·23
Tropical Fruit	7·2	55·5	18·0–245	9·2	45·0	18·5–112	0·08	9·6	51·0	21·2–184	7·6	45·0	10·5–159	7·7	44·3	18·0–184	0·27
Berries	4·7	44·3	24·0–124	9·8	38·5	24·0–70·1	**0·001**	6·4	35·2	19·0–110	7·2	57·7	24·0–135	8·5	41·9	24·0–80·0	0·28
Stone Fruit	5·2	151	66·0–295	7·4	145	54·0–151	**0·03**	5·8	140	23·3–166	5·7	145	47·3–175	7·5	151	109–288	0·23
Other Fruit	9·3	85·8	27·0–156	16·1	78·0	40·0–175	**<0·001**	11·4	85·8	40·0–175	11·5	78·0	23·3–170	15·4	78·0	44·5–170	**0·02**
Dried Fruit	8·0	24·1	8·9–50·0	8·3	18·8	10·8–32·0	0·87	5·1	13·8	7·8–26·8	9·1	23·0	15·3–46·9	10·1	21·2	9·4–46·9	**<0·001**
Fruit Juice§	19·3	150	150–150	17·3	150	150–150	0·17	16·7	150	150–150	19·4	150	150–150	18·6	150	150–150	0·41

	BMI (kg/m^2)†												
	<18·5			18·5–24·99			25·0–29·99			≥30·0			
	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	*P**
Total Fruit without Juice	37·3	219	164–343	51·5	170	81·0–290	45·6	188	150–315	42·2	164	75·0–262	**0·02**
Total Fruit including Juice‡	41·8	179	152–384	59·9	169	143–296	53·7	174	150–315	51·0	162	94·0–274	**0·01**
Citrus Fruit	9·0	15·7	15·7–131	10·7	92·8	75·0–150	10·6	131	75·0–193	11·8	99·0	75·0–193	0·10
Pome Fruit	14·9	164	37·9–164	23·2	164	153–188	24·4	164	164–188	19·7	164	153–188	0·06
Tropical Fruit	7·5	51·0	51·0–190	9·9	41·9	18·0–159	7·3	73·5	23·1–367	6·3	83·3	25·1–367	0·54
Berries	13·4	36·0	27·4–139	8·8	38·8	24·0–110	6·7	36·8	19·0–88·0	3·0	83·3	24·0–159	0·06
Stone Fruit	7·5	145	18·3–165	6·6	145	60·0–217	4·9	145	75·0–176	7·1	151	83·3–210	0·52
Other Fruit	17·9	68·8	13·9–100	13·9	85·0	27·0–175	12·3	136	33·3–160	10·7	78·0	44·0–170	0·44
Dried Fruit	4·5	50·0	50·0–150	10·2	18·8	12·7–40·2	8·2	24·1	9·4–46·9	4·1	8·5	4·2–24·0	**0·02**
Fruit Juice§	13·4	150	150–150	20·0	150	150–150	17·3	150	150–150	15·3	150	150–150	0·42

*From Kruskal–Wallis test on per capita intakes; significant *P* values indicated in bold font.
†*n* 2080, as 317 participants did not have a measured weight and height for calculation of BMI values.
‡Including fruit juice, up to 1 serving (125 ml or ½ cup).
§Up to 1 serving (125 ml or ½ cup).

Table 5 Proportions (%) of Australian young adults aged 18–34 years consuming fruit, and the median intake and interquartile range ((IQR); 25th–75th percentile) per consumer (g/d), according to Socio-Economic Index for Areas (SEIFA) and geographical location, National Nutrition and Physical Activity Survey 2011–12 (*n* 2397)

	SEIFA															
	Lowest 20 %			Second quintile			Third quintile			Fourth quintile			Highest 20 %			
	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	%	Median	IQR	*P**
Total Fruit without Juice	37·3	184	131–303	51·5	175	107–334	45·6	188	125–280	42·2	185	105–333	51·1	184	102–276	**0·001**
Total Fruit including Juice†	41·8	166	143–295	59·9	164	150–314	53·7	186	150–304	51·0	181	150–303	62·1	164	143–306	**<0·001**
Citrus Fruit	9·0	75·0	58·0–225	10·7	131	75·0–193	10·6	131	75·0–193	11·8	75·0	75·0–150	12·3	91·9	75·0–150	0·14
Pome Fruit	14·9	164	153–188	23·2	164	153–188	24·4	164	153–188	19·7	173	153–188	22·3	164	153–188	0·10
Tropical Fruit	7·5	73·5	10·8–294	9·9	72·0	9·8–190	7·3	40·0	23·3–73·9	6·3	62·9	19·2–367	9·7	51·0	16·4–159	**0·04**
Berries	13·4	36·0	20·8–83·3	8·8	96·0	44·3–139	6·7	38·5	23·3–72·0	3·0	43·4	24·0–110	11·2	30·7	18·0–66·0	**0·003**
Stone Fruit	7·5	151	83·3–165	6·6	145	40·0–201	4·9	145	75·0–151	7·1	151	60·0–210	7·1	118	46·4–290	0·23
Other Fruit	17·9	121	44·0–218	13·9	78·0	26·0–156	12·3	75·0	21·8–160	10·7	126	62·9–170	16·5	78·0	44·0–204	**0·02**
Dried Fruit	4·5	8·0	3·5–13·5	10·2	26·8	10·8–50·0	8·2	20·1	6·7–35·0	4·1	21·6	16·3–50·0	8·7	26·1	12·7–41·7	**0·02**
Fruit Juice‡	13·4	150	150–150	20·0	150	150–150	17·3	150	150–150	15·3	150	150–150	24·7	150	150–150	**<0·001**
	Geographical location															
	City			Inner regional			Outer regional/remote									
	%	Median	IQR	%	Median	IQR	%	Median	IQR							*P**
Total Fruit without Juice	49·1	188	128–307	44·1	160	75·0–215	44·8	188	102–294							**0·02**
Total Fruit including Juice†	57·9	170	150–304	51·0	164	113–285	51·9	187	150–309							**0·01**
Citrus Fruit	11·9	131	75·0–193	8·3	93·0	75·0–150	11·0	131	65·5–262							0·10
Pome Fruit	24·3	164	153–188	20·1	164	135–188	20·6	164	153–188							0·06
Tropical Fruit	8·0	51·0	16·4–190	8·1	23·1	14·3–73·5	9·9	56·6	40·0–193							0·54
Berries	7·6	38·5	24·0–101	5·1	24·0	19·0–114	9·6	56·6	24·0–80·2							0·06
Stone Fruit	6·5	151	60·0–217	5·1	145	40·0–210	7·2	145	66·0–151							0·52
Other Fruit	13·3	85·0	40·0–170	11·0	78·0	26·4–156	13·4	62·9	20·8–221							0·44
Dried Fruit	8·5	19·2	9·4–40·2	9·8	16·7	13·4–51·2	4·5	20·0	17·8–35·6							0·02
Fruit Juice‡	18·6	150	150–150	15·9	150	150–150	19·1	150	150–150							0·42

*From Kruskal–Wallis test on per capita intakes; significant *P* values indicated in bold font.
†Including fruit juice, up to 1 serving (125 ml or ½ cup).
‡Up to 1 serving (125 ml or ½ cup).

Table 6 Proportions of Australian young adults aged 18–34 years consuming a low, medium and high variety of vegetable and fruit sub-categories, National Nutrition and Physical Activity Survey 2011–12 (*n* 2397)

	18–24-year-olds (*n* 780)		25–29-year-olds (*n* 736)		30–34-year-olds (*n* 881)	
Number of sub-categories consumed*	%	*n*	%	*n*	%	*n*
Vegetables†						
<1	26·9	210	19·8	146	21·3	188
1–2 (low)	57·4	448	59·2	436	57·9	510
3–4 (medium)	15·0§	117	18·9	139	19·6	173
≥5 (high)	0·6	5	2·0	15	1·1	10
Fruit‡						
<1	67·4	526	62·6	461	59·8	527
1 (low)	24·2	189	28·0	206	29·7	262
2 (medium)	6·7	52	8·4	62	8·7	77
≥3 (high)	1·7	13	1·0	7	1·7	15

*Consumption of a category defined as eating at least half a serving of fruit or vegetable within the category (≥37·5 g of vegetables or ≥75 g of fruit).
†Excluding fried potatoes.
‡Excluding fruit juice and dried fruit.
§Significant difference in proportion scoring ≥3 for vegetable variety score by age using *post hoc* χ^2 analysis ($z=3·0$, $P<0·008$, Bonferroni-corrected *P* value).

(5 servings) minimum recommended daily intake. Approximately 15 % of the young adults consumed ≥5 servings of vegetables and ≥2 servings of fruit on the day prior to recall.

Fruit and vegetable variety

The variety of fruits and vegetables consumed by the respondents is presented in Table 6. Less than a quarter of population surveyed reported consuming 3–4 different vegetable categories on the day prior to the dietary recall. Among those who consumed vegetables, intake of starchy vegetables was high (approximately 1·2 servings) but consumption of the green and brassica group was less than half a serving (Table 2). A large proportion of the young adults consumed <1 type of fruit, with citrus, pome and stone fruits eaten the most among fruit consumers (Table 4). There were no differences in fruit variety (consuming ≥2 categories) by age or gender. However, those aged 18–24 years had the lowest vegetable variety score ($P=0·01$), with no differences by gender.

Analysis by meal occasion

Differences in fruit and vegetable intake were observed across meal occasions ($P<0·001$). The highest mean intake of vegetables occurred at dinner (131 (sd 212) g, 1·75 servings), followed by lunch (64·7 (sd 101) g). Less than a quarter of a serving of vegetables was reported at breakfast (12·5 (sd 52·2) g) and as snacks (15·5 (sd 64·5) g). Fruit consumption was highest between main meals with almost half a serving consumed as snacks (68·9 (sd 128) g). Table 7 demonstrates the differences in proportions consuming fruits and vegetables per meal occasion grouped according to the number of servings consumed throughout the day. Those consuming >5 vegetable servings daily had the highest proportion of consumers across all meals ($P<0·001$). Additionally, a larger proportion of respondents who consumed >2 fruit servings/d reported intake of fruit as a snack and at lunch compared with those consuming ≤1 serving/d ($P<0·001$; Table 7).

Associations between fruit and vegetable intake and lifestyle, anthropometry and sociodemographic variables: linear modelling

Table 8 shows the associations between fruit and vegetable intake and sociodemographic and lifestyle factors. A positive association was observed between age and fruit and vegetable intake ($P=0·002$, excluding juice; $P=0·003$ including juice; $P<0·001$, vegetables). When controlling for energy males consumed less vegetables than females ($P=0·002$). There were no associations found between BMI and intake (Table 8). While the removal of under-reporters increased β values positively, the associations remained non-significant. Living in outer regional and remote areas was associated with the lowest fruit intake ($P=0·01$, excluding juice). No associations were found between intake and SEIFA categories.

Discussion

The present secondary analysis of the 2011–12 NNPAS data confirms that fruit and vegetable intakes of young adults aged 18–34 years are suboptimal. The combined mean fruit and vegetable intake of the surveyed sample (328 g/d) fell short of the WHO standard, which recommends 400–500 g of fruits and vegetables daily for prevention of chronic disease risk[12] and aligns with previous reports on the global inadequacy of population intakes[52]. Most Australian young adults also failed to consume a variety of fruits and vegetables, with those in the youngest age group (18–24 years) reporting the lowest intakes and variety. Analyses by sociodemographic variables revealed that males may need more support than females to improve intake as well as those in regional areas who have

Table 7 Proportions (%) of Australian young adults aged 18–34 years consuming vegetables and fruits per meal occasion (breakfast, lunch, dinner and snacks), grouped according to the number of servings consumed throughout the day, National Nutrition and Physical Activity Survey 2011–12 (*n* 2397)

	Vegetables						
Meal occasion	≤75 g/d ≤1 serving/d (*n* 490)	76–150 g/d ≤2 servings/d (*n* 565)	151–225 g/d ≤3 servings/d (*n* 305)	226–300 g/d ≤4 servings/d (*n* 283)	301–375 g/d ≤5 servings/d (*n* 182)	>375 g/d >5 servings/d (*n* 360)	*P**
Breakfast	3·5	6·0	10·8	11·7	11·5	19·7	**<0·001**
Lunch	47·8	58·9	64·9	67·5	78·6	71·1	**<0·001**
Dinner	67·8	83·2	90·2	91·2	93·4	95·8	**<0·001**
Snacks‡	12·2	12·4	15·4	20·1	19·8	25·3	**<0·001**

	Fruit†			
Meal occasion	≤150 g/d ≤1 serving/d (*n* 402)	151–300 g/d ≤2 servings/d (*n* 479)	>300 g/d >2 servings/d (*n* 261)	*P**
Breakfast	31·1	22·5	31·8	0·01
Lunch	16·4	15·2	27·6	**<0·001**
Dinner	18·2	10·9	15·3	**0·01**
Snacks‡	46·3	78·7	81·2	**<0·001**

*From χ^2 analysis of differences in proportions of persons consuming vegetables/fruits at each meal according to categories of servings consumed; significant *P* values indicated in bold font.
†Excluding fruit juice.
‡Snacks included all foods consumed between main meals.

Table 8 Linear regression results: factors associated with vegetable and fruit intake among Australian young adults aged 18–34 years, National Nutrition and Physical Activity Survey 2011–12 (*n* 2397)

Sociodemographic variable	Vegetables β coefficient*	Fruit (excluding juice) β coefficient*	Fruit (including juice) β coefficient*
Age group (years)	$F=10·3$, $P<0·001$	$F=6·1$, $P=0·002$	$F=6·0$, $P=0·003$
18–24[R]	0·0	0·0	0·0
25–29	49·0	9·4	11·9
30–34	38·5	27·0	28·3
Gender	$F=9·3$, $P=0·002$	$F=1·2$, $P=0·28$	$F=0·003$, $P=0·95$
Male[R]	0·0	0·0	0·0
Female	31·6	7·2	0·4
BMI (kg/m^2)‡	$F=0·7$, $P=0·5$	$F=1·6$, $P=0·2$	$F=2·3$, $P=0·08$
<18·5[R]	−0·3	−20·8	−27·3
18·5–24·99	0·0	0·0	0·0
25·0–29·99	−18·0	0·7	−4·2
≥30·0	−15·3	−24·0	−31·8
Socio-Economic Index for Areas (SEIFA)	$F=0·8$, $P=0·5$	$F=0·4$, $P=0·82$	$F=2·0$, $P=0·09$
Lowest 20 %[R]	0·0	0·0	0·0
Second quintile	13·1	−0·3	−5·3
Third quintile	4·6	8·3	13·7
Fourth quintile	14·9	8·8	19·8
Highest 20 %	24·1	3·3	13·6
Geographical location	$F=1·5$, $P=0·2$	$F=4·4$, $P=0·01$	$F=2·6$, $P=0·07$
City[R]	0·0	0·0	0·0
Inner regional	16·0	−26·4	−21·6
Outer regional/remote	−21·1	−0·1	−2·4

*Beta coefficients represent the adjusted mean difference between each subgroup and the reference group (R), based on per capita intake in grams (*n* 2397), after controlling for confounders including age, gender, BMI, SEIFA, geographical location, smoking status and alcohol intake.
†Under-reporters (*n* 386) excluded.

less access to a variety of fresh vegetables. These findings can inform policy and health promotion practice to effectively close the gap between current consumption levels and recommended intake.

Young adults consumed a mean of 0·9 and 2·7 servings of fruits and vegetables daily, respectively. This is higher than the ABS analysis for 19–30-year-olds (0·7 and 2·2 servings of fruits and vegetables)[53], but includes all sources of fruits and vegetables using disaggregated data. Overall, vegetable intake of young adults may be slightly better than reported in previous analysis but is still well below recommendations, and therefore public health messages promoting fruit and vegetable consumption remain important.

Previous data collected in 1995 do not report intake of young adults separately; however, mean daily intake for those aged 19 years or over was 3·6 servings of vegetables and approximately 1 serving of fruit[36]. While the food items, classification of fruits and vegetables and method of analyses differed between the surveys, it is evident that intake of fruits and vegetables remains poor and is worsening. Thus, immediate action is required to assist this generation of adults to improve their intake.

Despite literature indicating that access to a variety of fruits and vegetables is lower and costs are higher in regional areas of Australia[39,54–56], no differences in intake were observed between geographical locations. However, those within regional locations reported consuming more starchy vegetables and less of the 'others' category. As fruits and vegetables are highly perishable, the costs of transportation to remote areas are high and with desert climates, water shortages and soil prohibiting local production in some areas[57], it is not surprising that young adults in isolated rural areas consume less perishable vegetables. To address this, social marketing campaigns could focus on the promotion of nutritionally equivalent frozen and low-sugar and low-sodium canned fruits and vegetables as a means of increasing variety at low cost, particularly in regional areas. Examples include frozen berries or canned beans, tomatoes and mushrooms.

Studies in Australia have explored differences in fruit and vegetable intake by SES. While Giskes *et al.* identified lower intakes among adolescents living lower-SES areas[35], and the New South Wales population health survey results (2014) showed that fewer people in disadvantaged areas met fruit and vegetable recommendations[58], no studies have specifically looked at young adults. The present analysis found no differences in mean vegetable intake of young adults by SEIFA quintile. However, among the higher SEIFA group there was a trend towards greater consumption of the 'other vegetables', such as mushrooms and avocado, which tend to be more expensive. It may be worthwhile to run local rather than national campaigns that address the specific barriers relevant to fruit and vegetable intake for the population within their area of residence. With the perceived cost of vegetables identified as a significant barrier to intake among young adults[28,59], campaigns could focus on budgeting for the inclusion of fruits and vegetables, particularly for lower SEIFA groups. Furthermore, previous research has indicated that there are no significant differences in knowledge of fruit and vegetable recommendations between socio-economic groups; however, those from higher SES quintiles scored significantly higher in their ability to make healthier food choices[60]. This suggests the lower-SES areas may need extra support in translating knowledge into behaviour.

The analysis of patterns of fruit intake by SEIFA group revealed that while the lowest intake was recorded for those in the lowest SEIFA quintile, the highest intake of fruit juice was among those of the top SEIFA group. These results contrast what is seen in the USA, where the highest juice consumption is reported among those of lower SES[61]. Industry reports on the trend of commercial fruit juice consumption estimate an annual growth in revenue from juice sales of 9·8 % in Australia[62]. This proliferation of juice sales through outlets that offer 'designer' juices may be contributing to a trend for juice consumption among young adults of higher SEIFA. Previous research in Australia highlighted that such juices were seen as a fashion accessory by young adults[63]. Although fruit juice can assist in meeting the recommended two fruit servings daily, the higher sugar and lower fibre content of these beverages and ease of overconsumption indicate that intake should continue to be monitored and emphasis placed on increasing whole fruit consumption and replacing juice with water. This is particularly important considering fruit juice promotes weight gain over the long term[64].

Overall, variety was poor among the young adults. Fruit consumers mainly reported intake of pome, citrus and stone fruit with lower intakes of berries and tropical fruit. Among vegetable consumers, intake of starchy vegetables was high but consumption of the green and brassica group was less than half a serving. While starchy vegetables contain carbohydrates (which provide energy) and some vitamins, green leafy and brassica vegetables are rich in folate which has been postulated to reduce the risk of cancer[18] and neural tube defects[65]. They are also a good source of phytochemicals, Fe and vitamin C. Our estimates of vegetable intake counted potatoes prepared without fat as a starchy vegetable but did not include fried potatoes as per the Australian dietary guidelines. Among consumers the median intake of fried potatoes (1·2 servings) was proportionally high compared with other vegetables.

Only 12 % of the young adults surveyed consumed legumes. The consumption of legumes is of value, as they are a relatively inexpensive source of protein, Fe, fibre and micronutrients. Thus, promoting intake of these protein- and nutrient-rich vegetables to young adults can help to improve vegetable intake while also reducing the total cost of meals. Additionally, with previous research highlighting the effect of exposure to fruits and vegetables in the early years of life on intake and variety consumed in adulthood[66], continued work is needed to promote consumption in younger children with initiatives such as the Stephanie Alexander Kitchen Garden Program[67].

To our knowledge, the current analysis is the first to examine fruit and vegetable intake by meal occasion. The findings demonstrated that vegetables are consumed mainly at dinner and lunch, with an opportunity to increase intake at breakfast and as snacks. Fruit consumption was highest between main meals with almost half a serving consumed as snack. Additionally, a greater proportion of respondents who met or exceeded the daily recommendations consumed fruits and vegetables throughout the day. Thus, public health practitioners should consider encouraging intake at all meals to increase the likelihood of reaching the recommended daily intake of fruits and vegetables.

Finally, the low level of fruit and vegetable intake within the young adult population is a concern considering the continued risk of overweight and obesity in this age group[68]. Given the cross-sectional nature of these data, it is not surprising that there was no association observed between BMI category and intake. Previous longitudinal studies have confirmed, however, that increasing vegetable intake is associated with a reduction in weight[69], with a recent systematic review confirming that consumption of whole fruit can reduce the risk for long-term weight gain in middle-aged adults[64]. Thus, promoting vegetable and whole fruit intake to young adults, especially those of higher BMI, may be beneficial to weight maintenance in their transition into adulthood. Furthermore, given the additional benefits of increased fruit and vegetable intake in reducing the risk of cancer, CVD and all-cause mortality[70], promoting increased intake in this young generation may reduce the future burden of chronic disease.

Strengths and limitations

As with most dietary assessment methods, the 24 h recall has some measurement error introduced by inaccurate recall or estimation of intake[71]. It is also important to note that those classified as 'non-consumers' on the day of the interview may not typically be non-consumers. Thus, one day recalls may not be a reflection of usual intake among individuals, but provide a good estimation and snapshot of consumption at a population level, allowing public health researchers to assess how intake changes over time. We also looked at the effect of under-reporting, with no significant effect found on associations.

A significant strength of our secondary analysis was the use of detailed intake data including fruits and vegetables consumed as part of any mixed dish, providing a more comprehensive estimation of intake. Future analysis could explore the major mixed-meal sources of fruits and vegetables.

Conclusions

Fruit and vegetable intake remains suboptimal for Australian young adults aged 18–34 years, with poorer intakes among 18–24-year-olds and males. Therefore, intensive efforts are warranted to effectively promote fruits and vegetables to this at-risk population group to increase intake as they transition into adulthood. The analyses documented herein highlight the specific opportunities for improving intake, namely supporting younger adults aged 18–24 years, with a focus on engaging males to increase vegetable intake, promoting fruits and vegetables at all meal occasions, with inclusion in mixed dishes, to increase likelihood of meeting daily requirements. For those in regional areas with limited access to a variety of fresh fruits and vegetables, canned and frozen options can be explored.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1368980017001124

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Chapter 3: Efficacy and external validity of electronic and mobile phone-based interventions promoting vegetable intake in young adults: A systematic review protocol.

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3.1 Publication details

This chapter presents the manuscript titled 'Efficacy and external validity of electronic and mobile phone-based interventions promoting vegetable intake in young adults: A systematic review protocol.' published in *Journal of Medical Internet Research: Research Protocols*, 2015, Volume 4, Issue 3:e92, doi:10.2196/resprot.4665 (see *Appendix 3*). It has been reformatted but contains exactly the same text.

3.2 Author contribution

I Monica Marina Nour (the candidate) was the primary researcher involved in developing the research question, search strategy and study design. The School Librarian, Rod Dyson assisted with refining the search strategy. I summarised the information and wrote the initial draft of this review protocol that was edited by the co-authors.

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3.3 Introduction to chapter

This chapter presents the protocol for a systematic review which aims to determine the effectiveness of randomised controlled trials harnessing modern communication technology such as texting, internet forums and websites for the delivery of interventions targeting the fruit and vegetable intakes of young adults. The review also aimed to assess the reporting of items needed for translation of programs to the population (external validity). Details of the frameworks/checklists used to guide this review protocol are provided as well as a description of the proposed search strategy and method of assessing study quality and risk of bias.

3.4 Abstract

Background

Despite social marketing campaigns and behavior change interventions, young adults remain among the lowest consumers of vegetables. The digital era offers potential new avenues for both social marketing and individually tailored programs, through texting, web, and mobile applications. The effectiveness and generalizability of such programs have not been well documented.

Objective

The aim of this systematic review is to evaluate the efficacy and external validity of social marketing, electronic, and mobile phone-based (mHealth) interventions aimed at increasing vegetable intake in young adults.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol will be used to conduct this systematic review. The search strategy will be executed across eleven electronic databases using combinations of the following search terms: "online intervention", "computer-assisted therapy", "internet", "website", "cell phones", "cyber", "telemedicine", "email", "social marketing", "social media", "mass media", "young adult", and "fruit and vegetables". The reference lists of included studies will also be searched for additional citations. Titles and abstracts will be screened against inclusion criteria and full texts of potentially eligible papers will be assessed by two independent reviewers. Data from

eligible papers will be extracted. Quality and risk of bias will be assessed using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies and The Cochrane Collaboration Risk of Bias assessment tool respectively. The external validity of the studies will be determined based on components such as reach, adoption, and representativeness of participants; intervention implementation and adaption; and program maintenance and institutionalization. Results will be reported quantitatively and qualitatively.

Results

Our research is in progress. A draft of the systematic review is currently being produced for publication by the end of 2015.

Conclusions

The review findings will assist the design and implementation of future eHealth and mHealth programs aimed at improving vegetable consumption in young adults.

Trial Registration

PROSPERO International Prospective Register of Systematic Reviews: CRD42015017763; http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015017763#.VVKtqfmqqko (Archived by WebCite at http://www.webcitation.org/6YU2UYrTn).

3.5 Introduction

The Forgotten Age Group

Despite national and global social marketing campaigns and behavior change interventions, the current population's intake of vegetables remains low (1). Among Australian adults, young adults are least likely to meet the recommended five or more serves a day (2). As they transition from parental supervision to independent living, young adults are establishing self-determined food habits that will have implications for their future health. It can take decades before diet-related diseases appear; however, a strong association has been established between fruit and vegetable consumption and a decreased risk of chronic diseases (3-11). For this age group, promoting the well-established long-term health benefits of vegetable consumption, as is typically done in nationwide social marketing campaigns, is not a salient enough motivator for this population, who are typically unconcerned about their future health and engage in more high-risk behaviors (12-14). This age group needs to be targeted separately in social marketing campaigns and behavior change interventions. Promoting the benefits they value, such as enhanced performance and physical ability, short-term health outcomes, and improved appearance may have greater impact.

Digitalization of Interventions

The rise of the digital era offers potential new avenues for both social marketing and individually tailored programs, through texting, web and mobile apps to deliver health messages and facilitate change. Research indicates that electronic (eHealth) and mobile phone (mHealth)-based strategies are a promising channel for the delivery of interventions aimed at promoting healthful behaviors (15-17). Young adults are among the most frequent users of these wireless information sharing platforms (18), and the total number of people using social networks is increasing rapidly (19). Harnessing this technology could allow for the widespread dissemination of interventions in a low cost, accessible, convenient, and age-appropriate manner.

Assessing Efficacy

When assessing the efficacy of interventions, the degree to which they effectively incorporate behavior change theories should be considered. A review of recent eHealth and mHealth interventions revealed that interventions which included more behavior change techniques had larger effects compared to those that used fewer techniques (20). Furthermore, consideration of the accuracy of measurement of fruit and vegetable intake is crucial when evaluating the effectiveness of interventions. Fruits and vegetables have varying nutrient profiles and product attributes, and thus should be promoted separately. Additionally, the assessment of vegetable intake should be measured separately from fruit using validated tools.

Assessing External Validity

Assessment of the external validity of studies is as equally important as determining efficacy. The external validity of studies has implications on the translation of interventions to the broader young adult population. With the young adult population neglected from many population-wide fruit and vegetable campaigns, investigation of the potential upscaling of current interventions is necessary.

To our knowledge, there is no published review to date focusing on the efficacy and generalizability of social marketing and eHealth and mHealth interventions on vegetable intake in young adults. This review addresses this gap in the literature.

Thus the aims are to: (1) systematically examine the effectiveness of social marketing, electronic and/or mobile phone-based interventions in increasing fruit and vegetable intake in young adults; (2) assess the efficacy/validity of tools used to monitor changes in fruit and vegetable intake; and (3) review the adequacy of reporting of external validity components.

3.6 Methods

Defining Search Terms

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol will be used to conduct this systematic review (21). The search terms have been selected to be broad and will include combinations, truncations, and synonyms of “online intervention”, “computer-assisted therapy”, “Internet”, “website”, “cell phones”, “cyber”, “telemedicine”, “email”, “fruit and vegetables”, “young adult”, and “randomized controlled trials”. A separate search will be conducted to identify studies reporting interventions using social marketing and mass media to increase fruit and vegetable intake in young adults. This search will encompass terms such as “young adult”, “fruit and vegetables”, “social marketing”, “social media”, and “mass media”. The Medline thesaurus Medical Subject Headings (MeSH) terms will be refined according to each database. Although we are primarily interested in the implications of interventions on vegetable intake, the search term was broadened to include “fruit” as studies commonly report on fruit and vegetables concurrently.

Search Strategy

The following electronic databases will be searched for papers published between January 1990 and March 2015: the Cochrane Library, Cochrane Library of Systematic Reviews, Cochrane Central Register of Controlled Trials, CINAHL, Medline, Embase, PubMed, PyschINFO, Scopus, Web of Science, and Science Direct. The start of 1990 was selected, as it corresponded with the period during which the use of email became widespread (22). Reference lists and JMIR journals will be hand searched for additional citations. Studies determined to be relevant to the review will be included.

Eligibility Criteria

Overview

The eligibility criteria for studies have been selected based on participants, interventions, comparisons, outcomes, and study designs (PICOS). Only studies written in English and published after 1990 will be included.

Participants

The target age group for the included studies will be young adults aged 18-35 years inclusive. The participants should be healthy, with no disease or illness which would impact the primary outcome or ability to modify fruit and vegetable intake. There will be no limitation based on gender, ethnicity or socioeconomic status. Interventions set outside of universities will also be included in the review.

Interventions

The type of interventions that will be considered in the initial search will be eHealth or mHealth-based interventions. These are studies that employ the use of mobile phone apps, texting, email, phone calls, and websites to deliver the intervention. The secondary search will not be limited to eHealth or mHealth interventions and will include social marketing and mass media interventions. These are defined as studies that employ the use of media advertising through television, radio, billboards, and/or social media platforms as well as other community-based activities such as group education and cooking classes to increase fruit and vegetable intake.

Comparisons

Comparisons will be made between baseline and follow up results within and between studies. The differences between intervention and control arms (no intervention or minimal contact) will also be explored.

Outcomes

The primary outcome that will be investigated is the change in fruit and vegetable intake between baseline and follow-up. This can be reported in serves, frequency or grams. Fruit will be included as an outcome to account for studies reporting fruit and vegetable intake concurrently.

Study Designs

The first search will be limited to randomized controlled trials (RCTs) or cluster-RCTs with an aim of increasing fruit and vegetable intake in young adults. The social marketing search will not be limited by study design.

Study Selection

Titles and abstracts of all retrieved studies will be exported to Endnote X6 citation management software (Thomson Reuters, Philadelphia, PA, USA). Duplicates will be deleted before titles and abstracts are reviewed to group papers into either of the following: (1) meeting selection criteria; (2) requiring further examination; or (3) excluded. Papers determined as potentially relevant to the review will be downloaded as full text and reviewed for eligibility by two evaluators (MMN, JC) and further categorized (Figure 3.1). Discrepancies in evaluators' results will be resolved by discussion and, when necessary, in consultation with a third reviewer (MAF). The reasons for exclusion of studies will be recorded in a PRISMA flowchart which will illustrate the search, screening, and selection results (Figure 3. 1).

Data Collection

A data extraction table will be designed using principles of the PRISMA statement for reporting systematic review (21), and the Cochrane Collaboration's tool for assessing risk of bias (23). Once piloted for use on included studies, the following data will be collected: study details (authors, year, country of publication, funding, and affiliations); participants (characteristics, setting, inclusion/exclusion criteria, attrition, and blinding); intervention and comparator details; duration; and outcome measure (change in fruit and vegetable intake).

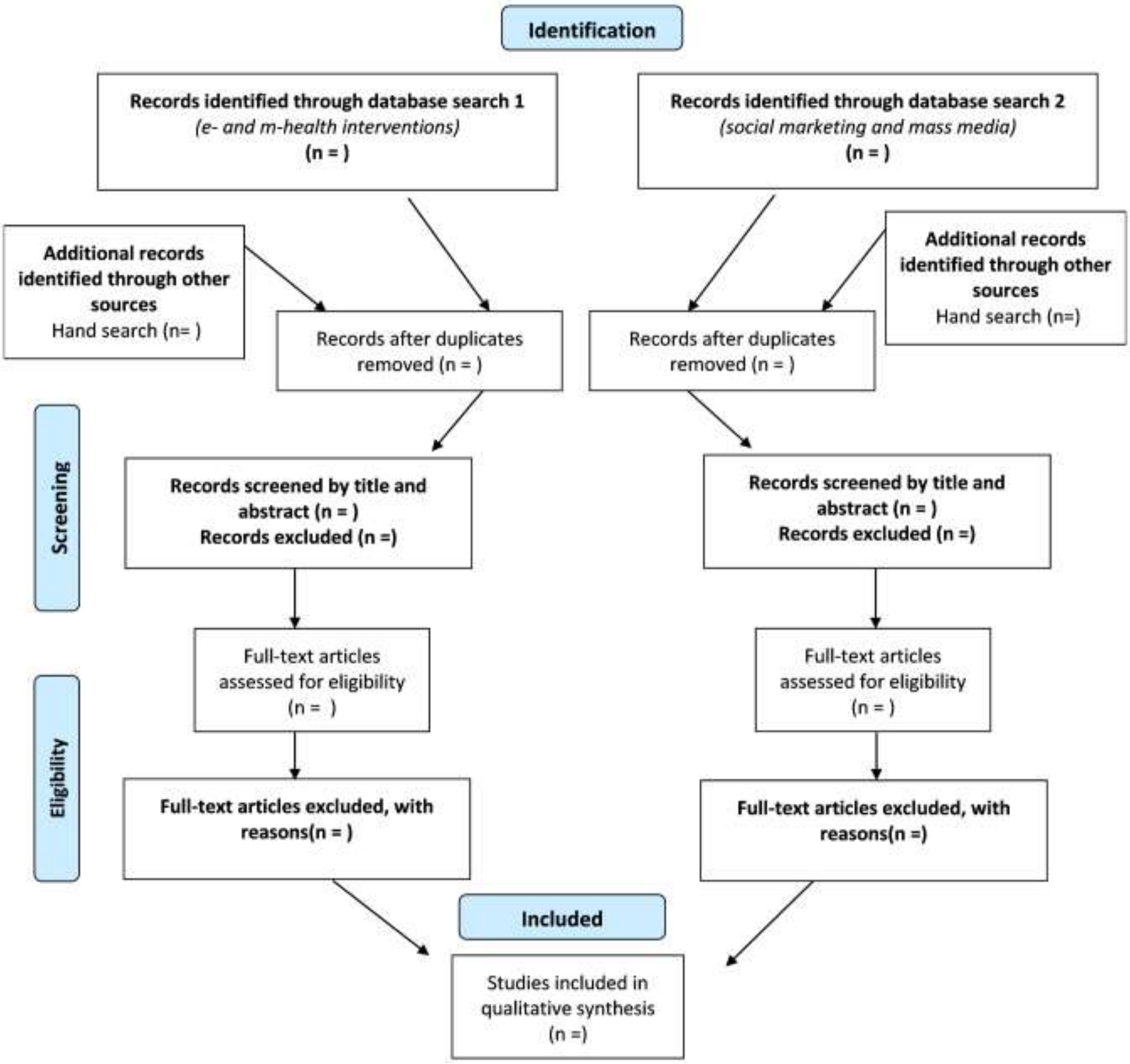

Figure 3.1: Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.

Data Analysis

Reporting of Intervention Outcomes

An appropriate method of reporting the treatment effect will be determined based on the type of data extracted from included studies. It is anticipated that the mean differences in fruit and vegetable intake between baseline and follow up will be reported. These results will be tabulated to enable qualitative description of results and heterogeneity assessment for potential pooling of results using meta-analysis.

Risk of Bias Assessment

Using the Cochrane Collaboration's tool (23), risk of bias will be determined for each included study, taking into consideration selection (random sequence generation and concealment of allocation methods), attrition (completeness of outcome data), detection (blinding of participants and personnel), and reporting (selective reporting of outcome measures). Two authors (MMN and JC) will independently evaluate each study for risk of bias and will code them as low-risk, high-risk or unclear risk. Any discrepancies will be settled through discussion.

Quality Assessment

The quality of each study will be determined by two independent parties using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (24). The following components will be considered in order to assign a quality rating to each study: study design, selection bias, blinding, confounders, outcome collection methods, participant withdrawals, and dropouts. Studies will be given a rating of “weak”, “moderate” or “strong” by two authors (MMN, JC), with conflicting ratings resolved through discussion with a third independent reviewer (MAF).

Rating External Validity

A table collating the reported external validity components of the included studies was designed based on the criteria for rating external validity developed by Green and colleagues (25). The table explores components under three sections: (1) reach, adoption and representativeness of participants; (2) intervention implementation and adaption; and (3) program maintenance and institutionalization (sustainability of program implementation). Qualitative and quantitative data relating to these external validity components will be extracted. Extracted data will be used to report the number and percentage of studies adhering to the external validity components. The adequacy and frequency of reporting of these components will be explored between studies.

3.7 Results

Our research is in progress. A draft of the systematic review is currently underway and will be submitted before the end of 2015.

3.8 Discussion

This review will present a summary of the efficacy and external validity of the published studies that have used eHealth and mHealth or social marketing strategies to engage young adults in improving their vegetable intake. The findings will provide a scope for the development of future interventions and social marketing campaigns targeted at this age group.

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3.10 Conclusion to chapter

The protocol presented in this chapter was registered with the online database of systematic reviews “PROSPERO”. During the review process minor modifications were made to the protocol such as updating the quality and risk of bias tools used and conducting a meta-analysis. These changes are reflected in the published review manuscript presented in Chapter Four.

Appendix 3

Appendix 3.1

Publication resulting from Chapter Three, JMIR Research Protocols 2015, 4 (3)
doi:10.2196/resprot.4665

(See next page)

Protocol

Efficacy and External Validity of Electronic and Mobile Phone-Based Interventions Promoting Vegetable Intake in Young Adults: A Systematic Review Protocol

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Abstract

Background: Despite social marketing campaigns and behavior change interventions, young adults remain among the lowest consumers of vegetables. The digital era offers potential new avenues for both social marketing and individually tailored programs, through texting, web, and mobile applications. The effectiveness and generalizability of such programs have not been well documented.

Objective: The aim of this systematic review is to evaluate the efficacy and external validity of social marketing, electronic, and mobile phone-based (mHealth) interventions aimed at increasing vegetable intake in young adults.

Methods: The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol will be used to conduct this systematic review. The search strategy will be executed across eleven electronic databases using combinations of the following search terms: “online intervention”, “computer-assisted therapy”, “internet”, “website”, “cell phones”, “cyber”, “telemedicine”, “email”, “social marketing”, “social media”, “mass media”, “young adult”, and “fruit and vegetables”. The reference lists of included studies will also be searched for additional citations. Titles and abstracts will be screened against inclusion criteria and full texts of potentially eligible papers will be assessed by two independent reviewers. Data from eligible papers will be extracted. Quality and risk of bias will be assessed using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies and The Cochrane Collaboration Risk of Bias assessment tool respectively. The external validity of the studies will be determined based on components such as reach, adoption, and representativeness of participants; intervention implementation and adaption; and program maintenance and institutionalization. Results will be reported quantitatively and qualitatively.

Results: Our research is in progress. A draft of the systematic review is currently being produced for publication by the end of 2015.

Conclusions: The review findings will assist the design and implementation of future eHealth and mHealth programs aimed at improving vegetable consumption in young adults.

Trial Registration: PROSPERO International Prospective Register of Systematic Reviews: CRD42015017763; http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015017763#.VVKtqfmqqko (Archived by WebCite at http://www.webcitation.org/6YU2UYrTn).

(JMIR Res Protoc 2015;4(3):e92) doi:10.2196/resprot.4665

KEYWORDS

young adults; vegetables; mHealth; eHealth; social marketing

Introduction

The Forgotten Age Group

Despite national and global social marketing campaigns and behavior change interventions, the current population's intake of vegetables remains low [1]. Among Australian adults, young adults are least likely to meet the recommended five or more serves a day [2]. As they transition from parental supervision to independent living, young adults are establishing self-determined food habits that will have implications for their future health. It can take decades before diet-related diseases appear; however, a strong association has been established between fruit and vegetable consumption and a decreased risk of chronic diseases [3-11]. For this age group, promoting the well-established long-term health benefits of vegetable consumption, as is typically done in nationwide social marketing campaigns, is not a salient enough motivator for this population, who are typically unconcerned about their future health and engage in more high-risk behaviors [12-14]. This age group needs to be targeted separately in social marketing campaigns and behavior change interventions. Promoting the benefits they value, such as enhanced performance and physical ability, short-term health outcomes, and improved appearance may have greater impact.

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Assessing Efficacy

When assessing the efficacy of interventions, the degree to which they effectively incorporate behavior change theories should be considered. A review of recent eHealth and mHealth interventions revealed that interventions which included more behavior change techniques had larger effects compared to those that used fewer techniques [20]. Furthermore, consideration of the accuracy of measurement of fruit and vegetable intake is crucial when evaluating the effectiveness of interventions. Fruits and vegetables have varying nutrient profiles and product attributes, and thus should be promoted separately. Additionally, the assessment of vegetable intake should be measured separately from fruit using validated tools.

Assessing External Validity

Assessment of the external validity of studies is as equally important as determining efficacy. The external validity of studies has implications on the translation of interventions to the broader young adult population. With the young adult population neglected from many population-wide fruit and vegetable campaigns, investigation of the potential upscaling of current interventions is necessary.

To our knowledge, there is no published review to date focusing on the efficacy and generalizability of social marketing and eHealth and mHealth interventions on vegetable intake in young adults. This review addresses this gap in the literature.

Thus the aims are to: (1) systematically examine the effectiveness of social marketing, electronic and/or mobile phone-based interventions in increasing fruit and vegetable intake in young adults; (2) assess the efficacy/validity of tools used to monitor changes in fruit and vegetable intake; and (3) review the adequacy of reporting of external validity components.

Methods

Defining Search Terms

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol will be used to conduct this systematic review [21]. The search terms have been selected to be broad and will include combinations, truncations, and synonyms of "online intervention", "computer-assisted therapy", "Internet", "website", "cell phones", "cyber", "telemedicine", "email", "fruit and vegetables", "young adult", and "randomized controlled trials". A separate search will be conducted to identify studies reporting interventions using social marketing and mass media to increase fruit and vegetable intake in young adults. This search will encompass terms such as "young adult", "fruit and vegetables", "social marketing", "social media", and "mass media". The Medline thesaurus Medical Subject Headings (MESH) terms will be refined according to each database. Although we are primarily interested in the implications of interventions on vegetable intake, the search term was broadened to include "fruit" as studies commonly report on fruit and vegetables concurrently.

Search Strategy

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Eligibility Criteria

Overview

The eligibility criteria for studies have been selected based on participants, interventions, comparisons, outcomes, and study designs (PICOS). Only studies written in English and published after 1990 will be included.

Participants

The target age group for the included studies will be young adults aged 18-35 years inclusive. The participants should be healthy, with no disease or illness which would impact the primary outcome or ability to modify fruit and vegetable intake. There will be no limitation based on gender, ethnicity or socioeconomic status. Interventions set outside of universities will also be included in the review.

Interventions

The type of interventions that will be considered in the initial search will be eHealth or mHealth-based interventions. These are studies that employ the use of mobile phone apps, texting, email, phone calls, and websites to deliver the intervention. The secondary search will not be limited to eHealth or mHealth interventions and will include social marketing and mass media interventions. These are defined as studies that employ the use of media advertising through television, radio, billboards, and/or social media platforms as well as other community-based activities such as group education and cooking classes to increase fruit and vegetable intake.

Comparisons

Comparisons will be made between baseline and follow up results within and between studies. The differences between intervention and control arms (no intervention or minimal contact) will also be explored.

Outcomes

The primary outcome that will be investigated is the change in fruit and vegetable intake between baseline and follow-up. This can be reported in serves, frequency or grams. Fruit will be included as an outcome to account for studies reporting fruit and vegetable intake concurrently.

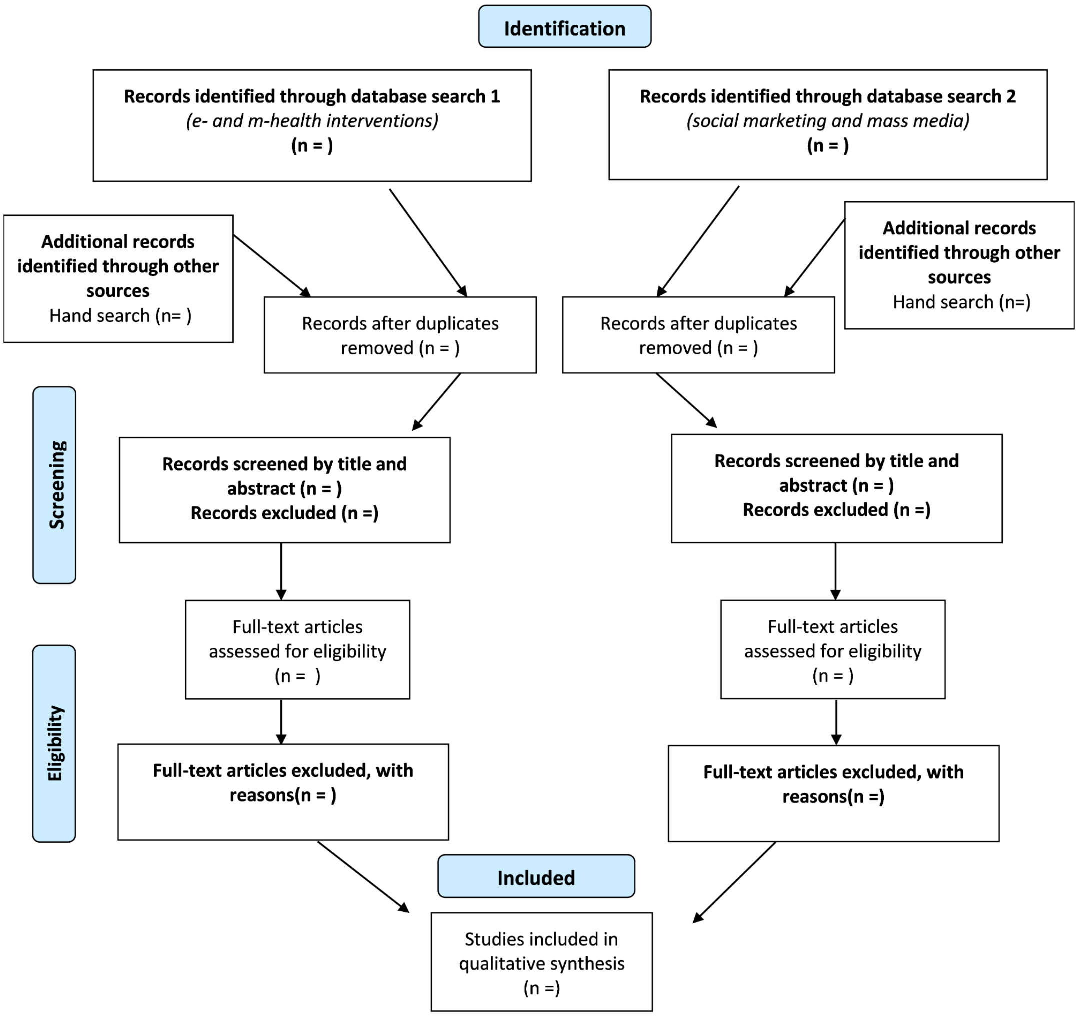
Study Designs

The first search will be limited to randomized controlled trials (RCTs) or cluster-RCTs with an aim of increasing fruit and vegetable intake in young adults. The social marketing search will not be limited by study design.

Study Selection

Titles and abstracts of all retrieved studies will be exported to Endnote X6 citation management software (Thomson Reuters, Philadelphia, PA, USA). Duplicates will be deleted before titles and abstracts are reviewed to group papers into either of the following: (1) meeting selection criteria; (2) requiring further examination; or (3) excluded. Papers determined as potentially relevant to the review will be downloaded as full text and reviewed for eligibility by two evaluators (MMN, JC) and further categorized (Figure 1). Discrepancies in evaluators' results will be resolved by discussion and, when necessary, in consultation with a third reviewer (MAF). The reasons for exclusion of studies will be recorded in a PRISMA flowchart which will illustrate the search, screening, and selection results (Figure 1).

Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.



Data Collection

A data extraction table will be designed using principles of the PRISMA statement for reporting systematic review [21], and the Cochrane Collaboration's tool for assessing risk of bias [23]. Once piloted for use on included studies, the following data will be collected: study details (authors, year, country of publication, funding, and affiliations); participants (characteristics, setting, inclusion/exclusion criteria, attrition, and blinding); intervention and comparator details; duration; and outcome measure (change in fruit and vegetable intake).

Data Analysis

Reporting of Intervention Outcomes

An appropriate method of reporting the treatment effect will be determined based on the type of data extracted from included studies. It is anticipated that the mean differences in fruit and vegetable intake between baseline and follow up will be reported. These results will be tabulated to enable qualitative description of results and heterogeneity assessment for potential pooling of results using meta-analysis.

Risk of Bias Assessment

Using the Cochrane Collaboration's tool [23], risk of bias will be determined for each included study, taking into consideration selection (random sequence generation and concealment of allocation methods), attrition (completeness of outcome data), detection (blinding of participants and personnel), and reporting (selective reporting of outcome measures). Two authors (MMN and JC) will independently evaluate each study for risk of bias and will code them as low-risk, high-risk or unclear risk. Any discrepancies will be settled through discussion.

Quality Assessment

The quality of each study will be determined by two independent parties using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies [24]. The following components will be considered in order to assign a quality rating to each study: study design, selection bias, blinding, confounders, outcome collection methods, participant withdrawals, and dropouts. Studies will be given a rating of "weak", "moderate" or "strong" by two authors (MMN, JC), with conflicting ratings resolved through discussion with a third independent reviewer (MAF).

Rating External Validity

A table collating the reported external validity components of the included studies was designed based on the criteria for rating external validity developed by Green and colleagues [25]. The table explores components under three sections: (1) reach, adoption and representativeness of participants; (2) intervention implementation and adaption; and (3) program maintenance and institutionalization (sustainability of program implementation). Qualitative and quantitative data relating to these external validity components will be extracted. Extracted data will be used to report the number and percentage of studies adhering to the external validity components. The adequacy and frequency of reporting of these components will be explored between studies.

Results

Our research is in progress. A draft of the systematic review is currently underway and will be submitted before the end of 2015.

Discussion

This review will present a summary of the efficacy and external validity of the published studies that have used eHealth and mHealth or social marketing strategies to engage young adults in improving their vegetable intake. The findings will provide a scope for the development of future interventions and social marketing campaigns targeted at this age group.

Acknowledgments

The authors thank the School of Molecular Bioscience Librarian Rod Dyson for his assistance with setting up the database search strategy. MMN and JC are PhD students, funded by the Australian Postgraduate Award scholarship.

Authors' Contributions

MMN, JC and MAF developed the research question and MMN drafted the review protocol. All authors have read the final protocol and will contribute to screening, extraction, analysis, and writing of the review manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

MEDLINE Search Strategy.

[PDF File (Adobe PDF File), 14KB - resprot_v4i3e92_app1.pdf]

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Abbreviations

EPHPP: Effective Public Health Practice Project
MESH: Medline thesaurus Medical Subject Headings
PICOS: participants, interventions, comparisons, outcomes and study designs
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analysis

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Chapter 4: Efficacy and External Validity of Electronic and Mobile Phone-Based Interventions Promoting Vegetable Intake in Young Adults: Systematic Review and Meta-Analysis.

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4.1 Publication details

This chapter presents the manuscript titled ‘Efficacy and External Validity of Electronic and Mobile Phone-Based Interventions Promoting Vegetable Intake in Young Adults: Systematic Review and Meta-Analysis.’ published in *Journal of Medical Internet Research*, 2016, Volume 18, Issue 4:e58, doi:10.2196/jmir.5082 (see *Appendix 4*). It has been reformatted but contains exactly the same text. This journal is the highest rated journal in the field of medical informatics with an impact factor of 5.175.

4.2 Author contribution

I Monica Marina Nour (the candidate) was the primary researcher involved in developing the research question, search strategy, selecting the studies, and extracting the data. Secondary author Miss Chen assisted with screening of articles and data extraction. Statistician Dr McGeechan provided advice regarding conducting a meta-analysis within STATA. I summarised the information and wrote the manuscript for publication which was edited by co-authors.

*Corresponding author

4.3 Introduction to chapter

This chapter reports a qualitative and quantitative synthesis of published RCTs that used electronic or mobile-phone based strategies to intervene within the young adult population to improve fruit and vegetable intake. Although the ultimate objective of this PhD research was to design a “vegetable” intervention, fruit and vegetables are often examined in combination. Thus, the review included studies reporting on both food groups (as opposed to vegetable intake only) to ensure the evidence base was extensively captured. Both effectiveness and external validity of the interventions is reviewed. A meta-analysis was performed to establish an effect size. The evidence was graded using the Cochrane Collaborations Grading of Recommendations, Assessment, Development and Evaluation (GRADE) framework to determine the quality of the body of work and its strength in guiding practice.

4.4 Abstract

Background

Young adults (18–35 years) remain among the lowest vegetable consumers in many western countries. The digital era offers opportunities to engage this age group in interventions in new and appealing ways.

Objective

This systematic review evaluated the efficacy and external validity of electronic (eHealth) and mobile phone (mHealth) -based interventions that promote vegetable intake in young adults.

Methods

We searched several electronic databases for studies published between 1990 and 2015, and 2 independent authors reviewed the quality and risk of bias of the eligible papers and extracted data for analyses. The primary outcome of interest was the change in vegetable intake postintervention. Where possible, we calculated effect sizes (Cohen *d* and 95% CIs) for comparison. A random effects model was applied to the data for meta-analysis. Reach and representativeness of participants, intervention implementation, and program maintenance were assessed to establish external validity. Published validation studies were consulted to determine the validity of tools used to measure intake. We applied the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system to evaluate the overall quality of the body of evidence.

Results

Of the 14 studies that met the selection criteria, we included 12 in the meta-analysis. In the meta-analysis, 7 studies found positive effects postintervention for fruit and vegetable intake, Cohen *d* 0.14–0.56 (pooled effect size 0.22, 95% CI 0.11–0.33, I2=68.5%, *P*=.002), and 4 recorded positive effects on vegetable intake alone, Cohen *d* 0.11–0.40 (pooled effect size 0.15, 95% CI 0.04–0.28, I2=31.4%, *P*=.2). These findings should be interpreted with caution due to variability in intervention design and outcome measures. With the majority of outcomes documented as a change in combined fruit and vegetable intake, it was difficult to determine intervention effects on vegetable consumption specifically. Measurement of intake was most commonly by self-report, with 5 studies using nonvalidated tools. Longer-term follow-up was lacking from most studies (n=12). Risk of bias was high among the included studies, and the overall body of evidence was rated as low quality. The applicability of interventions to the broader young adult community was unclear due to poor description of external validity components.

Conclusions

Preliminary evidence suggests that eHealth and mHealth strategies may be effective in improving vegetable intake in young adults; whether these small effects have clinical or nutritional significance remains questionable. With studies predominantly reporting outcomes as fruit and vegetable intake combined, we suggest that interventions report vegetables separately. Furthermore, to confidently establish the efficacy of these strategies, better-quality interventions are needed for young adults, using valid measures of intake, with improved reporting on costs, sustainability and long-term effects of programs.

Trial registration

PROSPERO International Prospective Register of Systematic Reviews: CRD42015017763;

http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015017763

(Archived by WebCite at http://www.webcitation.org/6fLhMgUP4)

4.5 Introduction

Poor fruit and vegetable intake contributes to 2.635 million deaths per year (1). Consuming the recommended 600 g daily could reduce this global burden by 1.8% (1), with adequate fruit and vegetable intake linked to minimized adiposity, improved weight management (2), and reduced risk of heart disease and some cancers (1). Despite several decades of government-led social marketing campaigns, alongside concerted effort by researchers and practitioners to facilitate behavior change, intake of vegetables remains suboptimal in many countries (3-6).

Australian young adults (18-34 years) are among the lowest consumers of vegetables, with only 4.7% consuming the recommended 5 or more servings a day (7). During this transitional phase of life, young adults are developing self-determined food habits that will affect their future health. While the association between fruit and vegetable consumption and reduced chronic disease risk is well established in the literature (2,8-15), promoting these long-term health benefits, as is typically done in nationwide social marketing campaigns, does not appear to motivate young adults (16,17). Young adults are typically less concerned about their future well-being and engage in more risky health behaviors (18). Consequently, this population should be targeted separately in interventions.

Research in the area of digital interventions has revealed that electronic (eHealth) and mobile phone (mHealth) -based strategies are effective in promoting healthful behaviors (19-21). eHealth and mHealth refer to the use of the Internet, mobile, or wireless devices to deliver health services and information to improve health outcomes or enhance health research (22,23). Examples of eHealth and mHealth strategies include text messaging, email, mobile phone apps, phone calls, and websites. Young adults are among the highest users of mobile phones and wireless information sharing platforms (24), with 89% of 18- to 29-year-olds in the United States reporting use of social networking sites (25). This offers an opportunity to engage young adults in interventions in new and appealing ways. Harnessing this technology to deliver social marketing and individually tailored programs could facilitate the widespread dissemination of interventions in an affordable, convenient, and age-appropriate manner.

Previous systematic reviews of fruit and vegetable consumption-promoting programs have identified that, while interventions produced some positive changes in knowledge and attitudes about the importance of fruit and vegetable consumption, there were only minor improvements in intake (26-28). These interventions were typically delivered to adults and children, and targeted fruit and vegetable intake concurrently. To our knowledge, to date there is no published review investigating the efficacy and external validity of social marketing and eHealth and mHealth interventions on vegetable intake in young adults. With greater perceived barriers for the consumption of vegetables, poorer knowledge about vegetable servings (29), and just over half of the population already meeting the recommended 2 fruit servings a day (7), it is evident that increasing vegetable intake is a greater challenge. Thus, investigating the implications of interventions on vegetable intake alone will help us understand how we can better support and facilitate improved vegetable consumption.

When evaluating the efficacy of interventions, the accuracy of outcomes should be considered. This is dependent on the validity of intake measurement tools. To compare outcomes across studies, definitions of what constitutes a vegetable serving is also important. This is a source of confusion for the public and for researchers, with variations between countries (30). In Australia, a serving of vegetables is approximately 75 g or half a cup of cooked vegetables (31), whereas in the United Kingdom a serving is equivalent to 80 g (32).

Furthermore, the specification of behavior change techniques used in interventions is essential to the process of revealing which strategies are effective in the target population and allowing replication of successful interventions (33). A review of recent eHealth and mHealth interventions found that studies that incorporated a greater number of behavior change techniques had the largest effects (34). Whether these effects can be generalized to the broader young adult population depends on external validity. Thus, evaluating the external validity of studies is as important as determining efficacy and will have implications for the translation of interventions into larger health promotion programs.

Therefore, in this review we aimed to (1) systematically examine the efficacy of social marketing, and electronic or mobile phone-based interventions in increasing vegetable intake in young adults, (2) assess the quality of the studies, including the validity of tools used to monitor changes in vegetable intake, and (3) review the adequacy of reporting of external validity components.

4.6 Methods

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (35) to develop the systematic review protocol, which has been published elsewhere (36). During the review process, we replaced the quality-assessment tool specified in the original protocol with the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system (37).

4.6.1 Search Strategy

We conducted the systematic literature search between April and August 2015 using the following electronic databases: ScienceDirect, MEDLINE, PyscINFO, Scopus, the Cochrane Library, CINAHL, Embase, and Web of Science. The last search was conducted on August 17, 2015, with no new relevant papers found. We excluded studies published before 1990, as email was not widely used before this period (38). After hand searching reference lists of key reviews and included studies, as well as conducting a manual search of JMIR journals, we included other relevant studies.

We conducted 2 searches. The first used combinations, synonyms, and truncations of "online intervention," "computer-assisted therapy," "electronic mail," "Internet," "website," "cell phones," "young adult" or "adult," "fruits," and "vegetables." While we were searching largely for eHealth and mHealth interventions, we used other relevant MEDLINE MeSH, such as "telemedicine," to encompass the terms "mHealth," "eHealth," "telehealth," and "mobile health." Furthermore, although we were mainly interested in the efficacy of vegetable interventions, we extended the search terms to include "fruit," as studies typically report on fruit and vegetables concurrently. Additionally, we used the term “adult” alongside “young adult” to broaden the search from 18- to 24-year-olds (the typical database definition of young adults) to 18- to 35-year-olds (based on the US National Institutes of Health cut-off for young adults) (39). Table 4.1 shows the first search strategy used in the MEDLINE. The full search strategy is presented as additional material in Appendix 4.1 (Tables S1 and S2).

We conducted separate database and Google searches to locate programs that used social marketing and mass media to increase fruit and vegetable intake in young adults. Search terms were “young adult,” “adults,” “fruits,” “vegetables,” “social marketing,” “social media,” and “mass media.” These studies were not limited by publication type and included gray literature, such as nonpublished evaluations of programs by organizations. Table 4.2 presents the second search strategy used in MEDLINE.

Table 4.1. Electronic database search: MEDLINE (search 1: eHealth and mHealth interventions).

Search number	Search statement[a]	No. of citations retrieved
1	Online intervention.mp or Computer-assisted therapy.mp. or Therapy, Computer-Assisted/	5242
2	Internet/ or Website.mp	55,352
3	Cell phones.mp or Cell phones/	5040
4	Telemedicine/ or Cyber.mp	12,148
5	email.mp or Electronic mail/	5193
6	Adult/or Young adult/ or young adult*.mp	4,093,057
7	Fruit/ or Fruit*.mp	65,586
8	Vegetable*.mp or Vegetables/	39,576
9	1 or 2 or 3 or 4 or 5	77,751
10	7 or 8	87,363
11	6 and 9 and 10	120
12	Limit 11 to (English language and humans and yr = 1990-current)	120

[a]Modifiers are * (search term as major focus of articles), .mp (multiple purpose search including all fields: title, original title, abstract, subject heading, name of substance, and registry word fields), and / (valid controlled vocabulary term which has been searched in the subject headings field of the database).

Table 4.2. Electronic database search: MEDLINE (search 2: social marketing and mass media interventions).

Search number	Search statement[a]	No. of citations retrieved
1	Adult/ or Young Adult/ or young adult*.mp.	4126,552
2	Fruit/ or fruit*.mp.	66,529
3	Vegetable*.mp. or Vegetables/	40,014
4	2 or 3	88,502
5	Social marketing.mp. or social marketing/	2976
6	Social media. mp or Mass Media/ or Social Media/	11,192
7	5 or 6	13,882
8	1 and 4 and 7	6
9	Limit 8 to (English language and humans and yr = 1990-current)	6

[a]Modifiers are * (search term as major focus of articles), .mp (multiple purpose search including all fields: title, original title, abstract, subject heading, name of substance, and registry word fields), and / (valid controlled vocabulary term which has been searched in the subject headings field of the database).

4.6.2 Eligibility Criteria

Criteria for inclusion of eHealth and mHealth interventions were as follows: (1) randomized controlled trials (RCTs) with a primary or secondary aim of increasing fruit and vegetable intake in young adults that (2) were targeted at young adults aged 18–35 years inclusive, (3) reported fruit and vegetable intake at baseline and follow-up, (4) involved healthy participants with no disease or illness that would affect the primary outcome or ability to modify fruit and vegetable intake, (5) were written in English, (6) were published after 1990, and (7) were limited to eHealth- and mHealth-based interventions, defined as studies using texting, email, mobile phone apps, phone calls, or websites to deliver the intervention.

Criteria for inclusion of social marketing and mass media interventions were identical to points (1) to (6) above, but were not limited by study design. Social marketing and mass media interventions were defined as those that used media advertising through the Internet, television, billboards, radio, or social media platforms such as Facebook.

4.6.3 Study Selection

We downloaded titles and abstracts of all retrieved studies to EndNote X6 citation management software (Thomson Reuters). Duplicates were removed, then titles and abstracts were reviewed by grouping papers into (1) those meeting selection criteria or (2) requiring further examination; or (3) they were excluded. Papers determined to be potentially relevant to the review were downloaded as full text and reviewed for eligibility by two assessors (MN, JC) and further categorized (Figure 4.1). We resolved discrepancies in assessors' results by discussion.

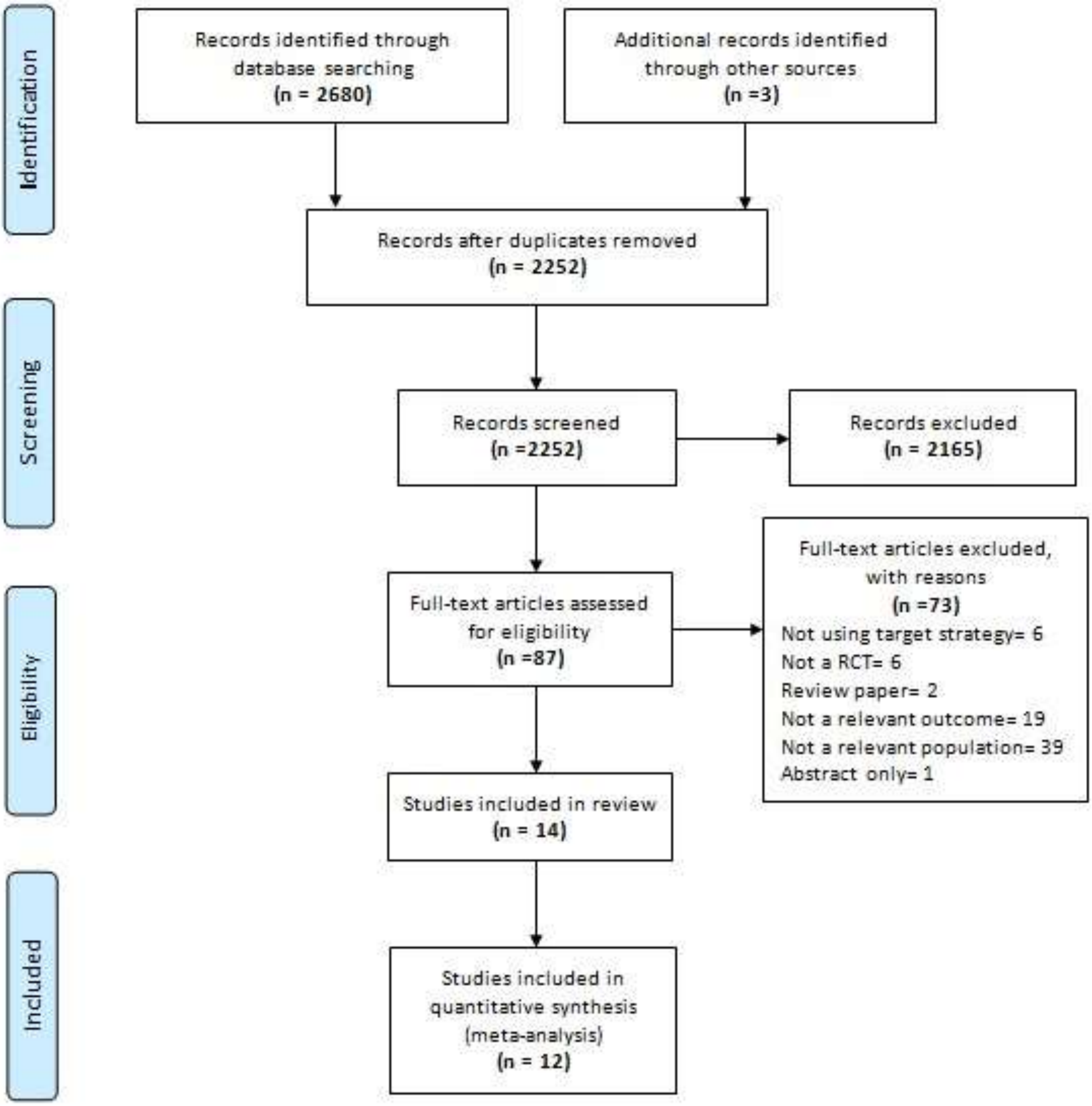

Figure 4.1 Flow diagram demonstrating the process of selecting the included studies of interventions promoting fruit and vegetable intake in young adults

4.6.4 Data Extraction Process

We created a data extraction table according to the principles of the PRISMA statement for reporting systematic reviews (35), with some additional elements included for completing the Cochrane Collaboration's risk of bias tool (40). Once we had piloted the process on a random selection of 4 of the included studies, 2 independent reviewers extracted the following data in duplicate: study details (authors, year, country of publication, funding, and affiliations); participants (characteristics, setting, inclusion and exclusion criteria, attrition, and blinding); intervention and comparator details; duration; and the summary outcome measure (change in fruit and vegetable intake between baseline and follow-up for the intervention and control arms). We also extracted the name of the tool used to assess changes in fruit and vegetable intake, as well as citations of available validation studies.

4.6.5 Data Synthesis and Analysis

The primary outcome of interest was the change in vegetable intake post-intervention. Where possible, for all study arms we recorded mean or median intakes (as servings, cups, frequency, or percentage consuming) pre- and post-intervention. If vegetable intake was not reported separately, we documented the change in fruit and vegetable intake. We also noted the measures of error (SE or SD) and associated *P* values for change between groups over time. To determine the magnitude of intervention outcomes, we calculated effect sizes (Cohen *d* and 95% CIs) for studies that reported sufficient data (means, and measure of error or frequencies). Web-based calculators (41) based on Lipsey and Wilson's formulas (42) assisted with calculations. We assessed the magnitude of the effect sizes according to

Cohen's categories, whereby an effect <0.2 is considered negligible, between 0.2 and 0.49 is small, 0.5-0.8 is medium, and >0.8 is large (43).

We also considered the clinical significance of outcomes. There is no consensus in the literature regarding what change in intake is considered clinically significant. However, several meta-analyses and longitudinal studies suggest a dose-response relationship, whereby an increase in vegetable intake by approximately 1 serving is protective for cardiovascular health (decreased risk of stroke and cardiovascular disease mortality by 11% and 4%, respectively) (44,45). Furthermore, every 1-serving increase in vegetable intake has been associated with a 0.12 kg reduction in weight (95% CI -0.35 to -0.14) (46). These studies define a serving of vegetables as approximately 1 cup of leafy vegetables or half a cup of cooked vegetables (frozen, fresh, or canned) in line with previous US and current Australian dietary guidelines (31,47).

To pool the outcomes for the meta-analysis, we grouped studies for which an effect size was calculated. We used STATA version 13 (StataCorp LP) to conduct the analyses using the metan, metabias, and metafunnel commands. A random effects model was applied. Publication bias was determined through Egger's statistical test for funnel plot asymmetry and visual inspection of the funnel plots of the Cohen *d* effect size (standardized mean difference), plotted against its standard error. The I^2 value for heterogeneity was calculated based on the Q statistic: ((Q statistic - df/Q statistic) × 100%). Cochrane Collaboration guidelines (48) suggest that an I^2 for heterogeneity below 40% is considered low, and a value above 50% is considered substantial.

4.6.6 Quality Assessment

Risk of Bias Assessment

Using the Cochrane Collaboration's tool (40), we established risk of bias at the individual study level, based on the following study elements: selection of participants (random sequence generation and concealment of allocation methods); attrition (completeness of outcome data); detection (blinding of participants and personnel); and reporting (selective reporting of outcome measures). Two authors (MN and JC) independently evaluated each study for risk of bias and coded them as having low risk, high risk, or unclear risk. Any differences in judgment were clarified through discussion.

GRADE Assessment

The quality of the body of evidence was determined by 2 independent reviewers (MN, JC) using the GRADE system (37). We considered 5 categories to ascribe a quality rating: limitations in study designs; consistency of results; directness of the evidence with regard to study populations, intervention design, and outcomes measured; precision of outcomes; and the presence of publication biases.

4.6.7 Rating Validity of Dietary Assessment Tools

We determined the validity of each tool used to measure changes in vegetable intake based on published literature demonstrating its accuracy (49-59). The checklist of requirements by Nelson et al (60) was also consulted to qualitatively examine the effectiveness of reporting on measurement tools. This checklist assesses factors such as data-collection procedures (objective measure vs self-report), methods of quantifying portions, variety of foods captured, food composition databases used and whether checking procedures were applied.

4.6.8 Rating External Validity

We assessed the external validity of included studies based on the Green and Glasgow's criteria (61). The assessment explored components under 3 sections: (1) reach and representativeness of participants, (2) intervention implementation and adaptation, and (3) program maintenance and institutionalization (sustainability of program implementation). Quantitative and qualitative data pertaining to these external validity components were extracted. We recorded specific data that were not reported as not reported, and if an assessment component did not apply to the particular study we reported it not applicable. Individual participation rate (%) was calculated as the percentage of eligible participants agreeing to participate. Attrition rate (%) was calculated as the percentage of participants who dropped out after randomization. Attrition was further grouped by intervention arm (treatment vs control). Extracted data were used to examine the number of studies adhering to the external validity components. The frequency and adequacy of reporting of these components were also examined and compared between studies.

4.7 Results

4.7.1 Study Selection

As the flow diagram in Figure 4.1 shows, we found 2680 studies through database searching and 3 additional studies through hand searching the references. We screened a total of 2252 papers by title and abstract. Of these, we assessed the full text of 87 studies. A total of 14 studies (62-75) met the selection criteria and were included in the review. See Appendix 4.2 for the complete list of references excluded by full text with corresponding reasons. None of these studies used social marketing strategies or mass media to encourage vegetable consumption in young adults specifically. Therefore, the remaining results report the effectiveness and external validity of eHealth and mHealth interventions aimed at increasing fruit and vegetable intake in young adults. We included 12 studies in the meta-analyses. For the meta-analysis, we combined the reported results in 2 groups for comparability: fruit and vegetable (8 studies) and vegetable only (5 studies); 1 study contributed results for both groups (64).

4.7.2 Study Reach and Representativeness of Participants

Overall, 7984 healthy people participated in the eHealth and mHealth RCTs (see Appendix 4.3, Table S3). There were, however, large discrepancies in the sample sizes. Only 3 of the 14 studies had recruited >500 participants at baseline (62-64), and 1 study had a sample size of <100 (64). More than half of the interventions were conducted in the United States (62,64,67,69,71,73,75), 4 in Australia (65,66,67,72), 1 in New Zealand (74), and 1 in

Malaysia (70). The target audience was college or university students for the majority of the studies (62,63,67-75), and 3 studies reported their target audience to be young adults (64-66).

Recruitment methods were reported for 13 of the 14 studies, but limited details were provided. All but 2 studies recruited through the university or college setting (64,66). Participants were recruited through undergraduate psychology courses in 2 studies (67,68), from random nonnutrition classes in 2 studies (69,70), and through advertisements and flyers posted on university grounds in 4 studies (62,63,65,71,72). In 1 study a recruitment table was set up on campus (73), and another study invited patients attending the student university health service (74). In 1 study (64) advertisements with a toll-free phone number were used, and the final study distributed letters of invitation through participating family doctors, along with electronic and print advertisements (66). Of the included studies, 9 indicated their participation rate, with a mean of 78.0%. The inclusion criteria were detailed by 10 studies, all of which specified age (years) as one of their criteria. Demographic data were provided by most of the studies although not consistently. Baseline age (years) was reported in all but 1 study (Appendix 4.3, Table S3), with a mean age of 20.8 years across the studies. The ethnicity of participants was reported to be >50% Caucasian or white in 7 studies. The percentage of female participants was reported by 13 studies, with women more commonly recruited than men (mean 69.8% female) (Appendix 4.3, Table S3).

4.7.3 Intervention Implementation and Adaptation

Details of the intervention and comparator groups were provided in detail. All studies recruited an intervention and a control group (see Appendix 4.4, Table S4), with 4 studies using multiple intervention and control arms (67,71,72,74). A total of 6 studies provided no treatment to the control arm (67,68,70,71,74,75), 7 studies gave the comparator group general information not containing the intervention material (62,64-66,69,72,73), and 1 study provided the control group with the intervention material on completion of the follow-up assessment (63). The duration of interventions and number of sessions were easily extrapolated from each study. The level of contact between researchers and participants ranged from one-off sessions (provision of feedback) to daily contact by email or text message (Appendix 4.4, Table S4). The majority of the interventions used online education through learning platforms, websites, and emailing, with only 2 studies using apps (65,66) and 4 using text messaging (65,66,70,72). No studies reported the use of social media platforms. The studies predominantly used goal setting for behavior change, with monitoring and feedback also commonly incorporated. For the majority of the interventions, the aim was to offset weight gain in young adulthood. Targeting improvements in fruit and vegetable intake was one such method used to address weight gain. While 1 study was designed to reduce health-risk behaviors in young adults (74), only 5 studies focused specifically on fruit and vegetable intake (64,68,69,72,75), and none targeted vegetables alone.

The reviewed studies varied in the detail provided regarding the behavior theories and techniques considered in the intervention design. The design of 5 studies was based on the transtheoretical model of behavior change, where the participants' stage of change determined the content received (63-66,75). A total of 6 studies were theory or education based (62,63,67,70,71,73). Social-cognitive theory informed 2 interventions (67,69). Half of the reviewed studies applied the behavioral construct of self-efficacy in their intervention (62,64,69,70,71,73,75). The study by Kypri and McAnally (74) did not report consideration of theoretical frameworks in their intervention design. The remaining 2 studies (68,72) were informed by the theory of planned behavior and the theory of habit formation (Appendix 4.4, Table S4). All the studies that we reviewed intervened at the individual level. Only 2 studies were implemented outside of the university setting, thus limiting the generalizability of the interventions to the overall young adult population. Of these studies, one (64) was targeted at lower socioeconomic status young adults, while the other mainly captured young adults from higher socioeconomic areas (66).

The duration of the interventions (excluding postintervention follow-up) ranged from one-off contact to 6 months of treatment, with a mean of 10 weeks (Appendix 4.4, Table S4). A total of 9 studies allocated a follow-up period (62-64,66,69,71-73), with a mean of 16 weeks. Adherence was most commonly documented as the number of sessions completed or the amount of materials viewed by participants (Appendix 4.4, Table S4), but was not consistently reported across studies. The mean level of compliance among those reporting adherence was 85.4%.

Delivery expertise varied among the studies (Appendix 4.4, Table S4). Research staff were more commonly reported to have conducted the interventions, with little specification of their qualifications and the number of research staff involved. Registered dietitians delivered 5 of the interventions (63,65,66,69,75). Other expertise included a health promotion officer (71) and outreach educators (64).

4.7.4 Study Maintenance and Institutionalization

The rate of attrition was documented in all reviewed studies. At completion of the interventions the mean attrition rate was 19.6% (see Appendix 4.5, Table S5). All but 4 studies (64,69,71,75) reported attrition for the control and intervention group separately, and 4 did not assess differences in characteristics between completers and noncompleters (65,70,71,73). Only 2 studies looked at the long-term impacts of the study, by assessing outcomes at least 12 months following treatment (62,63). Both of these studies found that the changes in fruit and vegetable intake were not maintained at follow-up (Appendix 4.5, Table S5). The sustainability of program implementation was poorly reported, with only 1 study mentioning that results would be used to refine the intervention for trial in a broader young adult population using a larger sample size (66). Finally, only 2 studies published a process evaluation documenting effective program elements (62,66).

4.7.5 Risk of Bias

We rated the majority of the studies reviewed as unclear to high risk because they did not perform intention-to-treat analyses, which introduced biases in the outcome data (attrition bias) (62,70-75) (see Appendix 4.6, Table S6). We rated 2 studies high in a second domain (detection bias) (71,73). The majority of the studies did not clarify their methods of blinding (n=8). Selection bias was mainly unclear within and across studies, with 5 studies not reporting the method of sequence generation in randomization (62,64,69,71,75) and only 2 studies specifying allocation concealment methods (66,74) (Appendix 4.6, Table S6). While all of the studies reported results for prespecified outcomes, we could not completely rule out reporter bias across studies because only 5 RCTs published their original protocol

(63,65,66,68,69) or provided details of their trial registration (66). However, no selective reporting was apparent based on the methods within the reviewed manuscripts (both successful and unsuccessful outcomes recorded). Overall, the combined lack of clarity of the level of bias across studies raises concerns about the plausibility of the studies' results.

4.7.6 GRADE Quality Rating

The reviewed interventions had several limitations in study design and did not address the research question directly, resulting in an overall low quality rating (Table 4.3).

Table 4.3. Overall assessment of quality in 14 studies (7984 participants in total) of promotion of fruit and vegetable intake using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system.

Category	**Rating with reasoning**
Limitations	–2 quality levels due to very serious limitations
Consistency	No subtraction of levels, as inconsistency doesn't affect confidence in results
Directness	–2 quality levels, as the population, outcomes, and study design are indirect
Precision	No subtraction of levels due to good precision
Publication bias	No subtraction of levels, as funnel plot symmetry suggests publication bias is unlikely
Overall quality	Low: our confidence in the effect estimate is limited

Study Limitations

All the included studies were RCTs. However, only 2 studies adequately concealed the difference between intervention arms (66,74). In 1 study, the study design and purpose of randomization was explained to participants, preventing allocation concealment (71). The remaining 11 studies did not clearly describe their method of concealment. Furthermore, 8 studies did not describe their method of blinding and 3 did not blind effectively (65,71,73). Half of the included studies had a loss to follow-up of >20% (62-64,67,72,73,75) and did not conduct intention-to-treat analysis (62,70-74). A total of 3 studies did not state methods for dealing with missing data or conducted analysis on completer populations (63,68,69). Several studies used nonvalidated measures of intake, further limiting the quality of the body of evidence.

Consistency

The studies with effect sizes for change in fruit and vegetable intake yielded an I^2 statistic of 68.5% (P value for heterogeneity =.002), indicating that there may be considerable heterogeneity. However, a higher heterogeneity can be caused by small variations in point estimates from studies with larger sample sizes, as is evident in Figure 4.2. An I^2 of 31.4% (P value for heterogeneity =0.2) for studies reporting vegetable intake separately suggests low heterogeneity.

Directness

While comparisons between control and intervention arms were direct for the included interventions, variations in study design, populations, and outcome measures meant that the overall body of evidence was indirect. The population of included studies was predominantly college students. Only 2 interventions recruited beyond the university or college setting, but they were still not representative of the broader young adult population. This review allowed for the inclusion of studies that measured changes in intake as a secondary outcome. Consequently, several studies were weight management interventions targeting fruit and vegetable intake as a component of the program. Only 5 studies targeted fruit and vegetables specifically (64,68,69,72,75) and none targeted vegetables alone. Measures of fruit and vegetable intake also varied considerably. Thus, the overall evidence is an indirect representation of the impact of eHealth and mHealth on vegetable intake.

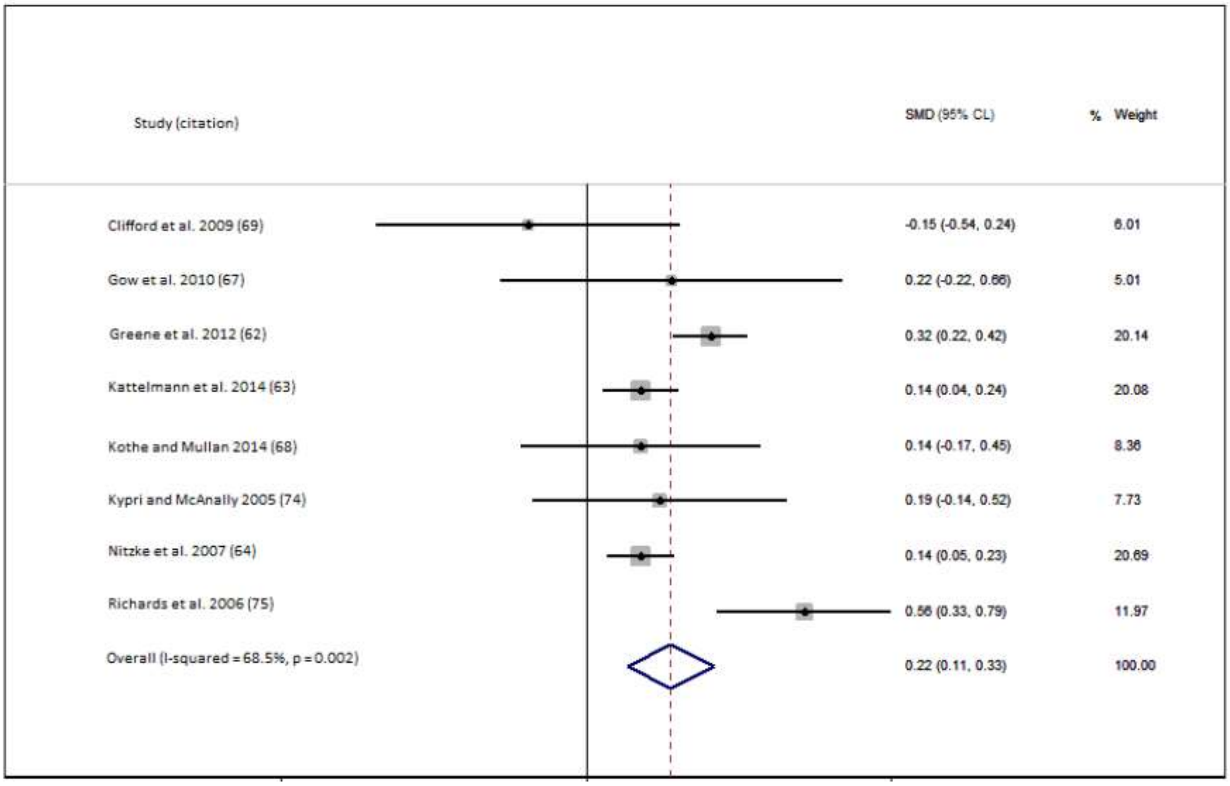

Figure 4.2: Forest plot of Cohen d effect size (standardized mean difference, SMD) for studies reporting change in fruit and vegetable intake combined. The diamond represents the overall effect size; the percentage weighting of each study toward the overall effect is indicated by the size of gray squares; and the 95% confidence limits are shown by horizontal lines. The overall intervention effect lies at the center of the larger clear diamond with right and left end points indicating the 95% confidence limits. Note: weights are from random effects analysis.

Precision

Only 6 of the 14 studies reported conducting power calculations (63,67-69,71,73). However, these were mainly based on primary outcomes other than vegetable intake, such as change in nutrition knowledge or weight. Sample size varied from 51 to 2024 participants but yielded 7984 in total, which is considered sufficient.

Publication Bias

While we implemented a comprehensive search strategy to capture the gray literature, we may have missed unpublished studies (interventions with insignificant or negative findings) or those published in journals not indexed in major databases. The outcomes of statistical tests of publication bias (Egger's test) were not reported, as these results are less accurate when based on fewer than 10 studies or when there is significant heterogeneity (48). Visual inspection of funnel plots (Figures 3 and and 4) indicated symmetry in the distribution of points around the mean effect size, suggesting that bias from missing studies is unlikely.

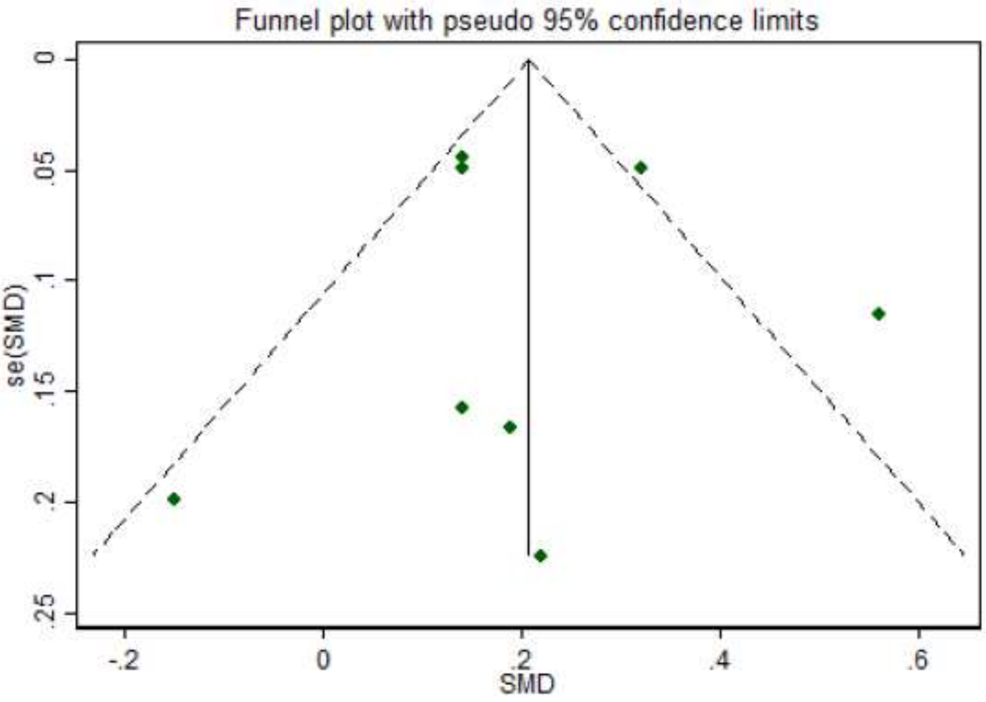

Figure 4.3: Funnel plot for risk of publication bias: intervention effect for fruit and vegetable intake represented by the standardized mean difference (SMD) plotted against the standard error, se(SMD). Dashed diagonal lines indicate the

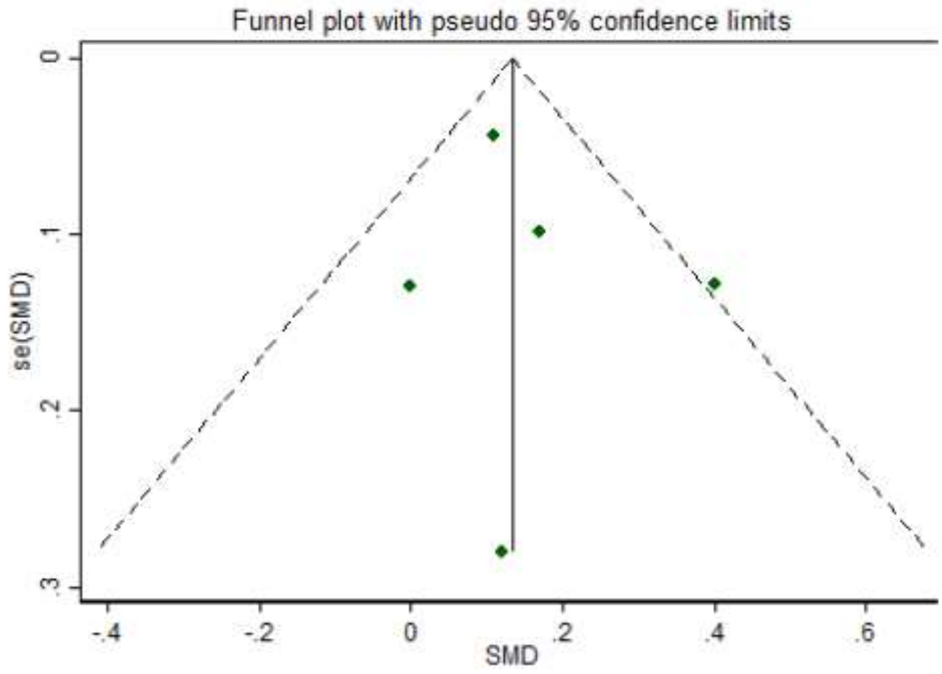

Figure 4.4: Funnel plot for risk of publication bias: intervention effect for vegetable intake represented by standardized mean difference (SMD) plotted against the standard error, se(SMD). Dashed diagonal lines indicate the pseudo 95% confidence limits and scatter dots represent individual studies.

4.7.7 Efficacy of Interventions

Of the 14 reviewed studies, 9 provided results for fruit and vegetable intake, and we included 8 in the meta-analysis. Of these studies, 7 found positive effects postintervention (62-64,67,68,74,75) (Cohen *d* 0.14-0.56), 4 of which were statistically significant (62-64,75). For all but 1 study (75), the magnitude of effect was small. In total, 2 studies also reported clinically significant improvements of ≥1 serving/day (62,75) (see Appendix 4.7, Table S7). The pooled effect size for interventions reporting change in fruit and vegetable intake was 0.22 (95% CI 0.11 to 0.33), indicating a small positive effect of eHealth and mHealth interventions on fruit and vegetable intake. The 4 studies (62-64,75) with significant effects contributed 72.9% weighting (Figure 4.4). The I^2 was 68.5%, P=.002, suggesting considerable heterogeneity between these studies, and so findings should be interpreted with caution.

Of the 6 studies that assessed vegetable intake independently of fruit (64-66,70-72), we included 5 in the meta-analysis, 4 of which had positive effects on vegetable intake (64-66,70) (Cohen *d* 0.11-0.40). Two of these positive effects were statistically significant (64,66). Increases in intake were <1 serving/day, with the exception of the results reported by Partridge et al (66) (Appendix 4.7, Table S7). The pooled effect size for change in vegetable intake was negligible at 0.15 (95% CI 0.04 to 0.28; I^2=31.4%, P=.2) (4.5).

Studies that were more successful in improving fruit or vegetable intake provided participants with individually tailored advice and feedback based on their stage of change (64,66,75) and incorporated goal setting (62,66,75). Of the studies producing clinically and statistically significant results for fruit or vegetable intake, or both (62,66,75), 1 used online theory education based on nondiet principles (62). This intervention was designed according to 2 educational models, Carey and colleague's system of instructional design (76) and Keller's instructional motivational model (77). Fruit and vegetable intake goals were set after completion of each weekly educational lesson, and self-evaluation of progress preceded the next weekly Web-based module. The study by Richards and colleagues (75) used motivational interviewing in combination with Web-based resources and emails. The resources were tailored to the participants' stage of change, where precontemplators and contemplators were given reasons to and tips on how to eat more fruits and vegetables, as well as a goal-setting framework. Action and maintenance participants received emails with tips for maintaining consumption and trying new fruits and vegetables. Finally, the study by Partridge et al (66) combined multiple eHealth and mHealth strategies to support behavior change, with text messaging found to be the most popular, and the website and discussion boards the least popular, among participants. The text messages contained reminders and tips on how to achieve their individualized goal set during their phone counseling session with a dietitian and were based on the 10 processes of change (transtheoretical model). Participants could monitor their fruit and vegetable intake goals using a personalized app that also provided recipes and tips on how to increase their intake.

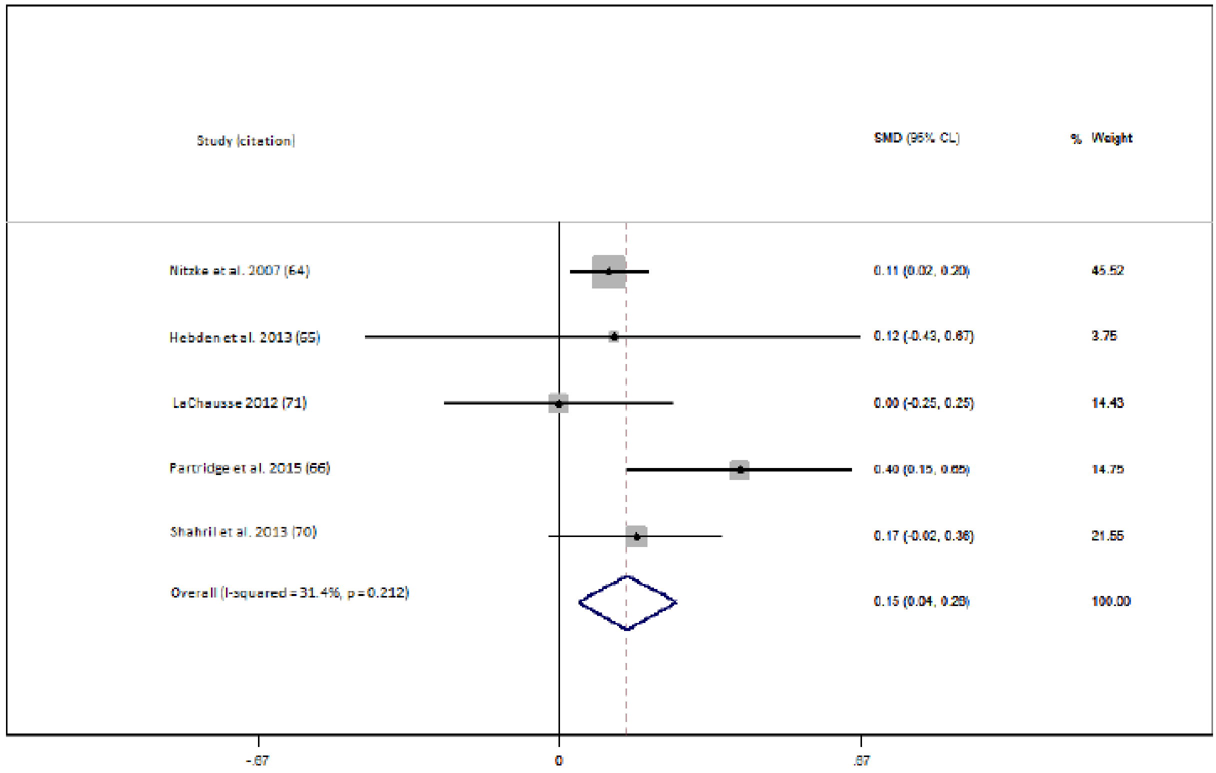

Figure 4.5. Forest plot of Cohen d effect size (standardized mean difference, SMD) for studies reporting change in vegetable intake separately. The diamond represents the overall effect size; the percentage weighting of each study toward the overall effect is indicated by the size of gray squares; and the 95% confidence limits are shown by horizontal lines. The overall intervention effect lies at the center of the larger clear diamond with right and left end points indicating the 95% confidence limits. Note: weights are from random effects analysis.

Validity of Dietary Assessment Tools

Of the reviewed studies, 5 used tools that had not been validated to assess changes in vegetable intake (68,69,71,73,75) (Table 4.4). While the majority of the tools were validated, only 1 was tested specifically in the young adult population (30). Of the studies that used validated tools, short screeners were most popular, including the US National Cancer Institute's fruit and vegetable screener (53), as well as short questions adapted from the Australian and New Zealand national nutrition surveys (52,54,56). Furthermore, only 2 studies defined what they classified as a serving (65,66), and the outcome measure for intake lacked consistency, with studies reporting change in terms of frequency, servings or cups of vegetables consumed, as well as the percentage meeting recommendations. No studies detailed which food composition databases they used for the analysis, or whether they checked records with respondents as per the requirements specified in the Nelson and colleagues' checklist (60). All but 1 study (70) used a self-report measurement tool. The study by Gow and Colleagues (67) did not specify what the outcome measure was (servings vs score).

Table 4.4 Validity of tools used to measure fruit and vegetable intake and source of tools.

Author (citation)	**Fruit and vegetable intake measurement tool and source (citation)**	**Tool validated for fruit and vegetables**
Clifford et al (69)	Food frequency questionnaire adapted from US National Cancer Institute's health habits and history questionnaire (59)	No
Franko et al (73)	Single-item question measuring daily fruit and vegetable consumption (51)	No
Gow et al (67)	Block food screener (49)	Yes
Greene et al (62)	2-item screener and National Cancer Institute screener (53)	Yes
Hebden et al (65)	Web-based short survey using questions from Australian national survey (30,52,56)	Yes
Kattelmann et al (63)	National Cancer Institute's vegetable screener (43)	Yes
Kothe and Mullan (68)	Self-report measure of previous day's consumption	No
Kypri and McAnally (74)	2 questions from New Zealand National Survey questionnaire (54)	Yes
LaChausse (71)	US Centers for Disease Control and Prevention's youth risk behavior survey (58)	No
Nitzke et al (64)	5 A Day screener (7-item fruit and vegetable screener) from 5 A Day program (53)	Yes
Partridge et al (66)	Short questions adapted from the Australian National Nutrition Survey (30,52,56)	Yes
Richards et al (75)	1-item food frequency questionnaire (50)	No
Rompotis et al (72)	Short question on fruit and vegetable intake (57)	Yes
Shahril et al (70)	Diet history	NA[a]

4.8 Discussion

This systematic review found preliminary evidence to suggest that eHealth and mHealth interventions may have a positive impact on fruit and vegetable intake among young adults. Meta-analyses revealed a small magnitude of effect on fruit and vegetable intake and a negligible effect on vegetable intake alone. Whether these effects have clinical or nutritional significance remains questionable. The quality of the body of evidence was rated low and therefore, findings should be interpreted with caution. Rather than making recommendations, we propose suggestions for improved research.

Among the studies that improved intake, only small changes were observed (<1 serving/day). This is consistent with conclusions from existing reviews, in which interventions appear to produce minor improvements in fruit and vegetable intake (26-28). The effectiveness of the reviewed interventions in creating sustainable change in the long term remains unclear, as follow-up periods were short. The observed dose-response clinical outcomes associated with increasing vegetable intake (44-46) are likely to become evident only in the longer term. Additionally, the link between vegetable intake and weight maintenance during the transition to adulthood occurs over time (78). Thus, investigators should integrate longer follow-up in intervention protocols. Future studies may also consider measuring secondary outcomes, such as weight and indicators of cardiovascular health, over time to understand the longer-term clinical implications of improved vegetable intake.

With the measurement and reporting of fruit and vegetable intakes as a summed value in most studies reviewed, the impact of the eHealth and mHealth strategies on vegetable consumption specifically remains unclear. Previous research has shown that knowledge of serving sizes is poorer for vegetables than for fruit (29), and for young adults, taste was a more important barrier to increasing vegetable consumption than it was for fruit (79). Fruit and vegetables also have varying nutrient profiles and product attributes. Considering these factors, it is apparent that vegetables should be promoted and measured separately from fruit. Additionally, most of the reviewed studies targeted fruit and vegetable intake as part of a larger weight management program. Thus, the impact of an intervention focusing primarily on vegetables is an important question for future research.

Previous research established the importance of considering behavior change theory in intervention design (33,80). The value of incorporating behavior change theory is reiterated by this review, where the majority of the successful studies incorporated behavior change constructs such as goal setting (62,66,73,75) and the provision of individually tailored advice and feedback was based on participants' stage of change (64,66,75). While the transtheoretical model has been long established as an effective means of improving fruit and vegetable intake (81), these studies suggest its efficacy in eHealth and mHealth interventions where, for instance, motivational and confidence-enhancing text messages or phone calls can benefit individuals who are in the earlier contemplative stages of change. There was no clear pattern, however, to indicate that the incorporation of more behavior change techniques initiated larger improvements as previously suggested in the literature (34). Researchers could consider investigating whether a combination of efficacious strategies and repeat exposure at a later date produces greater change to shed light on whether intensive short-duration or less-intensive, longer-duration interventions are more effective.

The mode of intervention delivery varied considerably between studies, making it difficult to determine which eHealth and mHealth strategies were most successful in supporting behavior change. However, 2 of the effective studies (66,75) used motivational phone counseling as part of their intervention. While details of the cost effectiveness of this design were not provided, generally, the individualized nature of this approach can be expensive, due to the necessity for trained staff and the monetary reimbursement required for their time. Consequently, the applicability of these studies to the whole population level may be limited. The use of other low-cost and convenient eHealth and mHealth techniques (texting and email) that can incorporate individually tailored information may be more feasible for interventions. Preliminary evidence suggests that these methods are successful (66,75); however, further research is required to confidently determine their efficacy.

Our review was unable to identify social marketing campaigns targeted specifically at young adults. Addressing this gap is an opportunity for future public health promotion projects, with research indicating that young adults have poor awareness of population-wide campaigns and perceive considerable barriers to increasing their intake despite the promoted health benefits (82). Additionally, we found no studies that incorporated social media platforms in their intervention. Using these high-reach and lower-cost information-sharing platforms can help to increase interactivity and collaborative content sharing. This may be the fastest and most wide-reaching way to engage young people, with approximately 89% of young adults using social media (19). Effectiveness studies on the use of social media to improve health behaviors are limited, although preliminary reports are encouraging (83,84).

There is considerable uncertainty regarding the accuracy of the findings summarized by this review, due to the use of non-validated self-report measures of intake, which may not be sensitive enough to detect small changes and may be subject to reporter bias. Therefore, further effort is required to develop validated tools for the measurement of vegetable intake in young adults for consistent and accurate reporting of intervention outcomes. Researchers need to specify what is considered a serving of vegetables to allow easier comparison of outcomes and should use objective measures of intake for validation. Biomarkers such as vitamin C and beta-carotene are useful indicators of fruit and vegetable intake, respectively. While tests for these biomarkers are potentially costly for use in large interventions, they would be feasible and reliable in small validation studies (85).

The degree to which the interventions can be translated to the general young adult populations is questionable, as the majority of studies were conducted in the university or college setting in a sample of educated young adults. While the latest statistics indicate that an increasing proportion of young adults are enrolled in tertiary education (86), those of lower socioeconomic status remain underrepresented (87). Future studies should limit the use of convenience sampling and aim to recruit a wider range of socioeconomic groups. Overall, the studies we reviewed did not consistently report on external validity, particularly program sustainability, costs, and long-term effects of the intervention. Process evaluations were also lacking. Consequently, the external validity of interventions for improving vegetable consumption in young adults is uncertain. There is a growing body of evidence in health research indicating that investigators are not reporting on external validity (88-90). Improvements in this area are required to determine the potential for implementation of study designs in broader health promotion programs. Of particular importance is consideration and reporting of the costs involved in upscaling these interventions, which will have implications for health promotion officers and policy makers (91). Furthermore, researchers should invest in conducting process evaluations to determine how to improve the efficacy of interventions and enhance their generalizability (92).

4.8.1 Strengths and Limitations

This is the first systematic review to report on the effect of eHealth and mHealth interventions on vegetable intake specifically and highlights relevant opportunities for future research. We conducted the review protocol in line with the PRISMA guidelines (35) and used a comprehensive search strategy. While we searched several electronic databases and made an effort to include gray literature, we may have missed some studies. The variability across interventions with differences in study designs and measures of vegetable intake, and the overall poor study quality, made it difficult to establish definitive conclusions. Consequently, we were reluctant to rule out any eHealth or mHealth approach as ineffective and rather discussed the outcomes as a means of highlighting gaps in the current literature and opportunities for future research to generate a stronger body of evidence on whether technology-based strategies are effective in this population. Finally, the lack of consistent reporting of external validity components prevented us from making conclusions about the potential for translating interventions to the wider young adult population.

4.8.2 Conclusions

Overall, this review revealed that young adults have been neglected in fruit and vegetable social marketing campaigns, and most interventions target fruit and vegetables concurrently. Very few good-quality eHealth and mHealth interventions using validated dietary assessment tools have been designed to support young adults in improving their vegetable intake. With preliminary evidence suggesting that eHealth and mHealth strategies may be an effective mode of delivering vegetable interventions, continued research using stronger and higher-quality study designs is required to better determine the efficacy of technology-based strategies for improving vegetable consumption in young adults. With previous research suggesting that multiple behavior change strategies should be used for greater improvements, researchers could consider combining promising strategies such as goal setting and tailored feedback in future interventions. The potential impact of using social media platforms to create awareness of the importance of eating enough vegetables also deserves attention. Finally, in light of the lack of reporting of external validity components in the reviewed papers, it is critical that future studies address key factors such as program costs, sustainability, and longer-term impact in order to determine the potential for upscaling interventions to the broader young adult population.

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4.10 Conclusion to chapter

The available evidence base is comprised of studies predominantly reporting outcomes as fruit and vegetable intake combined. Of the 14 studies that met selection criteria, six assessed vegetable intake independently of fruit, with four studies recording a positive effect. Of the effective studies, goal setting and self-monitoring strategies were commonly integrated, suggesting that these behaviour change techniques may be key mechanisms for improving vegetable intake and will be considered in the future intervention design. However, the reported effect size of the successful studies was small (0.15), and the quality of the body of evidence was low. It is estimated that a 10% increase in population wide vegetable intake (equivalent to 0.25 vegetable serves) would be enough reduce the Australian government's health expenditure by $99.9 million (in 2015-16 dollars). While e/mHealth strategies such as texting, phone coaching and online education platforms may be effective mediums for improving vegetable consumption among young adults; better-quality interventions, using valid measures of vegetable intake, in populations outside of the college/university environment are needed before they can be scaled to the population at large. Few studies using social media or gaming techniques were found. So, a review of nutrition-related interventions using social media and/or gamification was indicated.

Appendix 4

Appendix 4.1

Systematic Review Search Strategy (*Total search: 2680 articles (Search 1: 1482, Search 2: 1198))*

Table S1. Search 1: e- and m-health interventions, databases searched, search terms, limits applied and results

Database	Search ID number	Search terms	Results
Medline via Ovid	1	Online intervention.mp. or Computer-assisted therapy.mp. or Therapy, Computer-Assisted/	5242
	2	Internet/ or Website.mp	55352
	3	Cell phones.mp or Cell phones/	5040
	4	Telemedicine/ or Cyber.mp	12148
	5	email.mp or Electronic mail/	5193
	6	Adult/or Young adult/ or young adult*.mp	4093057
	7	Fruit/ or Fruit*.mp	65586
	8	Vegetable*.mp or Vegetables/	39576
	9	1 or 2 or 3 or 4 or 5	77751
	10	7 or 8	87363
	11	6 and 9 and 10	120
	12	Limit 11 to (English language and humans and yr = 1990-current)	**120**

Database	Search ID number	Search terms	Results
Cochrane database of systematic review	**1**	Online intervention.mp.	2
	2	Computer-assisted therapy.mp.	8
	3	Therapy, Computer-Assisted.mp. (mp=title, short title, abstract, full text, keywords, caption text)	30
	4	Telemedicine.mp. (mp=title, short title, abstract, full text, keywords, caption text)	52
	5	email.mp. (mp=title, short title, abstract, full text, keywords, caption text)	987
	6	cell phone.mp. (mp=title, short title, abstract, full text, keywords, caption text)	19
	7	1 or 2 or 3 or 4 or 5 or 6	1056
	8	Fruit*.mp. (mp=title, short title, abstract, full text, keywords, caption text)	243
	9	vegetable*.mp. (mp=title, short title, abstract, full text, keywords, caption text)	197
	10	8 or 9	310
	11	Adult*.mp. (mp=title, short title, abstract, full text, keywords, caption text)	5254
	12	young adult*.mp. (mp=title, short title, abstract, full text, keywords, caption text)	385
	13	11 or 12	5132
	14	7 and 10 and 13	**23**

Database	Search ID number	Search terms	Results
Web of science	1	TS=("online intervention*" OR "computer-tailored intervention*" OR internet OR "smart-phone*" OR website* OR email OR "electronic mail")	415,764
	2	TS=(Fruit* OR vegetable*)	1,247,542
	3	TS= (“young adult*” OR Adult*)	7,121, 146
	4	Combine 1 AND 2 AND 3 *Timespan=1990-2015, search language=English*	**286**
Science direct	1	pub-date > 1989 and "online intervention*" OR "computer-tailored intervention*" OR internet OR "smart-phone*" OR website* OR email OR "electronic mail" AND Fruit* OR vegetable* AND “young adult*” OR Adult* AND "Randomised controlled trial".	**675**
Cinahl	1	"online intervention"	35
	2	(MH "Therapy, Computer Assisted+")	3,232
	3	(MM "Internet") OR "internet"	32,763
	4	(MH "Cellular Phone+") OR "mobile phone*	5,066
	5	"email"	995
	6	(MH "Telemedicine+")	3,871
	7	(MH "Adult+") OR (MH "Young Adult")	682,569
	8	(MH "Fruit+") OR "fruit"	13,277
	9	(MH "Vegetables+") OR "vegetable"	11,752
	10	8 OR 9	15,668
	11	1 OR 2 OR 3 OR 4 OR 5 OR 6	41,390
	12	7 AND 10 AND 11	**26**

Database	Search ID number	Search terms	Results

Scopus	1	"online intervention*" OR "computer-tailored intervention*" OR internet OR "smart-phone*" OR website* OR email OR "electronic mail" AND Fruit* OR vegetable* AND "young adult*" OR Adult*	**194**
	2	'computer-tailored intervention'	38
	3	„internet"	100,043
	4	„smartphone"	2,126
	5	„website"	14,431
	6	„email"	42,976
	7	Fruit or vegetable	162,239
	8	'young adult' OR adult	5,148,352
	9	1 or 2 or 3 or 4 or 5 or 6	158,507
	10	7 and 8 and 9	**156**

PsycInfo	1	Computer-assisted therapy.mp. or Therapy, Computer-Assisted/	598
	2	Internet/ or Website.mp	26124
	3	Cell phones.mp or Cell phones/	2536
	4	Telemedicine/ or Cyber.mp	3912
	5	email.mp or Electronic mail/	6601
	6	Adult/or Young adult/ or young adult*.mp	33446
	7	Fruit/ or Fruit*.mp	155564
	8	Vegetable*.mp or Vegetables/	3657
	9	1 or 2 or 3 or 4 or 5	35816
	10	7 or 8	16452
	11	6 and 9 and 10	2
	12	Limit 11 to (English language and humans and yr = 1990-current)	**2**

Table S2: Search 2: social marketing and mass media interventions), databases searched, search terms, limits applied and results

Database	Search ID number	Search terms	Results
Medline via Ovid	1	Adult/ or Young Adult/ or young adult*.mp.	4126552
	2	Fruit/ or fruit*.mp.	66529
	3	Vegetable*.mp. or Vegetables/	40014
	4	2 or 3	88502
	5	Social marketing.mp. or social marketing/	2976
	6	Social media. mp or Mass Media/ or Social Media/	11192
	7	5 or 6	13882
	8	1 and 4 and 7	6
	9	Limit 8 to (English language and humans and yr = 1990-current)	**6**
Cochrane Database of Systematic Reviews	1	Adult/ or Young Adult/ or young adult*.mp.	386
	2	Fruit/ or fruit*.mp.	249
	3	Vegetable*.mp. or Vegetables/	197
	4	2 or 3	294
	5	Social marketing.mp. or social marketing/	36
	6	Social media. mp or Mass Media/ or Social Media/	17
	7	5 or 6	53
	8	1 and 4 and 7	0
	9	Limit 8 to (English language and humans and yr = 1990-current)	**0**

Database	Search ID number	Search terms	Results
Web of science	1	TS= (social media OR social marketing OR mass media)	431,098
	2	TS= (Fruit* OR vegetable*)	1,247,569
	3	TS=(“young adult*” OR Adult*)	7,123, 146
	4	1 AND 2 AND 3	**432**
Science direct	1	"social media" OR "social marketing" OR "mass media" AND Fruit* OR vegetable* AND "young adult*" .	**302**
Cinahl	1	(MH "Social Media") OR "social media"	3512
	2	(MH "Communications Media+") OR "mass media"	317,892
	3	(MH "Social Marketing") OR "social marketing"	974
	4	(MH "Adult+") OR (MH "Young Adult")	682,594
	5	(MH "Fruit+") OR "fruit"	13,283
	6	(MH "Vegetables+") OR "vegetable"	11,762
	7	1 OR 2 OR 3	319,897
	8	5 OR 6	15,704
	9	4 AND 7 AND 8	**165**

Database	Search ID number	Search terms	Results

Scopus		"social media" OR "social marketing" OR "mass media" AND fruit* OR vegetable* AND "youn g adult*"	287
Embase	1	„social marketing‟/exp OR „social marketing‟	3509
	2	„social media‟	4449
	3	„mass media‟	4157
	4	1 or 2 or 3	11,849
	5	„young adult‟ or „young adults‟	138,234
	6	„fruits and vegetables‟ or „fruit‟ or „vegetable‟	162,845
	7	4 and 5 and 6	**6**
PsycInfo	1	Adult/ or Young Adult/ or young adult*.mp.	33964
	2	Fruit/ or fruit*.mp.	15808
	3	Vegetable*.mp. or Vegetables/	3748
	4	2 or 3	16715
	5	Social marketing.mp. or social marketing/	1225
	6	Social media. mp or Mass Media/ or Social Media/	11955
	7	5 or 6	13102
	8	1 and 4 and 7	2
	9	Limit 8 to (English language and humans and yr = 1990-current)	**0**

Appendix 4.2

Studies excluded by full text with reasons (n=73)

Not using target strategy

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Not relevant outcome

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Appendix 4.3

Table S3: Study descriptions of reach and representativeness of participants (n=14)

Authors, year, country, citation	Target audience	Recruitment methods	Participation rate (%)	Key inclusion criteria	*N* (study arms)	Baseline characteristics
Clifford *et al.* (2009) USA (69)	College students living off campus	Students volunteered from non- nutrition courses	60.8	NR	101 (I=50, C=51)	Age: NR; Gender: M, F=63%; 93% live off campus; 52% cook dinner ≥4 times/week
Franko *et al.* (2008) USA (73)	College students aged 18-24 yrs	Information and recruitment table on University grounds	79.0	Age: 18-24 yo; enrolled as full-time undergraduate student; not dieting	476 (group I=165, group II= 164, C=147)	Age: I=20.1 +/-1.7 yrs. II=20.0 +/ 1.7 yrs. C=20.1 +/-1.7 yrs; 58.2% White; Gender: M,F=52.3%
Gow *et al.*(2010) USA (67)	First year college students aged 22 yrs or younger	Recruited from Psychology courses through classroom announcements &fliers	94.6	Age: ≤22 yrs; First year college students.	170(internet=40, feedback=39, combined=40, control=40)	Age: 18.1 yrs; Gender: M, F=74%; 53.8% White; 60.8% Living in dormitory; Mean BMI: 24.38kg/m^2
Greene *et al.* (2012) USA (62)	College students aged 18-24 yrs	Flyers, table tents in dining halls,newspaper ads, online and class announcements.	64.4	Age: 18 to 24 yo; BMI: >18.5 kg/m^2; healthy; not pregnant, lactating or studying nutrition or exercise science	1689 (I=830, C=859)	Age: Completers 19.07 yrs +/- 1.1, Non-completers 19.2 yrs +/- 1.2; Gender: M, F=62%; 79% White
Hebden *et al.* (2013) Australia (65)	Young adults aged 18-35 yrs from university population	Advertisements posted around the university and published in staff and student newsletters	92.7	Age: 18–35 yo; BMI 24–31.99 or 23–23.99 kg/m^2 with weight gain >2 kg in past 12 months; can receive SMS; have regular internet access; not dieting, pregnant or planning pregnancy in next 3 months; no medical condition that influences body weight.	51 (I=26, C=25)	Age: C= 23.1 +/-3.7 yrs, I=22.6 +/-5.4 yrs; Gender: M, F=80.4%; Lives with parents/other: 53%
Kattelmann *et al.* (2014) USA (63)	College students aged 18-24 yrs	In-class & campus housing meetings, e- mails, letters, and flyers on campuses	49.2	Age: 18–24 yo; full-time 1st- 3rd yr student with access to internet; not studying nutrition, exercise, or health promotion. BMI >18.5 kg/m^2; healthy; not pregnant.	1,639 (I=824 C= 815)	Age: 19.3 +/- 1.1 yrs; 72.1 % White; 73.8% live on campus; 11.5% consuming >5 cups fruit and veg/day
Kothe and Mullan (2014) Australia (68)	First year undergrad psychology students	Recruited as part of psychology course	NR	NR	162 (I=81, C=81)	Mean Age: 18.84 yrs; Gender: M, F=83.3%; 78.4% Living with parents; 46.9% Australian, 25.3% North Asian

Authors, year, country, citation	Target audience	Recruitment methods	Participation rate (%)	Key inclusion criteria	*N* (study arms)	Baseline characteristics
Kypri and McAnally (2005) New Zealand(74)	17-24 yos attending university health service	Patients attending university student health service invited to participate	82.0	NR	218 (group A=72, group B=74, group C=72)	Mean Age: 20.2 +/- 1.5 yrs;Gender: M, F=49%; 75% European, 8% Maori
LaChausse (2012) USA (71)	Undergraduate University students	E-mail messages, flyers and announcements on school billboards.	89.4	NR	312 (MSB=106, Campus=70, C=136)	Age: MSB=26.7 +/- 9.8 yrs, Campus=25.1+/-8.9 yrs, C=22.8+/-6.4 yrs; Gender: M,F=75.6% 44% Hispanic, 21.2% White
Nitzke *et al.* (2007) USA (64)	Young adults aged 18-24 yrs	Personal contacts and standardized posted ads with toll-free phone numbers	100	Age: 18–24 yo; not enrolled in a nutrition program in previous 12 months, limited income (receiving welfare or income <16,000 PA, if college student-paying own college expenses)	2024 (I=1004, C= 1020)	Mean Age= 20.6 yrs; Gender: M,F=61.2%; 53.7% Caucasian, 27.1% African American; 41% live with parents; 86% responsible for food preparation
Partridge *et al.* (2015) Australia (66)	Young adults aged 18-35 yrs	Invitations from participating doctors, electronic or print ads, university newsletters, posters, mailbox drops and newspapers	64.4	18-35 yo, BMI 25-31.9 kg/m^2, or 23-24.9 kg/m^2 with weight gain >2 kg in last 12 months; fruit intake >2 servings daily; vegetable intake >5 servings daily; SSB intake ≥1 L weekly; takeout food> once/week; and/or engaged in moderate-intensity PA <60 minutes daily.	250 (I=125, C=125)	Mean Age: 27.7 yrs; Gender: M, F=61.7%; 69.4% English speaking only; 75.4% living in socially advantaged area
Richards *et al.* (2006) USA (75)	College students aged 18-24 yrs	NR	NR	Age: 18-24 yo; non-dietetic major; have current e-mail, mail address, and telephone number.	314 (I=157, C=157)	Age: 20.4 +/-1.5 yrs; Gender: M, F=75.2%; 96.8% White
Rompotis *et al.* (2014) Australia (72)	Undergraduate psychology students	Electronic bulletin board	NR	Age: 18-34 yo; own a mobile phone and a student email account	161 (email I=30, email C1=29, email C2=29, SMS I=26, SMS C1=24, SMS C2=23)	Mean age=19.5 yrs; Gender: M, F= 81.7%
Shahril *et al.* (2013) Malaysia (70)	18 and 24 yo University students.	Students recruited from class lists based on study eligibility criteria	NR	Age: 18-24 yo; actively using mobile phone, first or second year diploma or degree from management studies; healthy and able to read, write, speak, and understand Malay or English	417 (I = 205, C= 212)	Mean Age=19.1 yrs; Gender: M, F= 87.6%

BMI, body mass index; C, control; C1, control group 1; C2, control group 2; F, female; I, intervention; M, male; MSB, my student body; NR, not reported; PA, physical activity; SMS, short message service; SSB, sugar sweetened beverage; yrs, years, yo, years old

Appendix 4.4

Table S4 Study Description of intervention implementation and adaption (n=14)

Author, year, citation	Intervention type	Intervention setting	Intervention description Comparator description	Number of sessions Delivery expertise	Intervention/ follow-up post	Adherence to protocol
Clifford *et al.* 2009 (68)	Nutrition- oriented cooking show based on SCT	Individual University (n=1) Online	I: view 4 15-minute cooking programs C: view 4 5-minute programs on sleep disorders.	I: 4x15-minute videos C: 4x5-minute videos Dietician (n=1)	4 wks 4 months	NR
Franko *et al.* (2008) (72)	Theory/ education based with goal setting	Individual University (n=6) Online	I: Exposure to web nutrition education (text based audio info, interactive activities and goal setting) C: Exposure to interactive anatomy education website	I: experimental I -2 online sessions, experimental II- 2 online sessions + 1 booster C:2 control web sessions. RS (n=NR)	2 wks 6 months	I: 94% completed sessions and post test II: 93.3% completed sessions and post test
Gow *et al.* (2010) (66)	Theory/ education based with monitoring and feedback based on SOC (TTM)	Individual University (n = 1) Online Email	I: Online intervention on healthy eating and exercise FI: weight and caloric feedback only (via email) CI: Combined feedback and online intervention C: no treatment	I: 6× approx. 45 min weekly FI: 6× weekly emails in response to self- reported weight CI: both 1 and 2. NR	6 wks 3 months	Significant differences between groups attending ≥4 sessions (CI 82.1%; I 65.8% and FI 89.9%) >3 session required
Greene *et al.* (2012) (61)	Theory/ education based with goal setting and feedback	Individual University (n = 8) Online	I: Individualized online profile page with feedback on current intake vs recommended. Access to web-based nutrition and PA curriculum based on non- diet approach C: Profile page only.	10 × 15 min weekly online lessons RS (n=NR)	12 wks 15 months	84% of intervention group completed 10/10 sessions. 5.1% didn't complete any sessions
Hebden *et al.* (2013) (64)	Behavior change based SOC (TTM). Monitoring and feedback with goal setting	Individual Mobile phone Online Email	I: Diet booklet with instructions. Participants selected 2/4 lifestyle behaviors e.g. F&V intake. Received SMS, emails based on SOC, and access to phone apps and web forums. C: Diet booklet only.	1 initial in-person consultation; 48 SMS (4/wk); 48 emails (4/wk) Unlimited access to apps and Internet Forums. Dietician (n=1)	12 wks No f/u	99.6% SMS delivery, 48.8% replies with 13/26 replying to over half, 100% email delivery
Kattelmann *et al.* (2014) (62)	Theory/ education based using SOC (TTM) tailoring and goal setting	Individual University (n = 13) Online Email	I: Access to voluntary mini educational lessons & e- mails with personalized videos tailored to SOC, to reinforce lesson & prompt goal setting. C: Access to material after f/u	I: 21 educational Lessons 4 nudges per wk (1 as a reminder to view lesson) Dieticians (n=NR)	10 wks 12 months	I: 75% completed 10 wk intervention.
Kothe and Mullan (2014) (67)	Promoting behavior incorporating theory of planned behavior	Individual University (n = 1) Email	I: received emails promoting F&V consumption. Messages targeted attitude, subjective norm, and perceived behavioral control. C: no exposure to emails	I: Emails every 3 days over 1 month RS (n=NR)	4 wks No f/u	NR

Author, year, citation	Intervention type	Intervention setting	Intervention description Comparator description	Number of sessions Delivery expertise	Intervention/ follow-up post intervention	Adherence to protocol
Kypri and McAnally (2005) (73)	Feedback based on authority recommendations and social norms	Individual University (n = 1) Online, Email	I: web-based assessment and personalized feedback using health authority recommendations, social norms and self-comparison C1: assessment only C2: minimal contact	1 session RS (n=NR)	6 wks No f/u	NR
LaChausse (2012) (70)	Theory/ education based Individualized feedback	Individual University (n = 8) Online	I: Online nutrition education course C1: on-campus nutrition education course, reflection papers on course discussions and exams. C2: no exposure	I: 2 hours/ wk over 12- weeks C1: 1 2hr session/wk over 12 wks Health promotion officer (n=1)	12 wks 2 wks	I: logged into the online course M= 29.84 times (SD = 12.44) over 12wks. C1: NR
Nitzke *et al.* (2007) (63)	Individualized feedback based on SOC (TTM)	Individual home based 10 states Phone calls	I: mailed materials (individualized feedback on current intake & advice based on SOC) and phone calls enforcing material. C: mailed non-tailored pamphlet.	I: 2 phone calls over 6 months and series of mailed material RS & outreach educators (n=NR)	6 months 6 months	NR
Partridge *et al.* (2015) (65)	Behavior Change based on SOC (TTM) Monitoring and feedback with goal setting	Individual Mobile phone Online Email SMS	I: Received 18 page diet booklet and 8 SMS, 1 email weekly based on SOC, and 5 personalized coaching calls, access to phone apps, blog, website C: Received printed dietary & PA guidelines & 4 SMS	I: 8 SMS, 1 email weekly, 5 personalized coaching calls (10-15 mins each, 25 mins for initial) C: 1 SMS every 3 wks during wk 1-12 Dietician (n=2)	12 wks 6 months (only 12 wk data available)	4.6/5 coaching calls completed, 53.7% replied to SMS, 76.4% use of emails, 74.5% didn't use apps, 65.5% used booklet, 59.1% didn't use website
Richards *et al.* (2006) (74)	Individually tailored motivational interviewing based on SOC (TTM), with goal setting	Individual University (n=1) Online Email Phone calls	I: received stage-based newsletters, motivational interview (by phone) to identify barriers and solutions to F&V consumption, tailored e- mails: recipes, nutrition facts, F&V tips, Websites C: assessment only	I: 4 newsletters, 1 motivational interview, minimum of 2 emails Dietician (n=1)	4 months No f/u	52.3% visited website, 95.5% received motivational interview phone call
Rompotis *et al.* (2014) (71)	Habit formation	Individual University (n=1) Mobile phone Email	I: F&V intake-habit formation messages 1) via emails 2) via SMS C1: general F&V messages 1) via emails 2) via SMS C2:general healthy eating messages 1) via emails 2) via SMS	1: 24 emails 2: 24 SMS Over 8 wks RS (n=NR)	8 wks 8 wks	NR
Shahril *et al.* (2013) (69)	Theory/ Education Based	Individual University (n=4) SMS	I: Lecture on dietary guidelines, brochures and SMS enforcing information C: No exposure	I: 1 SMS every 5 days+ 1 hour nutrition lecture + 3 pamphlets RS, nutritionist (n=1)	10 wks No f/u	NR

C, control; C1, control group 1; C2, control group 2; CI, combined intervention; FI, feedback intervention; f/u, follow up; F&V, fruit and vegetables; I, intervention; II, intervention group 2; M, mean; NR, not reported; PA, physicalactivity RS, research staff; SCT, social cognitive theory; SMS, short message service; SOC, stage of change; TTM, transtheoreticalmodel; wks, weeks

Appendix 4.5

Table S5: Study maintenance and institutionalization (n=14)

Author, year, citation	Attrition	Control vs. Intervention (% differential attrition)	Compared drop outs	Long term effects	Program sustainability
Clifford *et al.* 2009 (69)	NR	NR	No differences between completers and non-completers.	Changes not maintained at 4 month follow up	NR
Franko *et al.* (2008) (73)	26.7	30.6 vs 23.6 (I), 26.1 (II)	NR	Changes not maintained at 6 month follow up	NR
Gow *et al.*(2010) (67)	20.8	20 vs. 43.9 (II); 41.0 (FI) and 20.5 (CI)	Drop outs reported less F&V consumption than completers ($P < 0.5$)	Changes not maintained at 3 month follow up	NR
Greene *et al.* (2012)(62)	20.2 (12 wks) 33.3 (15 mo)	17.7 vs. 22.9 (12 wks) 31.2 vs 35.5 (15 mo)	A greater proportion of completers were white ($P< 0.05$) and had a lower BMI at baseline ($P< 0.05$)	Changes not maintained at 15 month follow up	NR
Hebden *et al.* (2013) (65)	9.8	0 vs 19.3	NR	No follow up	Results used to refine mhealth for larger study in a broader young adult population.
Kattelmann *et al.* (2014) (63)	24.3	23.6 vs 25	More completers (70.4% vs 60.7%) were female and had never used cigarettes (71.7% vs 65.6%).	Changes not maintained at 12 month follow up	NR
Kothe & Mullan (2014) (68)	18.5	17.3 vs. 19.8	No differences between completers and non-completers.	No follow up	NR
Kypri & McAnally (2005) (74)	13.3	12.5 vs. 15.3 (I), 12.2 (II)	Greater proportion of smokers among non-completers ($P< 0.05$).	No follow up	NR
LaChausse (2012) (71)	2.5	NR	NR	NR	NR
Nitzke *et al.* (2007) (64)	38 (12 months)	NR	Education less than high school completion, non-White ethnicity, male gender, living with children, and income ≤$800/month predicted attrition ($P< .001$).	Changes maintained at 6 month follow up 12 month post-intervention NR.	Sustainability of changes measured at 6 months but not beyond, and not for broader young adult population.
Partridge *et al.* (2015) (66)	8.0	0 vs 8.0	No demographic differences between completers and non- completers. However non- completers consumed more take away food at baseline.	Study still underway	Study still underway
Richards *et al.* (2006)(75)	28	NR	More female completers ($P<.001$)	No follow up	NR
Rompotis *et al.* (2014) (72)	55.3	52.0 (C1)email, 62.0 (C2)email vs. 47.0 (I)email; 62.0 (C1)SMS, 57.0	No significant differences found between completers and non-completers.	NR	NR
Shahril *et al.* (2013) (70)	8.9	4.7 vs. 13.2	NR	No follow up	NR

C,control; C1, control group 1; C2, control group 2; CI, combined intervention; FI, feedback intervention; F&V, fruit and vegetables; I, intervention; II, intervention group 2; Mo, months; NR, not reported; vs, versus; wks, weeks

Appendix 4.6

Table S6. Risk of bias as assessed by the Cochrane Collaboration Tool for included studies (n=14)

First author, Citation	Selection bias									
	Random sequence generation		Allocation concealment		Attrition bias		Detection bias		Reporting bias	
	Cochrane judgment	**Supporting evidence**	**Cochrane judgment**	**Supporting evidence**	**Cochrane judgment**	**Supporting evidence**	**Cochrane judgment**	**Supporting evidence**	**Cochrane judgment**	**Supporting evidence**
Clifford et al. (2009)	Unclear risk	Method of randomization not reported	Unclear risk	Method not described	Unclear risk	Unclear if intention to treat analysis performed	Unclear risk	Insufficient information to determine if researchers or participants were blinded to allocation of participants	Low risk	All pre-specified outcomes were reported
Franko et al (2008)	Low risk	Software program used. No further details specified.	Unclear risk	Method not described	High risk	Intention to treat analysis not performed; Missing data not dealt with appropriately (direct likelihood estimation technique used however this is not data missing at random)	High risk	Research assistants aware of allocation	Low risk	All pre-specified outcomes were reported
Gow et al. (2010)	Low risk	Software program used. No further details specified.	Unclear risk	Method not described	Low risk	Intention to treat analysis performed by assigning dropouts (18/40 in the Internet group, 16/39 in the feedback group, 8/40 in the combined group, 8/40 in the control) their baseline results	Unclear risk	Insufficient information to determine if researchers or participants were blinded to allocation of participants	Low risk	All pre-specified outcomes were reported
Greene et al. (2012)	Unclear risk	Method of randomization not reported, however stratified by institution and gender	Unclear risk	Method not described	High risk	Intention to treat analysis not performed (18 control subjects exposed to intervention and excluded from outcome analysis)	Unclear risk	Insufficient information to determine if researchers or participants were blinded to allocation of participants	Low risk	All pre-specified outcomes were reported
Hebden et al. (2013)	Low risk	Computer software used to generate random sequence	Unclear risk	One investigator supervised randomization but concealment not described	Low risk	Intention to treat analysis performed by imputing baseline values for missing follow-up data (5/26 dropouts in intervention group; 3 disontinued;2 unable to attend follow-up; 0 lost in control group)	High risk	Assessors were not blinded to allocation	Low risk	All pre-specified outcomes were reported
Kattelmann et al (2014)	Low risk	Randomized via a computer-generated program.	Unclear risk	Method not described	Unclear risk	Completers and non-completers compared statistically however not specified if non-completers included in analysis	Unclear risk	Insufficient information to determine if researchers or participants were blinded to allocation of participants	Low risk	All pre-specified outcomes were reported

First author, Citation	Selection bias									
	Random sequence generation		Allocation concealment		Attrition bias		Detection bias		Reporting bias	
	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence	Cochrane judgment	Supporting evidence
Kothe and Mullan (2014)	Low risk	Participants were computer randomized to the intervention or control group.	Unclear risk	Method not described	Unclear risk	Unclear if intention to treat analysis performed	Unclear risk	Insufficient information to determine if researchers or participants were blinded to allocation of participants	Low risk	All pre-specified outcomes were reported
Kypri and McAnally (2005)	Low risk	Participants were assigned by a computerized random number generator in blocks of 15 (five per trial arm).	Low risk	Allocation concealment achieved by not informing participants that they were participating in an intervention, and research assistant recruiting was not informed of allocation- done by	High risk	Intention to treat analysis not performed. Missing data for group C at baseline not adjusted.	Low risk	Researchers and participants were blinded to allocation	Low risk	All pre-specified outcomes were reported
LaChausse (2012)	Unclear risk	Method of randomization not reported	High risk	Participants made aware of randomized control study design in orientation session	High risk	Intention to treat analysis not performed, 8 Non-completers of post-test survey excluded from analyses	High risk	Orientation explained the 3 arms of the study to all participants thus blinding was not possible	Low risk	All pre-specified outcomes were reported
Nitzke et al. (2007)	Unclear risk	Method of randomization not reported	Unclear risk	Method not described	Low risk	Intention to treat analysis performed by using baseline data for non-completers at 12 months	Unclear risk	Insufficient information to determine if assessors or participants were blinded to allocation (assessors were from independent) survey	Low risk	All pre-specified outcomes were reported
Partridge et al. (2015)	Low risk	Computer software used to generate random sequence by independent researcher	Low risk	Randomization by independent researcher, allocation concealed from investigators Participants aware of 2 groups but nature of control arm concealed to prevent detection of allocation	Low risk	Intention to treat analysis performed on missing data	Low risk	Researchers and participants were blinded to allocation	Low risk	All pre-specified outcomes were reported
Richards et al. (2006)	Unclear risk	Method of randomization not reported	Unclear risk	Method not described	High risk	Intention to treat analysis not performed. Non-completers excluded from analyses	Unclear risk	Insufficient information to determine if assessors or participants were blinded to allocation	Low risk	All pre-specified outcomes were reported
Rompotis et al. (2014)	Low risk	Randomized using a random number generator through Research Randomizer	Unclear risk	Method not described	High risk	Only the 71 completers were included in analyses with no intention to treat analyses performed	Unclear risk	Insufficient information to determine if assessors or participants were blinded to allocation	Low risk	All pre-specified outcomes were reported
Shahril et al. (2013)	Low risk	Randomized by drawing sealed envelopes containing group assignment.	Unclear	Investigators could not foresee assignment because sealed envelopes containing group assignment were used. However unclear if participants aware of intervention arms	High risk	Intention to treat analysis not performed, dropout was not balanced between groups (27/205 in intervention group and 10/212 in control group)	Low risk	Assessor who was dealing with data was blinded to allocation	Low risk	All pre-specified outcomes were reported

Appendix 4.7

Change in fruit and vegetable intake between baseline and follow-up for intervention and control arms with calculated effect size

Author (year), citation	**e/mHealth strategies**	**Results**	
		Baseline to post intervention	**Effect Size Cohen's d (95% CI)**
Clifford *et al.* (2009) (69)	Online cooking videos	*Data as mean (SE) F&V serves/day* **Intervention:** pre: 2.82 (0.25), post: 2.46 (0.30) **Control:** pre: 2.67 (0.25), post: 2.77 (0.29) ***P* =** NS (*p* >0.05)	*F&V* -0.15 (-0.54; 0.24)
Franko *et al.* (2008) (73)	Online education	*Data as mean (SE) F&V serves/day*[1] **Intervention** I: pre: 3.2 (0.1), post: 3.65, II: pre: 3.0, post: 3.66 **Control:** pre: 2.9 (0.1), post: 3.07 ***P*** <0.01	N/A *(No SE reported post intervention for calculation)*
Gow *et al.* (2010) (67)	Online education, Email	*Data as mean (pre: SD, post: SE) F&V score (value of score not defined)* **Intervention + FB group:** pre: 1.32 (1.67), post: 1.73 (0.21), **Intervention only:** pre: 1.87 (1.54), post: 1.63 (0.21), **FB only:** pre: 1.46 (1.64), post:1.57 (0.22) **Control:** pre: 1.80 (1.43), post: 1.44 (0.21) ***P* =** NS (*p* value NR)	*F&V* I + FB: 0.22 (-0.22; 0.66) I only: 0.14 (-0.29; 0.58) FB only: 0.1 (0.34; 0.54)
Greene *et al.* (2012) (62)	Online education	*Data as mean (SE) F&V cups/day* **Intervention:** 2 item screener: pre: 2.6 (0.10) post: 3.7 (0.10) NCI: pre: 3.3 (0.12), post: 4.1 (0.16) **Control:** 2 item screener: pre: 2.6 (0.09), post: 2.5 (0.10) NCI: pre: 3.1 (0.12), post: 2.8 (0.15) ***P*** <0.001 (for both tools)	*F&V* 2 Item 0.46 (0.35; 0.57) *F&V* NCI 0.32 (0.21; 0.43)
Hebden *et al.* (2013) (65)	SMS, Apps, Email, Website	*Data as median serves/day (IQR 25–75%)* **Intervention:** V: pre: 2.0 (1.0–3.0), post: 2.0 (2.0–4.0) F: pre: 1.5 (1.0–2.0), post: 2.0 (1.0–3.0) **Control:** V: pre: 2.0 (2.0–3.0), post: 3.0 (2.0–4.0) F: pre: 2.0 (1.0–2.0), post: 2.0 (1.0–3.0) V: ***P***= 0.66 , F: ***P***= 0.96	*Vegetables* 0.12 (-0.43; 0.67) *Fruit* 0.01(-0.53; 0.60)
Kattelmann *et al.* (2014) (63)	Online education, Email	*Data as mean (SD) F&V cups/day* **Intervention:** pre: 2.6 (2.1), post: 2.8 (2.1) **Control:** pre: 2.7 (1.9), post: 2.5 (2.1) ***P***= 0.001	*F&V* 0.14 (0.03; 0.25)
Kothe & Mullan (2014) (68)	Email	*Data as mean (SD) F&V serves/day* **Intervention:** pre: 4.69 (1.92), post: 5.31 (2.08) **Control:** pre: 4.59 (2.22), post: 5.02 (2.10) ***P***= 0.499	*F&V* 0.14 (-0.2; 0.48)
Kypri and McAnally (2005) (74)	Online assessment, Email	*Data as % meeting F&V recommendations* **Intervention:** pre: 24%, post 33% **Control:** pre: 21%, post 26% ***P***= 0.44	*F&V* 0.19 (-0.15; 0.52)
LaChausse (2012) (71)	Online web-based education	*Data as mean (SD) frequency of F&V consumption* **Intervention:** F: pre: 2.67 (1.25), post: 3.37 (1.6), V: pre: 2.44 (1.22), post: 2.80 (1.35) **Control:** F: pre: 3.24 (1.55), post: 3.15 (1.48), V: 2.65 (1.32), post: 2.8 (1.35) ***P***=*0.04*	*Vegetables* 0 (-2.35; 2.35) *Fruit* 0.14 (-0.12; 0.40)

Author (year), citation	e/mHealth strategies	Results	
		Baseline to post intervention	**Effect Size Cohen's d (95% CI)**
Nitzke *et al.* (2007) (64)	Phone calls	*Data as mean (SD) F&V serves/day*[3] **Intervention:** F: pre: 2.36 (2.5), post 2.59 (4.11) V: pre: 1.69 (1.33), post: 1.82 (1.40) (***P*** < 0.05) **Control:** F: pre: 2.37 (2.36), post: 2.21 (1.96), V: pre: 1.67 (121), post: 1.67 (121) COMBINED F&V **Intervention:** pre: 4.04 (3.18), post 4.40 (4.58) **Control:** pre: 4.03 (3.10), post: 3.87 (2.67) (***P*** < 0.05)	*Vegetables:* 0.11 (0.03; 0.20) *Fruit:* 0.12(0.03; 0.21) *F&V* 0.14 (0.03; 0.26)
Partridge *et al.* (2015) (66)	SMS Mobile Apps Website Email	*Data as % consuming ≥2 F & ≥4 V serves/day* **Intervention:** F: pre: 33.3%, post: 75.6%, V: pre: 15.4%, post: 35% **Control:** F: pre: 38.4%, post: 60.0%, V: pre: 14.4 %, post: 22.4% F: ***P***= 0.18, V: ***P***=0.009[4]	*Vegetables*: 0.40 (0.04; 0.70) *Fruit:* 0.8 (0.33; 1.31)
Richards *et al.* (2006) (75)	Website Email Phone calls	*Data as mean (SE) F&V serves/day* **Intervention:** pre: 2.2 (0.1), post: 3.2 (0.1) **Control:** pre: 2.1 (0.1), post: 2.5 (0.1) ***P*** < 0.001	*F&V* 0.56 (0.33; 0.79)
Rompotis *et al.* (2014) (72)	SMS Email	**All groups:** Pre: 2.32, post: 2.66 (+0.34 V serves/day across the groups) ***P*** < 0.009 (change in intake NR by group or for fruit) NS differences between groups *P*=0.30	N/A No control vs intervention mean and SE/SD for calculation
Shahril *et al.* (2013) (70)	SMS	*Data as mean (SE) F&V serves/day* **Intervention:** F[5]: pre: 0.40 (0.05), post: 1.16 (0.08), V: pre:1.39 (0.06), post: 1.45 (0.06) **Control:** F[5]: 0.35 (0.04), post: 0.32 (0.04), V: pre: 1.31(0.06), post: no change in V F: ***P*** < 0.001, V: ***P***=0.12	*Fruit* 1.0 (0.8; 1.2) *Vegetables* 0.17 (-0.03; 0.37)

[1], data based on single item F&V tool as no post test data for FFQ; [2], Intervention + feedback group compared to the control; [3] 3 month data reported (6 month NA); [4] p values based on shift in intake for intervention vs. control arms, [5] including fruit juice; BCT, behavior change techniques; FB, feedback, FFQ, food frequency questionnaire; F&V, fruit and vegetables; I, intervention; IQR. Interquartile range; msg, message; NA, not applicable; NCI, national cancer institute; NR, not reported; NS, not significant; PA, physical activity; SM S, short message service; SOC, stages of change; SSB, sugar sweetened beverages; TA, take away; wks, weeks

Appendix 4.8

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(See next page)

Original Paper

Efficacy and External Validity of Electronic and Mobile Phone-Based Interventions Promoting Vegetable Intake in Young Adults: Systematic Review and Meta-Analysis

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Abstract

Background: Young adults (18–35 years) remain among the lowest vegetable consumers in many western countries. The digital era offers opportunities to engage this age group in interventions in new and appealing ways.

Objective: This systematic review evaluated the efficacy and external validity of electronic (eHealth) and mobile phone (mHealth) -based interventions that promote vegetable intake in young adults.

Methods: We searched several electronic databases for studies published between 1990 and 2015, and 2 independent authors reviewed the quality and risk of bias of the eligible papers and extracted data for analyses. The primary outcome of interest was the change in vegetable intake postintervention. Where possible, we calculated effect sizes (Cohen *d* and 95% CIs) for comparison. A random effects model was applied to the data for meta-analysis. Reach and representativeness of participants, intervention implementation, and program maintenance were assessed to establish external validity. Published validation studies were consulted to determine the validity of tools used to measure intake. We applied the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system to evaluate the overall quality of the body of evidence.

Results: Of the 14 studies that met the selection criteria, we included 12 in the meta-analysis. In the meta-analysis, 7 studies found positive effects postintervention for fruit and vegetable intake, Cohen *d* 0.14–0.56 (pooled effect size 0.22, 95% CI 0.11–0.33, I^2=68.5%, *P*=.002), and 4 recorded positive effects on vegetable intake alone, Cohen *d* 0.11–0.40 (pooled effect size 0.15, 95% CI 0.04–0.28, I^2=31.4%, *P*=.2). These findings should be interpreted with caution due to variability in intervention design and outcome measures. With the majority of outcomes documented as a change in combined fruit and vegetable intake, it was difficult to determine intervention effects on vegetable consumption specifically. Measurement of intake was most commonly by self-report, with 5 studies using nonvalidated tools. Longer-term follow-up was lacking from most studies (n=12). Risk of bias was high among the included studies, and the overall body of evidence was rated as low quality. The applicability of interventions to the broader young adult community was unclear due to poor description of external validity components.

Conclusions: Preliminary evidence suggests that eHealth and mHealth strategies may be effective in improving vegetable intake in young adults; whether these small effects have clinical or nutritional significance remains questionable. With studies predominantly reporting outcomes as fruit and vegetable intake combined, we suggest that interventions report vegetables separately. Furthermore, to confidently establish the efficacy of these strategies, better-quality interventions are needed for young adults, using valid measures of intake, with improved reporting on costs, sustainability and long-term effects of programs.

Trial registration: PROSPERO International Prospective Register of Systematic Reviews: CRD42015017763; http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015017763 (Archived by WebCite at http://www.webcitation.org/6fLhMgUP4)

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KEYWORDS

young adults; vegetable consumption; mHealth; eHealth; social marketing

Introduction

Poor fruit and vegetable intake contributes to 2.635 million deaths per year [1]. Consuming the recommended 600 g daily could reduce this global burden by 1.8% [1], with adequate fruit and vegetable intake linked to minimized adiposity, improved weight management [2], and reduced risk of heart disease and some cancers [1]. Despite several decades of government-led social marketing campaigns, alongside concerted effort by researchers and practitioners to facilitate behavior change, intake of vegetables remains suboptimal in many countries [3-6].

Australian young adults (18-34 years) are among the lowest consumers of vegetables, with only 4.7% consuming the recommended 5 or more servings a day [7]. During this transitional phase of life, young adults are developing self-determined food habits that will affect their future health. While the association between fruit and vegetable consumption and reduced chronic disease risk is well established in the literature [2,8-15], promoting these long-term health benefits, as is typically done in nationwide social marketing campaigns, does not appear to motivate young adults [16,17]. Young adults are typically less concerned about their future well-being and engage in more risky health behaviors [18]. Consequently, this population should be targeted separately in interventions.

Research in the area of digital interventions has revealed that electronic (eHealth) and mobile phone (mHealth) -based strategies are effective in promoting healthful behaviors [19-21]. eHealth and mHealth refer to the use of the Internet, mobile, or wireless devices to deliver health services and information to improve health outcomes or enhance health research [22,23]. Examples of eHealth and mHealth strategies include text messaging, email, mobile phone apps, phone calls, and websites. Young adults are among the highest users of mobile phones and wireless information sharing platforms [24], with 89% of 18- to 29-year-olds in the United States reporting use of social networking sites [25]. This offers an opportunity to engage young adults in interventions in new and appealing ways. Harnessing this technology to deliver social marketing and individually tailored programs could facilitate the widespread dissemination of interventions in an affordable, convenient, and age-appropriate manner.

Previous systematic reviews of fruit and vegetable consumption-promoting programs have identified that, while interventions produced some positive changes in knowledge and attitudes about the importance of fruit and vegetable consumption, there were only minor improvements in intake [26-28]. These interventions were typically delivered to adults and children, and targeted fruit and vegetable intake concurrently. To our knowledge, to date there is no published review investigating the efficacy and external validity of social marketing and eHealth and mHealth interventions on vegetable intake in young adults. With greater perceived barriers for the consumption of vegetables, poorer knowledge about vegetable servings [29], and just over half of the population already meeting the recommended 2 fruit servings a day [7], it is evident that increasing vegetable intake is a greater challenge. Thus, investigating the implications of interventions on vegetable intake alone will help us understand how we can better support and facilitate improved vegetable consumption.

When evaluating the efficacy of interventions, the accuracy of outcomes should be considered. This is dependent on the validity of intake measurement tools. To compare outcomes across studies, definitions of what constitutes a vegetable serving is also important. This is a source of confusion for the public and for researchers, with variations between countries [30]. In Australia, a serving of vegetables is approximately 75 g or half a cup of cooked vegetables [31], whereas in the United Kingdom a serving is equivalent to 80 g [32].

Furthermore, the specification of behavior change techniques used in interventions is essential to the process of revealing which strategies are effective in the target population and allowing replication of successful interventions [33]. A review of recent eHealth and mHealth interventions found that studies that incorporated a greater number of behavior change techniques had the largest effects [34]. Whether these effects can be generalized to the broader young adult population depends on external validity. Thus, evaluating the external validity of studies is as important as determining efficacy and will have implications for the translation of interventions into larger health promotion programs.

Therefore, in this review we aimed to (1) systematically examine the efficacy of social marketing, and electronic or mobile phone-based interventions in increasing vegetable intake in young adults, (2) assess the quality of the studies, including the validity of tools used to monitor changes in vegetable intake, and (3) review the adequacy of reporting of external validity components.

Methods

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework [35] to develop the systematic review protocol, which has been published elsewhere [36]. During the review process, we replaced the quality-assessment tool specified in the original protocol with the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system [37].

Search Strategy

We conducted the systematic literature search between April and August 2015 using the following electronic databases: ScienceDirect, MEDLINE, PyscINFO, Scopus, the Cochrane Library, CINAHL, Embase, and Web of Science. The last search was conducted on August 17, 2015, with no new relevant papers found. We excluded studies published before 1990, as email was not widely used before this period [38]. After hand searching reference lists of key reviews and included studies, as well as conducting a manual search of JMIR journals, we included other relevant studies.

We conducted 2 searches. The first used combinations, synonyms, and truncations of "online intervention," "computer-assisted therapy," "electronic mail," "Internet," "website," "cell phones," "young adult" or "adult," "fruits," and "vegetables." While we were searching largely for eHealth and mHealth interventions, we used other relevant MEDLINE MeSH, such as "telemedicine," to encompass the terms "mHealth," "eHealth," "telehealth," and "mobile health." Furthermore, although we were mainly interested in the efficacy of vegetable interventions, we extended the search terms to include "fruit," as studies typically report on fruit and vegetables concurrently. Additionally, we used the term "adult" alongside "young adult" to broaden the search from 18- to 24-year-olds (the typical database definition of young adults) to 18- to 35-year-olds (based on the US National Institutes of Health cut-off for young adults) [39]. Table 1 shows the first search strategy used in the MEDLINE. The full search strategy is presented in Multimedia Appendix 1 (Tables S1 and S2).

Table 1. Electronic database search: MEDLINE (search 1: eHealth and mHealth interventions).

Search number	Search statement[a]	No. of citations retrieved
1	Online intervention.mp or Computer-assisted therapy.mp. or Therapy, Computer-Assisted/	5242
2	Internet/ or Website.mp	55,352
3	Cell phones.mp or Cell phones/	5040
4	Telemedicine/ or Cyber.mp	12,148
5	email.mp or Electronic mail/	5193
6	Adult/or Young adult/ or young adult*.mp	4,093,057
7	Fruit/ or Fruit*.mp	65,586
8	Vegetable*.mp or Vegetables/	39,576
9	1 or 2 or 3 or 4 or 5	77,751
10	7 or 8	87,363
11	6 and 9 and 10	120
12	Limit 11 to (English language and humans and yr = 1990-current)	120

[a]Modifiers are * (search term as major focus of articles), .mp (multiple purpose search including all fields: title, original title, abstract, subject heading, name of substance, and registry word fields), and / (valid controlled vocabulary term which has been searched in the subject headings field of the database).

We conducted separate database and Google searches to locate programs that used social marketing and mass media to increase fruit and vegetable intake in young adults. Search terms were "young adult," "adults," "fruits," "vegetables," "social marketing," "social media," and "mass media." These studies were not limited by publication type and included gray literature, such as nonpublished evaluations of programs by organizations. Table 2 presents the second search strategy used in MEDLINE.

Table 2. Electronic database search: MEDLINE (search 2: social marketing and mass media interventions).

Search number	Search statement[a]	No. of citations retrieved
1	Adult/ or Young Adult/ or young adult*.mp.	4126,552
2	Fruit/ or fruit*.mp.	66,529
3	Vegetable*.mp. or Vegetables/	40,014
4	2 or 3	88,502
5	Social marketing.mp. or social marketing/	2976
6	Social media. mp or Mass Media/ or Social Media/	11,192
7	5 or 6	13,882
8	1 and 4 and 7	6
9	Limit 8 to (English language and humans and yr = 1990-current)	6

[a]Modifiers are * (search term as major focus of articles), .mp (multiple purpose search including all fields: title, original title, abstract, subject heading, name of substance, and registry word fields), and / (valid controlled vocabulary term which has been searched in the subject headings field of the database).

Eligibility Criteria

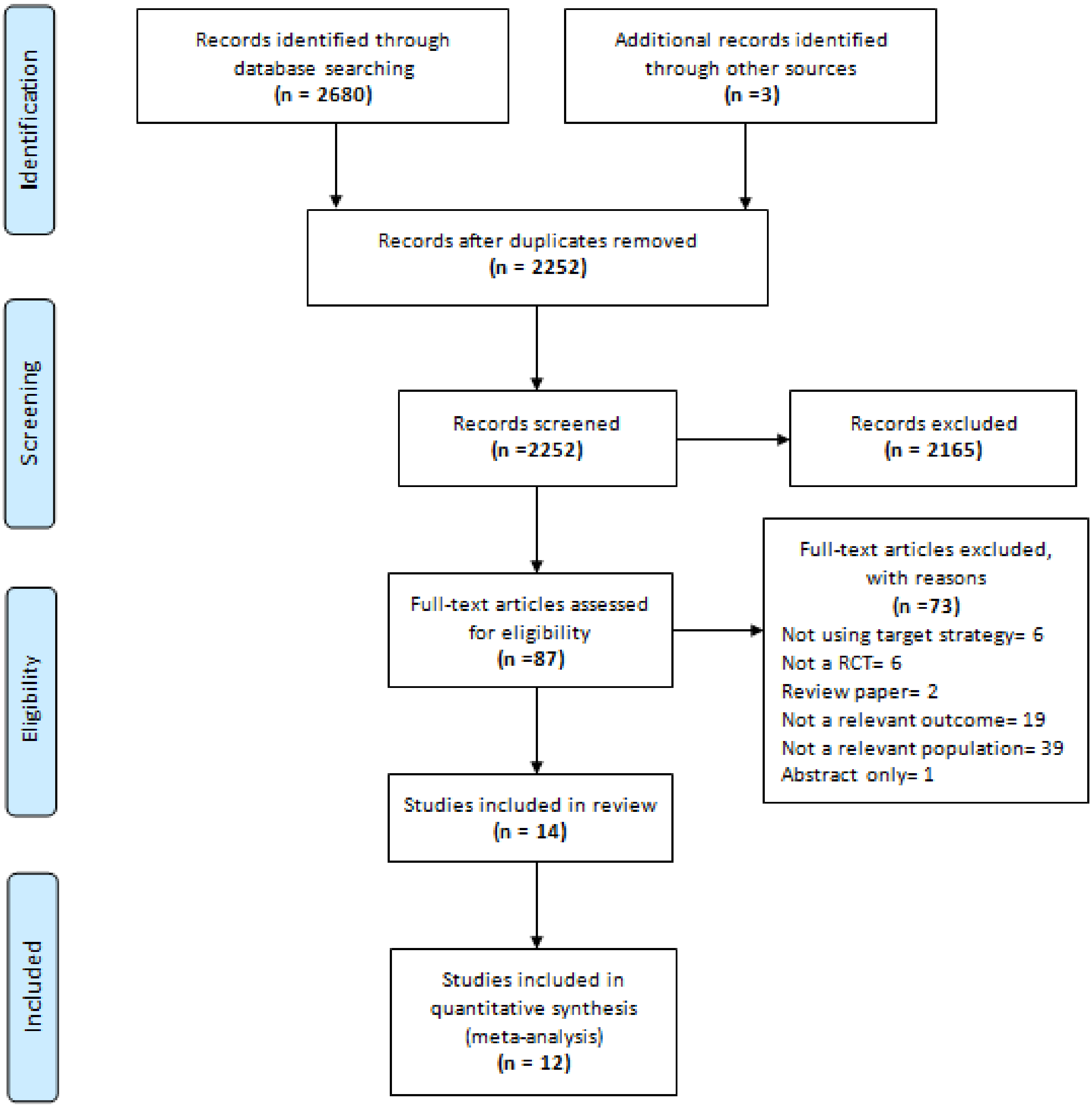
Criteria for inclusion of eHealth and mHealth interventions were as follows: (1) randomized controlled trials (RCTs) with a primary or secondary aim of increasing fruit and vegetable intake in young adults that (2) were targeted at young adults aged 18–35 years inclusive, (3) reported fruit and vegetable intake at baseline and follow-up, (4) involved healthy participants with no disease or illness that would affect the primary outcome or ability to modify fruit and vegetable intake, (5) were written in English, (6) were published after 1990, and (7) were limited to eHealth- and mHealth-based interventions, defined as studies using texting, email, mobile phone apps, phone calls, or websites to deliver the intervention.

Criteria for inclusion of social marketing and mass media interventions were identical to points (1) to (6) above, but were not limited by study design. Social marketing and mass media interventions were defined as those that used media advertising through the Internet, television, billboards, radio, or social media platforms such as Facebook.

Study Selection

We downloaded titles and abstracts of all retrieved studies to EndNote X6 citation management software (Thomson Reuters). Duplicates were removed, then titles and abstracts were reviewed by grouping papers into (1) those meeting selection criteria or (2) requiring further examination; or (3) they were excluded. Papers determined to be potentially relevant to the review were downloaded as full text and reviewed for eligibility by two assessors (MN, JC) and further categorized (Figure 1). We resolved discrepancies in assessors' results by discussion.

Figure 1. Flow diagram demonstrating the process of selecting the included studies of interventions promoting fruit and vegetable intake in young adults. Other sources included a Google search, a hand search of reference lists of relevant systematic reviews and included studies, and a manual search of JMIR journals.



Data Extraction Process

We created a data extraction table according to the principles of the PRISMA statement for reporting systematic reviews [35], with some additional elements included for completing the Cochrane Collaboration's risk of bias tool [40]. Once we had piloted the process on a random selection of 4 of the included studies, 2 independent reviewers extracted the following data in duplicate: study details (authors, year, country of publication, funding, and affiliations); participants (characteristics, setting, inclusion and exclusion criteria, attrition, and blinding); intervention and comparator details; duration; and the summary outcome measure (change in fruit and vegetable intake between baseline and follow-up for the intervention and control arms). We also extracted the name of the tool used to assess changes in fruit and vegetable intake, as well as citations of available validation studies.

Data Synthesis and Analysis

The primary outcome of interest was the change in vegetable intake postintervention. Where possible, for all study arms we recorded mean or median intakes (as servings, cups, frequency, or percentage consuming) pre- and postintervention. If vegetable intake was not reported separately, we documented the change in fruit and vegetable intake. We also noted the measures of error (SE or SD) and associated *P* values for change between groups over time. To determine the magnitude of intervention outcomes, we calculated effect sizes (Cohen *d* and 95% CIs) for studies that reported sufficient data (means, and measure of error or frequencies). Web-based calculators [41] based on Lipsey and Wilson's formulas [42] assisted with calculations. We assessed the magnitude of the effect sizes according to Cohen's categories, whereby an effect <0.2 is considered negligible, between 0.2 and 0.49 is small, 0.5-0.8 is medium, and >0.8 is large [43].

We also considered the clinical significance of outcomes. There is no consensus in the literature regarding what change in intake is considered clinically significant. However, several meta-analyses and longitudinal studies suggest a dose-response relationship, whereby an increase in vegetable intake by approximately 1 serving is protective for cardiovascular health (decreased risk of stroke and cardiovascular disease mortality by 11% and 4%, respectively) [44,45]. Furthermore, every 1-serving increase in vegetable intake has been associated with a 0.12 kg reduction in weight (95% CI -0.35 to -0.14) [46]. These studies define a serving of vegetables as approximately 1 cup of leafy vegetables or half a cup of cooked vegetables (frozen, fresh, or canned) in line with previous US and current Australian dietary guidelines [31,47].

To pool the outcomes for the meta-analysis, we grouped studies for which an effect size was calculated. We used STATA version 13 (StataCorp LP) to conduct the analyses using the metan, metabias, and metafunnel commands. A random effects model was applied. Publication bias was determined through Egger's statistical test for funnel plot asymmetry and visual inspection of the funnel plots of the Cohen *d* effect size (standardized mean difference), plotted against its standard error. The I^2 value for heterogeneity was calculated based on the Q statistic: [(Q statistic - df/Q statistic) × 100%]. Cochrane Collaboration guidelines [48] suggest that an I^2 for heterogeneity below 40% is considered low, and a value above 50% is considered substantial.

Quality Assessment

Risk of Bias Assessment

Using the Cochrane Collaboration's tool [40], we established risk of bias at the individual study level, based on the following study elements: selection of participants (random sequence generation and concealment of allocation methods); attrition (completeness of outcome data); detection (blinding of participants and personnel); and reporting (selective reporting of outcome measures). Two authors (MN and JC) independently evaluated each study for risk of bias and coded them as having low risk, high risk, or unclear risk. Any differences in judgment were clarified through discussion.

GRADE Assessment

The quality of the body of evidence was determined by 2 independent reviewers (MN, JC) using the GRADE system [37]. We considered 5 categories to ascribe a quality rating: limitations in study designs; consistency of results; directness of the evidence with regard to study populations, intervention design, and outcomes measured; precision of outcomes; and the presence of publication biases.

Rating Validity of Dietary Assessment Tools

We determined the validity of each tool used to measure changes in vegetable intake based on published literature demonstrating its accuracy [49-59]. The checklist of requirements by Nelson et al [60] was also consulted to qualitatively examine the effectiveness of reporting on measurement tools. This checklist assesses factors such as data-collection procedures (objective measure vs self-report), methods of quantifying portions, variety of foods captured, food composition databases used and whether checking procedures were applied.

Rating External Validity

We assessed the external validity of included studies based on the Green and Glasgow's criteria [61]. The assessment explored components under 3 sections: (1) reach and representativeness of participants, (2) intervention implementation and adaptation, and (3) program maintenance and institutionalization (sustainability of program implementation). Quantitative and qualitative data pertaining to these external validity components were extracted. We recorded specific data that were not reported as not reported, and if an assessment component did not apply to the particular study we reported it not applicable. Individual participation rate (%) was calculated as the percentage of eligible participants agreeing to participate. Attrition rate (%) was calculated as the percentage of participants who dropped out after randomization. Attrition was further grouped by intervention arm (treatment vs control). Extracted data were used to examine the number of studies adhering to the external validity components. The frequency and adequacy of reporting of these components were also examined and compared between studies.

Results

Study Selection

As the flow diagram in Figure 1 shows, we found 2680 studies through database searching and 3 additional studies through hand searching the references. We screened a total of 2252 papers by title and abstract. Of these, we assessed the full text of 87 studies. A total of 14 studies [62-75] met the selection criteria and were included in the review. See Multimedia Appendix 2 for the complete list of references excluded by full text with corresponding reasons. None of these studies used social marketing strategies or mass media to encourage vegetable consumption in young adults specifically. Therefore, the remaining results report the effectiveness and external validity of eHealth and mHealth interventions aimed at increasing fruit and vegetable intake in young adults. We included 12 studies in the meta-analyses. For the meta-analysis, we combined the reported results in 2 groups for comparability: fruit and vegetable (8 studies) and vegetable only (5 studies); 1 study contributed results for both groups [64].

Study Reach and Representativeness of Participants

Overall, 7984 healthy people participated in the eHealth and mHealth RCTs (see Multimedia Appendix 3, Table S3). There were, however, large discrepancies in the sample sizes. Only 3 of the 14 studies had recruited >500 participants at baseline [62-64], and 1 study had a sample size of <100 [64]. More than half of the interventions were conducted in the United States [62,64,67,69,71,73,75], 4 in Australia [65,65,67,72], 1 in New Zealand [74], and 1 in Malaysia [70]. The target audience was college or university students for the majority of the studies [62,63,67-75], and 3 studies reported their target audience to be young adults [64-66].

Recruitment methods were reported for 13 of the 14 studies, but limited details were provided. All but 2 studies recruited through the university or college setting [64,66]. Participants were recruited through undergraduate psychology courses in 2 studies [67,68], from random nonnutrition classes in 2 studies [69,70], and through advertisements and flyers posted on university grounds in 4 studies [62,63,65,71,72]. In 1 study a recruitment table was set up on campus [73], and another study invited patients attending the student university health service [74]. In 1 study [64] advertisements with a toll-free phone number were used, and the final study distributed letters of invitation through participating family doctors, along with electronic and print advertisements [66]. Of the included studies, 9 indicated their participation rate, with a mean of 78.0%. The inclusion criteria were detailed by 10 studies, all of which specified age (years) as one of their criteria. Demographic data were provided by most of the studies although not consistently. Baseline age (years) was reported in all but 1 study (Multimedia Appendix 3, Table S3), with a mean age of 20.8 years across the studies. The ethnicity of participants was reported to be >50% Caucasian or white in 7 studies. The percentage of female participants was reported by 13 studies, with women more commonly recruited than men (mean 69.8% female) (Multimedia Appendix 3, Table S3).

Intervention Implementation and Adaptation

Details of the intervention and comparator groups were provided in detail. All studies recruited an intervention and a control group (see Multimedia Appendix 4, Table S4), with 4 studies using multiple intervention and control arms [67,71,72,74]. A total of 6 studies provided no treatment to the control arm [67,68,70,71,74,75], 7 studies gave the comparator group general information not containing the intervention material [62,64-66,69,72,73], and 1 study provided the control group with the intervention material on completion of the follow-up assessment [63]. The duration of interventions and number of sessions were easily extrapolated from each study. The level of contact between researchers and participants ranged from one-off sessions (provision of feedback) to daily contact by email or text message (Multimedia Appendix 4, Table S4). The majority of the interventions used online education through learning platforms, websites, and emailing, with only 2 studies using apps [65,66] and 4 using text messaging [65,66,70,72]. No studies reported the use of social media platforms. The studies predominantly used goal setting for behavior change, with monitoring and feedback also commonly incorporated. For the majority of the interventions, the aim was to offset weight gain in young adulthood. Targeting improvements in fruit and vegetable intake was one such method used to address weight gain. While 1 study was designed to reduce health-risk behaviors in young adults [74], only 5 studies focused specifically on fruit and vegetable intake [64,68,69,72,75], and none targeted vegetables alone.

The reviewed studies varied in the detail provided regarding the behavior theories and techniques considered in the intervention design. The design of 5 studies was based on the transtheoretical model of behavior change, where the participants' stage of change determined the content received [63-66,75]. A total of 6 studies were theory or education based [62,63,67,70,71,73]. Social-cognitive theory informed 2 interventions [67,69]. Half of the reviewed studies applied the behavioral construct of self-efficacy in their intervention [62,64,69,70,71,73,75]. The study by Kypri and McAnally [74] did not report consideration of theoretical frameworks in their intervention design. The remaining 2 studies [68,72] were informed by the theory of planned behavior and the theory of habit formation (Multimedia Appendix 4, Table S4). All the studies that we reviewed intervened at the individual level. Only 2 studies were implemented outside of the university setting, thus limiting the generalizability of the interventions to the overall young adult population. Of these studies, one [64] was targeted at lower socioeconomic status young adults, while the other mainly captured young adults from higher socioeconomic areas [66].

The duration of the interventions (excluding postintervention follow-up) ranged from one-off contact to 6 months of treatment, with a mean of 10 weeks (Multimedia Appendix 4, Table S4). A total of 9 studies allocated a follow-up period [62-64,66,69,71-73], with a mean of 16 weeks. Adherence was most commonly documented as the number of sessions completed or the amount of materials viewed by participants (Multimedia Appendix 4, Table S4), but was not consistently reported across studies. The mean level of compliance among those reporting adherence was 85.4%.

Delivery expertise varied among the studies (Multimedia Appendix 4, Table S4). Research staff were more commonly reported to have conducted the interventions, with little specification of their qualifications and the number of research staff involved. Registered dietitians delivered 5 of the interventions [63,65,66,69,75]. Other expertise included a health promotion officer [71] and outreach educators [64].

Study Maintenance and Institutionalization

The rate of attrition was documented in all reviewed studies. At completion of the interventions the mean attrition rate was 19.6% (see Multimedia Appendix 5, Table S5). All but 4 studies [64,69,71,75] reported attrition for the control and intervention group separately, and 4 did not assess differences in characteristics between completers and noncompleters [65,70,71,73]. Only 2 studies looked at the long-term impacts of the study, by assessing outcomes at least 12 months following treatment [62,63]. Both of these studies found that the changes in fruit and vegetable intake were not maintained at follow-up (Multimedia Appendix 5, Table S5). The sustainability of program implementation was poorly reported, with only 1 study mentioning that results would be used to refine the intervention for trial in a broader young adult population using a larger sample size [66]. Finally, only 2 studies published a process evaluation documenting effective program elements [62,66].

Risk of Bias

We rated the majority of the studies reviewed as unclear to high risk because they did not perform intention-to-treat analyses, which introduced biases in the outcome data (attrition bias) [62,70-75] (see Multimedia Appendix 6, Table S6). We rated 2 studies high in a second domain (detection bias) [71,73]. The majority of the studies did not clarify their methods of blinding (n=8). Selection bias was mainly unclear within and across studies, with 5 studies not reporting the method of sequence generation in randomization [62,64,69,71,75] and only 2 studies specifying allocation concealment methods [66,74] (Multimedia Appendix 6, Table S6). While all of the studies reported results for prespecified outcomes, we could not completely rule out reporter bias across studies because only 5 RCTs published their original protocol [63,65,66,68,69] or provided details of their trial registration [66]. However, no selective reporting was apparent based on the methods within the reviewed manuscripts (both successful and unsuccessful outcomes recorded). Overall, the combined lack of clarity of the level of bias across studies raises concerns about the plausibility of the studies' results.

GRADE Quality Rating

The reviewed interventions had several limitations in study design and did not address the research question directly, resulting in an overall low quality rating (Table 3).

Table 3. Overall assessment of quality in 14 studies (7984 participants in total) of promotion of fruit and vegetable intake using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system.

Category	Rating with reasoning
Limitations	–2 quality levels due to very serious limitations
Consistency	No subtraction of levels, as inconsistency doesn't affect confidence in results
Directness	–2 quality levels, as the population, outcomes, and study design are indirect
Precision	No subtraction of levels due to good precision
Publication bias	No subtraction of levels, as funnel plot symmetry suggests publication bias is unlikely
Overall quality	Low: our confidence in the effect estimate is limited

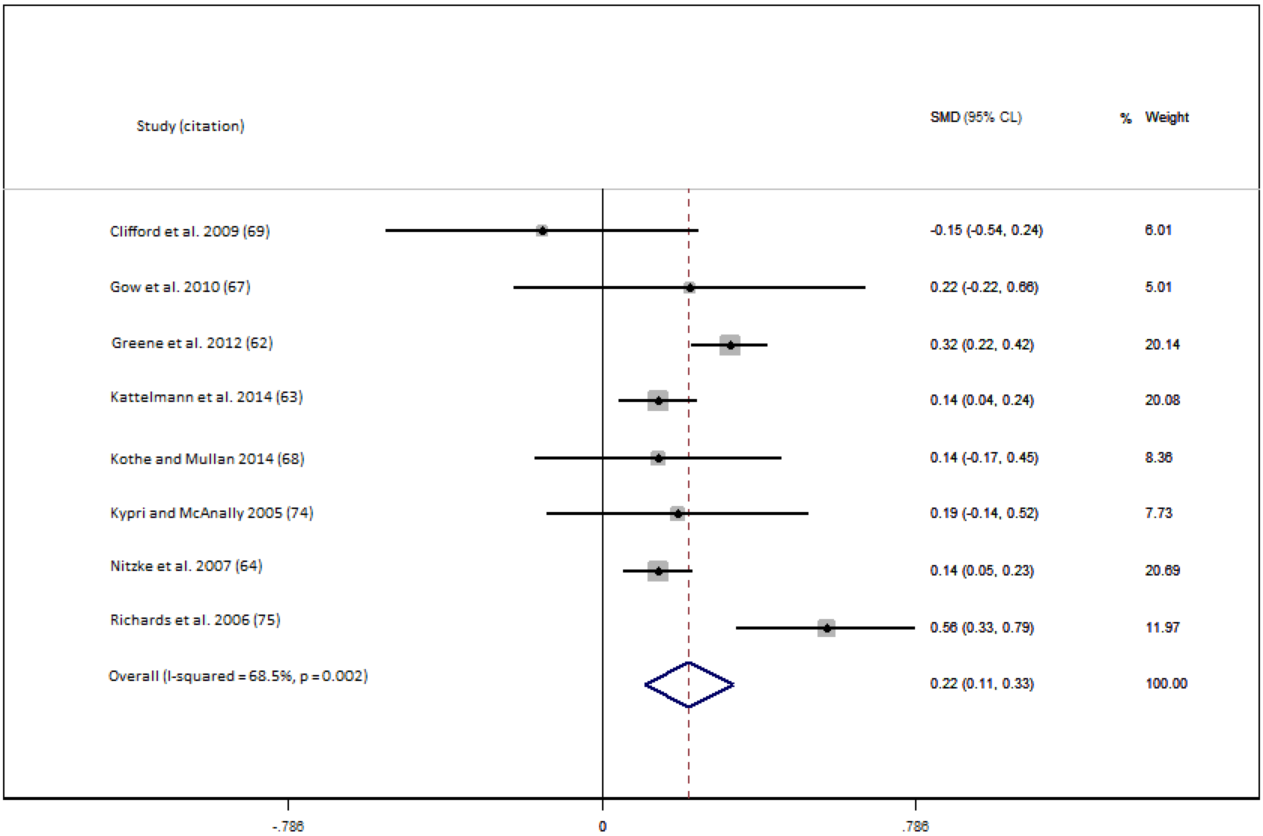
Study Limitations

All the included studies were RCTs. However, only 2 studies adequately concealed the difference between intervention arms [66,74]. In 1 study, the study design and purpose of randomization was explained to participants, preventing allocation concealment [71]. The remaining 11 studies did not clearly describe their method of concealment. Furthermore, 8 studies did not describe their method of blinding and 3 did not blind effectively [65,71,73]. Half of the included studies had a loss to follow-up of >20% [62-64,67,72,73,75] and did not conduct intention-to-treat analysis [62,70-74]. A total of 3 studies did not state methods for dealing with missing data or conducted analysis on completer populations [63,68,69]. Several studies used nonvalidated measures of intake, further limiting the quality of the body of evidence.

Consistency

The studies with effect sizes for change in fruit and vegetable intake yielded an I^2 statistic of 68.5% (P value for heterogeneity =.002), indicating that there may be considerable heterogeneity. However, a higher heterogeneity can be caused by small variations in point estimates from studies with larger sample sizes, as is evident in Figure 2. An I^2 of 31.4% (P value for heterogeneity =0.2) for studies reporting vegetable intake separately suggests low heterogeneity.

Figure 2. Forest plot of Cohen d effect size (standardized mean difference, SMD) for studies reporting change in fruit and vegetable intake combined. The diamond represents the overall effect size; the percentage weighting of each study toward the overall effect is indicated by the size of gray squares; and the 95% confidence limits are shown by horizontal lines. The overall intervention effect lies at the center of the larger clear diamond with right and left end points indicating the 95% confidence limits. Note: weights are from random effects analysis.



Directness

While comparisons between control and intervention arms were direct for the included interventions, variations in study design, populations, and outcome measures meant that the overall body of evidence was indirect. The population of included studies was predominantly college students. Only 2 interventions recruited beyond the university or college setting, but they were still not representative of the broader young adult population. This review allowed for the inclusion of studies that measured changes in intake as a secondary outcome. Consequently, several studies were weight management interventions targeting fruit and vegetable intake as a component of the program. Only 5 studies targeted fruit and vegetables specifically [64,68,69,72,75] and none targeted vegetables alone. Measures of fruit and vegetable intake also varied considerably. Thus, the overall evidence is an indirect representation of the impact of eHealth and mHealth on vegetable intake.

Precision

Only 6 of the 14 studies reported conducting power calculations [63,67-69,71,73]. However, these were mainly based on primary outcomes other than vegetable intake, such as change in nutrition knowledge or weight. Sample size varied from 51 to 2024 participants but yielded 7984 in total, which is considered sufficient.

Publication Bias

While we implemented a comprehensive search strategy to capture the gray literature, we may have missed unpublished studies (interventions with insignificant or negative findings) or those published in journals not indexed in major databases. The outcomes of statistical tests of publication bias (Egger's test) were not reported, as these results are less accurate when based on fewer than 10 studies or when there is significant heterogeneity [48]. Visual inspection of funnel plots (Figures 3 and 4) indicated symmetry in the distribution of points around the mean effect size, suggesting that bias from missing studies is unlikely.

Figure 3. Funnel plot for risk of publication bias: intervention effect for fruit and vegetable intake represented by the standardized mean difference (SMD) plotted against the standard error, se(SMD). Dashed diagonal lines indicate the pseudo 95% confidence limits and scatter dots represent individual studies.

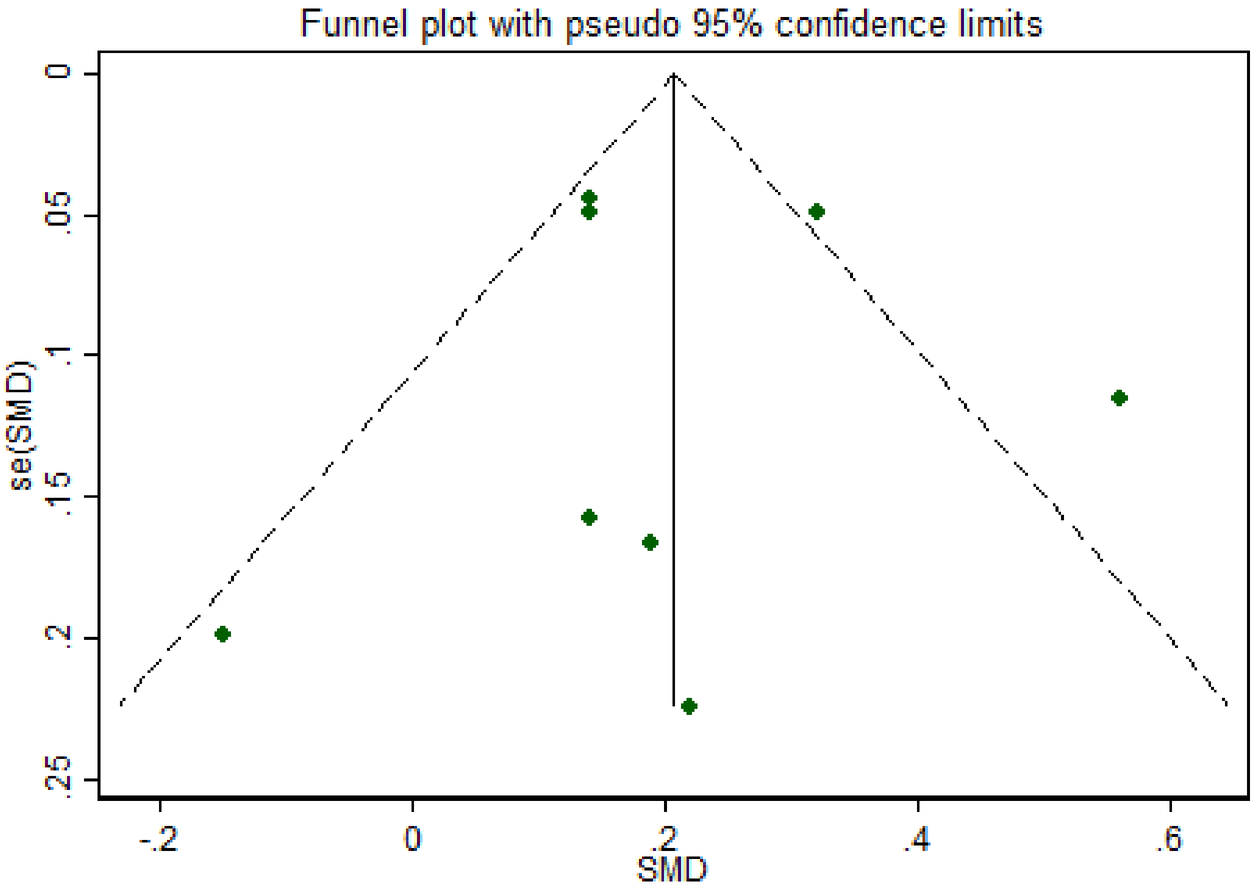
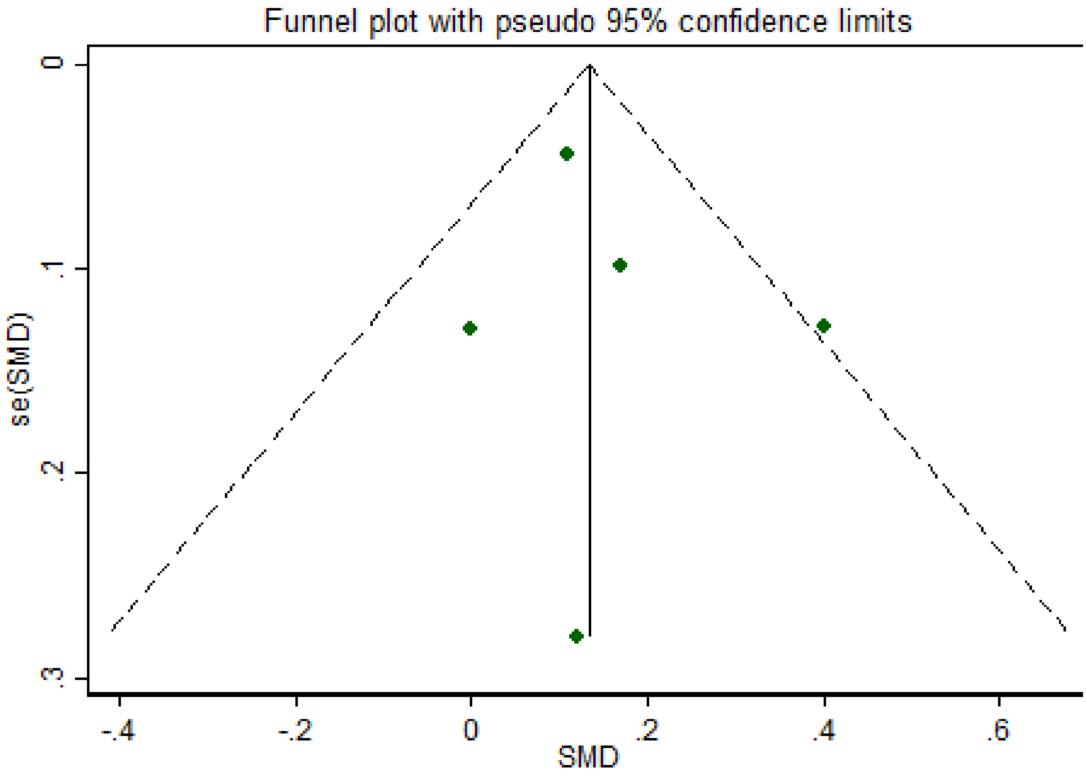


Figure 4. Funnel plot for risk of publication bias: intervention effect for vegetable intake represented by standardized mean difference (SMD) plotted against the standard error, se(SMD). Dashed diagonal lines indicate the pseudo 95% confidence limits and scatter dots represent individual studies.



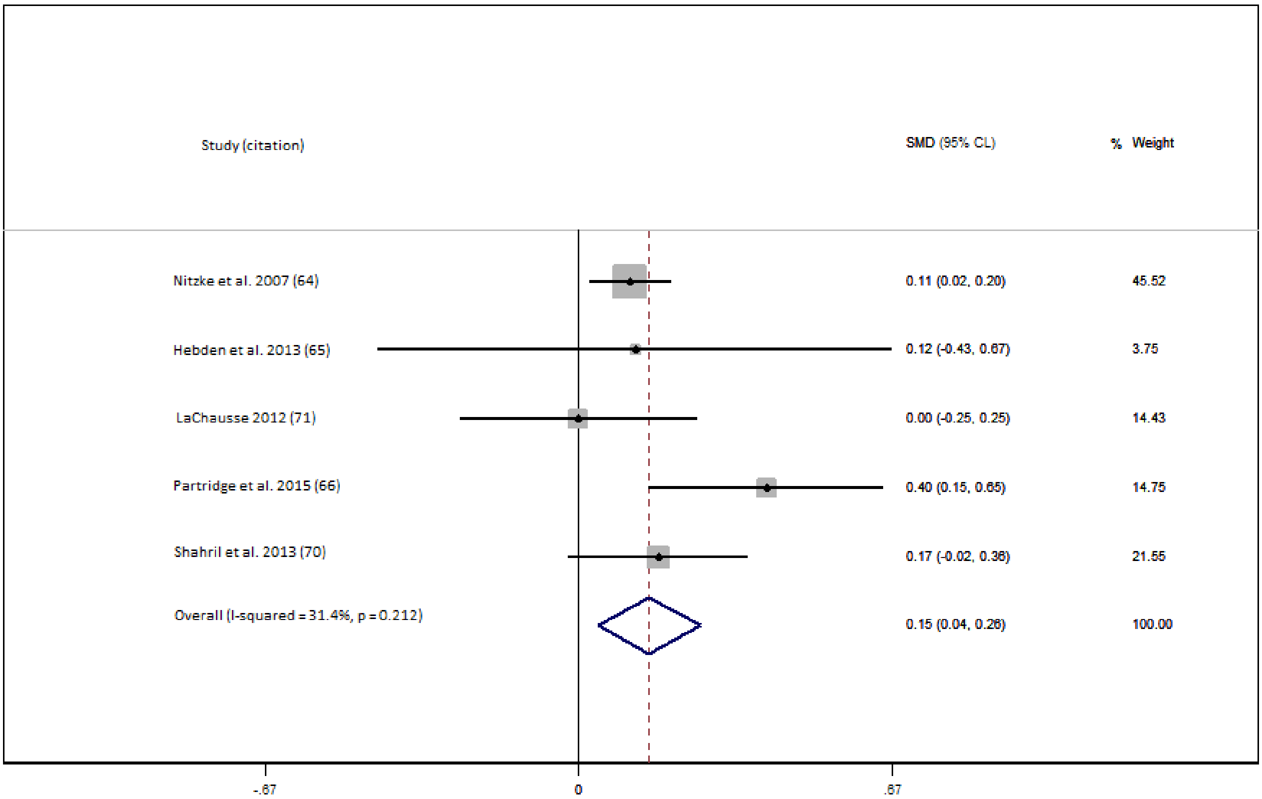
Efficacy of Interventions

Of the 14 reviewed studies, 9 provided results for fruit and vegetable intake, and we included 8 in the meta-analysis. Of these studies, 7 found positive effects postintervention [62-64,67,68,74,75] (Cohen *d* 0.14-0.56), 4 of which were statistically significant [62-64,75]. For all but 1 study [75], the magnitude of effect was small. In total, 2 studies also reported clinically significant improvements of ≥1 serving/day [62,75] (see Multimedia Appendix 7, Table S7). The pooled effect size for interventions reporting change in fruit and vegetable intake was 0.22 (95% CI 0.11 to 0.33), indicating a small positive effect of eHealth and mHealth interventions on fruit and vegetable intake. The 4 studies [62-64,75] with significant effects contributed 72.9% weighting (Figure 4). The I^2 was 68.5%, *P*=.002, suggesting considerable heterogeneity between these studies, and so findings should be interpreted with caution.

Of the 6 studies that assessed vegetable intake independently of fruit [64-66,70-72], we included 5 in the meta-analysis, 4 of which had positive effects on vegetable intake [64-66,70] (Cohen *d* 0.11-0.40). Two of these positive effects were statistically significant [64,66]. Increases in intake were <1 serving/day, with the exception of the results reported by Partridge et al [66] (Multimedia Appendix 7, Table S7). The pooled effect size for change in vegetable intake was negligible at 0.15 (95% CI 0.04 to 0.28; I^2=31.4%, *P*=.2) (Figure 5).

Studies that were more successful in improving fruit or vegetable intake provided participants with individually tailored advice and feedback based on their stage of change [64,66,75] and incorporated goal setting [62,66,75]. Of the studies producing clinically and statistically significant results for fruit or vegetable intake, or both [62,66,75], 1 used online theory education based on nondiet principles [62]. This intervention was designed according to 2 educational models, Carey and colleague's system of instructional design [76] and Keller's instructional motivational model [77]. Fruit and vegetable intake goals were set after completion of each weekly educational lesson, and self-evaluation of progress preceded the next weekly Web-based module. The study by Richards and colleagues [75] used motivational interviewing in combination with Web-based resources and emails. The resources were tailored to the participants' stage of change, where precontemplators and contemplators were given reasons to and tips on how to eat more fruits and vegetables, as well as a goal-setting framework. Action and maintenance participants received emails with tips for maintaining consumption and trying new fruits and vegetables. Finally, the study by Partridge et al [66] combined multiple eHealth and mHealth strategies to support behavior change, with text messaging found to be the most popular, and the website and discussion boards the least popular, among participants. The text messages contained reminders and tips on how to achieve their individualized goal set during their phone counseling session with a dietitian and were based on the 10 processes of change (transtheoretical model). Participants could monitor their fruit and vegetable intake goals using a personalized app that also provided recipes and tips on how to increase their intake.

Figure 5. Forest plot of Cohen d effect size (standardized mean difference, SMD) for studies reporting change in vegetable intake separately. The diamond represents the overall effect size; the percentage weighting of each study toward the overall effect is indicated by the size of gray squares; and the 95% confidence limits are shown by horizontal lines. The overall intervention effect lies at the center of the larger clear diamond with right and left end points indicating the 95% confidence limits. Note: weights are from random effects analysis.



Validity of Dietary Assessment Tools

Of the reviewed studies, 5 used tools that had not been validated to assess changes in vegetable intake [68,69,71,73,75] (Table 4). While the majority of the tools were validated, only 1 was tested specifically in the young adult population [30]. Of the studies that used validated tools, short screeners were most popular, including the US National Cancer Institute's fruit and vegetable screener [53], as well as short questions adapted from the Australian and New Zealand national nutrition surveys [52,54,56]. Furthermore, only 2 studies defined what they classified as a serving [65,66], and the outcome measure for intake lacked consistency, with studies reporting change in terms of frequency, servings or cups of vegetables consumed, as well as the percentage meeting recommendations. No studies detailed which food composition databases they used for the analysis, or whether they checked records with respondents as per the requirements specified in the Nelson and colleagues' checklist [60]. All but 1 study [70] used a self-report measurement tool. The study by Gow and Colleagues [67] did not specify what the outcome measure was (servings vs score).

Table 4. Validity of tools used to measure fruit and vegetable intake and source of tools.

Author [citation]	Fruit and vegetable intake measurement tool and source [citation]	Tool validated for fruit and vegetables
Clifford et al [69]	Food frequency questionnaire adapted from US National Cancer Institute's health habits and history questionnaire [59]	No
Franko et al [73]	Single-item question measuring daily fruit and vegetable consumption [51]	No
Gow et al [67]	Block food screener [49]	Yes
Greene et al [62]	2-item screener and National Cancer Institute screener [53]	Yes
Hebden et al [65]	Web-based short survey using questions from Australian national survey [30,52,56]	Yes
Kattelmann et al [63]	National Cancer Institute's vegetable screener [43]	Yes
Kothe and Mullan [68]	Self-report measure of previous day's consumption	No
Kypri and McAnally [74]	2 questions from New Zealand National Survey questionnaire [54]	Yes
LaChausse [71]	US Centers for Disease Control and Prevention's youth risk behavior survey [58]	No
Nitzke et al [64]	5 A Day screener (7-item fruit and vegetable screener) from 5 A Day program [53]	Yes
Partridge et al [66]	Short questions adapted from the Australian National Nutrition Survey [30,52,56]	Yes
Richards et al [75]	1-item food frequency questionnaire [50]	No
Rompotis et al [72]	Short question on fruit and vegetable intake [57]	Yes
Shahril et al [70]	Diet history	NA[a]

[a]NA: Not applicable.

Discussion

This systematic review found preliminary evidence to suggest that eHealth and mHealth interventions may have a positive impact on fruit and vegetable intake among young adults. Meta-analyses revealed a small magnitude of effect on fruit and vegetable intake and a negligible effect on vegetable intake alone. Whether these effects have clinical or nutritional significance remains questionable. The quality of the body of evidence was rated low and therefore, findings should be interpreted with caution. Rather than making recommendations, we propose suggestions for improved research.

Among the studies that improved intake, only small changes were observed (<1 serving/day). This is consistent with conclusions from existing reviews, in which interventions appear to produce minor improvements in fruit and vegetable intake [26-28]. The effectiveness of the reviewed interventions in creating sustainable change in the long term remains unclear, as follow-up periods were short. The observed dose-response clinical outcomes associated with increasing vegetable intake [44-46] are likely to become evident only in the longer term. Additionally, the link between vegetable intake and weight maintenance during the transition to adulthood occurs over time [78]. Thus, investigators should integrate longer follow-up in intervention protocols. Future studies may also consider measuring secondary outcomes, such as weight and indicators of cardiovascular health, over time to understand the longer-term clinical implications of improved vegetable intake.

With the measurement and reporting of fruit and vegetable intakes as a summed value in most studies reviewed, the impact of the eHealth and mHealth strategies on vegetable consumption specifically remains unclear. Previous research has shown that knowledge of serving sizes is poorer for vegetables than for fruit [29], and for young adults, taste was a more important barrier to increasing vegetable consumption than it was for fruit [79]. Fruit and vegetables also have varying nutrient profiles and product attributes. Considering these factors, it is apparent that vegetables should be promoted and measured separately from fruit. Additionally, most of the reviewed studies targeted fruit and vegetable intake as part of a larger weight management program. Thus, the impact of an intervention focusing primarily on vegetables is an important question for future research.

Previous research established the importance of considering behavior change theory in intervention design [33,80]. The value of incorporating behavior change theory is reiterated by this review, where the majority of the successful studies incorporated behavior change constructs such as goal setting [62,66,73,75] and the provision of individually tailored advice and feedback was based on participants' stage of change [64,66,75]. While the transtheoretical model has been long established as an effective means of improving fruit and vegetable intake [81], these studies suggest its efficacy in eHealth and mHealth interventions where, for instance, motivational and confidence-enhancing text messages or phone calls can benefit individuals who are in the earlier contemplative stages of change. There was no clear pattern, however, to indicate that the incorporation of more behavior change techniques initiated larger improvements as previously suggested in the literature [34]. Researchers could consider investigating whether a combination of efficacious strategies and repeat exposure at a later date produces greater change to shed light on whether intensive short-duration or less-intensive, longer-duration interventions are more effective.

The mode of intervention delivery varied considerably between studies, making it difficult to determine which eHealth and mHealth strategies were most successful in supporting behavior change. However, 2 of the effective studies [66,75] used motivational phone counseling as part of their intervention. While details of the cost effectiveness of this design were not provided, generally, the individualized nature of this approach can be expensive, due to the necessity for trained staff and the monetary reimbursement required for their time. Consequently, the applicability of these studies to the whole population level may be limited. The use of other low-cost and convenient eHealth and mHealth techniques (texting and email) that can incorporate individually tailored information may be more feasible for interventions. Preliminary evidence suggests that these methods are successful [66,75]; however, further research is required to confidently determine their efficacy.

Our review was unable to identify social marketing campaigns targeted specifically at young adults. Addressing this gap is an opportunity for future public health promotion projects, with research indicating that young adults have poor awareness of population-wide campaigns and perceive considerable barriers to increasing their intake despite the promoted health benefits [82]. Additionally, we found no studies that incorporated social media platforms in their intervention. Using these high-reach and lower-cost information-sharing platforms can help to increase interactivity and collaborative content sharing. This may be the fastest and most wide-reaching way to engage young people, with approximately 89% of young adults using social media [19]. Effectiveness studies on the use of social media to improve health behaviors are limited, although preliminary reports are encouraging [83,84].

There is considerable uncertainty regarding the accuracy of the findings summarized by this review, due to the use of non-validated self-report measures of intake, which may not be sensitive enough to detect small changes and may be subject to reporter bias. Therefore, further effort is required to develop validated tools for the measurement of vegetable intake in young adults for consistent and accurate reporting of intervention outcomes. Researchers need to specify what is considered a serving of vegetables to allow easier comparison of outcomes and should use objective measures of intake for validation. Biomarkers such as vitamin C and beta-carotene are useful indicators of fruit and vegetable intake, respectively. While tests for these biomarkers are potentially costly for use in large interventions, they would be feasible and reliable in small validation studies [85].

The degree to which the interventions can be translated to the general young adult populations is questionable, as the majority of studies were conducted in the university or college setting in a sample of educated young adults. While the latest statistics indicate that an increasing proportion of young adults are enrolled in tertiary education [86], those of lower socioeconomic status remain underrepresented [87]. Future studies should limit the use of convenience sampling and aim to recruit a wider range of socioeconomic groups. Overall, the studies we reviewed did not consistently report on external validity, particularly program sustainability, costs, and long-term effects of the intervention. Process evaluations were also lacking. Consequently, the external validity of interventions for improving vegetable consumption in young adults is uncertain. There is a growing body of evidence in health research indicating that investigators are not reporting on external validity [88-90]. Improvements in this area are required to determine the potential for implementation of study designs in broader health promotion programs. Of particular importance is consideration and reporting of the costs involved in upscaling these interventions, which will have implications for health promotion officers and policy makers [91]. Furthermore, researchers should invest in conducting process evaluations to determine how to improve the efficacy of interventions and enhance their generalizability [92].

Strengths and Limitations

This is the first systematic review to report on the effect of eHealth and mHealth interventions on vegetable intake specifically and highlights relevant opportunities for future research. We conducted the review protocol in line with the PRISMA guidelines [35] and used a comprehensive search strategy. While we searched several electronic databases and made an effort to include gray literature, we may have missed some studies. The variability across interventions with differences in study designs and measures of vegetable intake, and the overall poor study quality, made it difficult to establish definitive conclusions. Consequently, we were reluctant to rule out any eHealth or mHealth approach as ineffective and rather discussed the outcomes as a means of highlighting gaps in the current literature and opportunities for future research to generate a stronger body of evidence on whether technology-based strategies are effective in this population. Finally, the lack of consistent reporting of external validity components prevented us from making conclusions about the potential for translating interventions to the wider young adult population.

Conclusions

Overall, this review revealed that young adults have been neglected in fruit and vegetable social marketing campaigns, and most interventions target fruit and vegetables concurrently. Very few good-quality eHealth and mHealth interventions using validated dietary assessment tools have been designed to support young adults in improving their vegetable intake. With preliminary evidence suggesting that eHealth and mHealth strategies may be an effective mode of delivering vegetable interventions, continued research using stronger and higher-quality study designs is required to better determine the efficacy of technology-based strategies for improving vegetable consumption in young adults. With previous research suggesting that multiple behavior change strategies should be used for greater improvements, researchers could consider combining promising strategies such as goal setting and tailored feedback in future interventions. The potential impact of using social media platforms to create awareness of the importance of eating enough vegetables also deserves attention. Finally, in light of the lack of reporting of external validity components in the reviewed papers, it is critical that future studies address key factors such as program costs, sustainability, and longer-term impact in order to determine the potential for upscaling interventions to the broader young adult population.

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Authors' Contributions

MN, JC, and MAF developed the research question. MN drafted the review manuscript and JC assisted with screening, extraction, and data analysis. All authors have read and contributed to the final manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Additional supporting information Table s1. Search 1: e- and m-health interventions, databases searched, search terms, limits applied and results and Table s2. Search 2: social marketing and mass media interventions, databases searched, search terms, limits applied and results.

[PDF File (Adobe PDF File), 155KB - jmir_v18i4e58_app1.pdf]

Multimedia Appendix 2

List of references excluded by full-text with reasons (n=73).

[PDF File (Adobe PDF File), 47KB - jmir_v18i4e58_app2.pdf]

Multimedia Appendix 3

Table S3. Study descriptions of reach and representativeness of participants (n=14).

[PDF File (Adobe PDF File), 58KB - jmir_v18i4e58_app3.pdf]

Multimedia Appendix 4

Table S4.Study Description of intervention implementation and adaption (n=14).

[PDF File (Adobe PDF File), 284KB - jmir_v18i4e58_app4.pdf]

Multimedia Appendix 5

Table S5.Study maintenance and institutionalization (n=14).

[PDF File (Adobe PDF File), 165KB - jmir_v18i4e58_app5.pdf]

Multimedia Appendix 6

Table S6. Risk of bias as assessed by the cochrane collaboration tool for included studies.

[PDF File (Adobe PDF File), 54KB - jmir_v18i4e58_app6.pdf]

Multimedia Appendix 7

Table S7. Change in fruit and vegetable intake between baseline and follow-up for intervention and control arms with calculated effect size Cohen's d (95% CI) (n=14).

[PDF File (Adobe PDF File), 164KB - jmir_v18i4e58_app7.pdf]

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Abbreviations

GRADE: Grading of Recommendations Assessment, Development and Evaluation
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT: randomized controlled trial

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Chapter 5: A Narrative Review of Social Media and Game-Based Nutrition Interventions Targeted at Young Adults

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5.1 Publication details

This chapter presents the manuscript titled 'A Narrative Review of Social Media and Game-Based Nutrition Interventions Targeted at Young Adults' published in *Journal of The Academy of Nutrition and Dietetics* 2017, Volume 117, Issue 5:pages 735-752, doi: http://dx.doi.org/10.1016/j.jand.2016.12.014 (see *Appendix 5*). It has been reformatted but contains exactly the same text.

5.2 Author contribution

I Monica Marina Nour (the candidate) was the primary researcher involved in developing the research question and producing the final manuscript for publication. Together with secondary author Ms Yeung, I refined the search strategy, screened and selected the studies to be included, and extracted the data. Ms Yeung assisted with summarising the information for the initial manuscript draft however the final manuscript was written by the candidate and edited by all co-authors.

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5.3 Introduction to chapter

The review presented in the previous chapter found no studies that used social networking sites or apps with gaming as behaviour change platforms to improve fruit and/or vegetable intake. Thus, a new search of the literature was needed to find any evidence on the use of these media to deliver nutrition interventions to young adults. Given the infancy of this area of research, the search strategy was extended beyond fruit and vegetable intake to include all social media or game based interventions which reported on nutrition outcomes in young adults.

5.4 Abstract

The increased popularity of social media and mobile gaming among young adults provides an opportunity for innovative nutrition programs. This review evaluated the efficacy of these strategies in interventions targeted at 18- to 35-year-olds. The protocol was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Ten scientific databases, information technology conference proceedings, and gray literature were searched. Two reviewers conducted screening, data extraction, and quality assessments. Interventions were included if they used social media or electronic games. Comparisons were made pre- to post-intervention, or between intervention and control arms. Outcomes of interest included change in nutrition knowledge, attitudes, behavior, or weight and/or body composition. Eleven social media-based (randomized controlled trials (RCT) n=7) and six game-based (RCT n=1)) interventions were included. Overall quality of studies was low. Social media-based strategies included forum/blogs (n=5), Facebook (n=5), Twitter (n=1), YouTube (n=1), and chat rooms (n=1). Eight (RCT n=6) of 11 social media-based studies demonstrated improvements in outcomes. Findings suggested that social media may be more effective when combined with other strategies. Virtual reality games (n=3), web-based games (n=2), and a mobile application (n=1) were used in the gaming interventions. While a significant increase in knowledge was reported by three gaming studies (RCT=1), two used nonvalidated tools and longer-term measures of weight and behavioral outcomes were limited. The use of social media and gaming for nutrition promotion is in its infancy. Preliminary evidence suggests that these strategies have some utility for intervening with young adults. Further research using high-quality study designs is required, with measurement of outcomes over longer time periods. The systematic review protocol is registered with PROSPERO (registration number: CRD42015025427).

5.5 Introduction

Optimizing nutrition is essential in the prevention of chronic diseases and the maintenance of good health and well-being (1). 'Young adulthood', defined as 18 to 35 years, is a transitional stage during which individuals gain independence and are likely to form life-long eating habits (2). This population group is generally unware of, or less concerned with the relationship between diet and health (2-4). Their typical diet is high in sodium, sugar sweetened beverages and foods prepared outside the home, and is low in fruits and vegetables (5-9). Such dietary patterns increase disease risk factors (10-12), yet population wide nutrition campaigns do not usually target young adults (13). Thus, an opportunity exists for interventionists to positively influence nutrition habits during young adulthood to reduce future disease burden.

The current generation of young adults has grown up alongside the rapid progression in technology. Conventional methods of communication technology have changed and young adults commonly read material on, and share information through social media sites such as Facebook™, YouTube™, and Twitter™ (14). The popularity of social media has created a wide reaching communication platform for health promotion and an opportunity to facilitate lifestyle behavior change. Using social media channels for the delivery of health information may reduce the time burden of traditional interventions, such as in-person or group consultations. Previous systematic reviews have explored the effectiveness of social media based interventions in children, adolescents and adults (15-19), but not in young adults specifically. Of concern in these studies, was the absence of high quality study designs using behavioral theory-based frameworks (17, 18).

In addition to the well-known social media channels aforementioned, there is an increasing trend of gaming in health interventions (20). Gamification, also known as experimental or serious games, is defined as the use of game components in a non-game context to motivate users (21). One component of games is the concept of rewards that promote continuous participation (22). Such a concept can be used not only for engagement, but also as a technique for behavior change. Rewards have been shown to reinforce positive behaviors enabling change (23), habit formation and maintenance of new behaviors (24). Given the popularity of social media (25) and gaming (26) among young adults, appropriate application of these strategies provides a potentially more accessible and flexible method to disseminate dietary behavior change interventions.

The primary aim of this systematic review was to evaluate the efficacy of social media and game-based interventions in nutrition promotion and behavior modification. More-specific objectives were to describe the social media and gaming nutrition campaigns/interventions, according to content, strategies, duration, and frequency of contact; and assess the efficacy of the social media− and game-based strategies in supporting changes in weight or body composition and/or dietary behavior change and enhancing engagement with the intervention.

5.6 Methods

5.5.1 Design

This systematic review was conducted based on the methods described in the Cochrane Guidelines for Systematic Reviews of Health Promotion and Public Health Interventions (27) and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (28). The review protocol was registered with PROSPERO (registration number: CRD42015025427).

5.5.2 Definitions

In this review, the following definitions were assumed: Social media are Internet-based platforms that allow the publication of information and interaction between the content creator and recipients (29). Popular social media platforms include blogs/forums, chat rooms, Facebook, Instagram, Twitter, and YouTube. Other electronic technologies that involve little or no interaction among users were excluded under this definition. For instance, text messages and websites solely for information-delivery purposes were not categorized as social media. Gamification (experimental or serious games) is the use of game components in a non-game context (eg, nutrition education) to motivate users (21). This review focused on game-based interventions delivered via digital sources. Young adults were defined as those aged 18 to 35 years, based on the National Institutes of Health cut point (30).

5.5.3 Search Strategy

A comprehensive search strategy was developed in consultation with two experienced librarians and was used to identify eligible articles from the following electronic databases:

CINAHL, the Cochrane Library, Embase, Lilacs, MEDLINE, PubMed, PyschINFO, Science Direct, Scopus, and Web of Science. Reference lists, government reports, and unpublished proceedings from information technology and computer−human interaction conferences were hand searched to obtain additional articles relevant to the review topic. These included the Ubiquitous Computing (UbiComp) Conference; the Computer Human Interaction Conference; and the Conference on User Modelling, Adaptation and Personalization held in the past 5 years (2011 to 2015). Databases were searched from 1990 to March 2016. This period was chosen to reflect the advent of social media (31). A combination and broad coverage of search terms and MEDLINE thesaurus Medical Subject Headings (MeSH) were selected, including young adults, social media, blogging, telemedicine, experimental game, serious game, gamification, diet, obesity, weight loss, and body mass index (BMI, calculated as kg/m^2). Appropriate indexation, truncations, and synonyms were used for each database to maximize sensitivity. The search strategy is presented in Table 5.1 with results from one database, MEDLINE included.

Table 5.1: Database search strategy including search terms and the number of articles retrieved from MEDLINE(conducted on the 26th of August 2015) to be screened for inclusion in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults.

Search ID	Search Terms[a]	Results
1	gamification.mp.	22
2	‘experimental game*’.mp.	32
3	‘serious game*’.mp.	81
4	gaming.mp.	1017
5	1 or 2 or 3 or 4	1131
6	internet/ or blogging/ or social media/	56115
7	Internet/	54297
8	Games, Experimental/	1529
9	Telemedicine/	12686
10	Diet/	117136
11	Obesity/	137649
12	Overweight/	14494
13	Weight Loss/	26796
14	Body Mass Index/	89887
15	Adult/ or Young Adult/	4225899
16	10 or 11 or 12 or 13 or 14	317842
17	weight loss.mp. or Weight Loss/	63988
18	Internet/ or internet.mp.	67062
19	16 or 17	347557
20	social media.mp. or Social Media/	2550
21	6 or 7 or 8 or 9 or 18 or 20	80883
22	5 or 21	81680
23	15 and 19 and 22	637
24	Limit 23 to (yr=”1990 –Current” and (“adult (19 to 44 years)” or “young adult and adult (19-24 and 19-44)”) and english and humans)	612

[a]Modifiers are * (search term as major focus of articles), .mp (multiple purpose search including all fields: title, original title, abstract, subject heading, name of substance, and registry word fields), and / (valid controlled vocabulary term which has been searched in the subject headings field of the database).

5.5.4 Study Selection

Studies were downloaded to Endnote X7 citation management software (32) and duplicates removed before screening. Two reviewers independently screened the articles by title and abstract, then by full text to determine eligibility. A third reviewer was consulted for articles with uncertainties. There was no limitation on country of publication, but non-English publications were excluded. Articles with no accessible full text were excluded after attempts to contact authors and retrieve them using library request were unsuccessful.

Participants

Articles were included if interventions were targeted at young adults aged 18 to 35 years. A more lenient criterion was applied for the game-based studies due to the minimal availability of articles and, as such, studies were included if the majority of participants (≥90%) fell within the age range of 18 to 35 years and mean age was younger than 35 years. Study participants had to be generally healthy, non-pregnant, and have no illnesses that could impact normal dietary behavior. There were no limitations concerning sex, ethnicity, education, or socioeconomic status.

Interventions

Eligible articles made use of social media− or electronic-based experimental games to promote good nutrition. These digital strategies were either the main component of an intervention or used as one part of a combination of intervention strategies.

Comparisons

Comparisons varied based on study type and included pre- and post-intervention, or intervention and control arm.

Outcomes

The outcomes of interest included nutrition knowledge; attitude or behavior change; and/or change in weight, fat mass, and BMI. Outcomes pertaining to user engagement were also of interest, including frequency of interaction with or usage of social media or gaming program components.

Study Designs

To improve the comprehensiveness of the review, and considering that such social media and gaming strategies are not commonly trialed using a controlled experimental design, no limitation was placed on study design.

5.5.5 Data Extraction

Data were extracted from eligible studies to a data extraction sheet. Information collected included study details (author, date, country of publication, and study type), participant descriptors (age range, population/sample size, and characteristics), study design, intervention features (mode of delivery, theory applied, and duration and follow-up period), level of engagement with the program, and outcomes and the methods and/or tools used to measure change. Behavior change theories and techniques were extracted when explicitly mentioned by the authors within the article and no interpretation or coding of possible techniques was applied by the reviewers.

5.5.6 Data Analysis and Synthesis

The study characteristics were discussed narratively and tabulated to allow comparison and qualitative evaluation of intervention design, participant characteristics, social media/gaming strategies, and intervention outcome(s). Studies that reported a statistically significant change with respect to the comparison group (ie, baseline to post intervention for pre- and post-studies) and intervention arm to control for randomized controlled trials (RCTs) were considered as having a positive outcome.

5.5.7 Quality and Risk of Bias Assessment

Two independent reviewers rated the included studies for quality and risk of bias using the Quality Criteria Checklists for Primary Research developed by the Academy of Nutrition and Dietetics (33). This tool was chosen due to its suitability for evaluating different study designs. Components assessed included selection bias, blinding, comparability of study groups, rate of withdrawal and dropouts, methods of data collection and statistical analysis, and specification of funding. A positive, negative, or neutral rating was given to each study. Positive or high-quality ratings were reserved for studies that provided a clear description of the intervention and met six or more of the assessment criteria. A neutral or medium-quality rating was designated to studies that met main criteria, but were not completely free from bias, and a negative rating allocated to studies that failed on six or more domains (30). Any discrepancies in the assessment were resolved by discussion with a third reviewer.

5.7 Results

5.6.1 Study Selection and Outcome Reporting

A total of 7,495 records were identified through database searching. A total of 17 studies (6 game-based (34-39), and 11 social media−based (40-50) met the eligibility criteria. The reasons for exclusion by full text were recorded (see Appendix 5.1). The detailed study selection process is illustrated in Figure 5.1. The included studies were heterogeneous in their design and outcome reporting, preventing the pooling of findings. As a result, outcomes and study details have been collated using tables and described narratively according to strategies used; outcomes assessed; and intervention design components, including behavior change theory, duration, and intensity.

5.6.2 Study Characteristics

Tables 5.2 and 5.3 present the key characteristics of the included social media− and game-based studies, respectively. Across the 16 (34-45,47-50) studies that specified sample size, a total of 3,732 participants were included, with 73% females. The majority of studies targeted college students (35-37,40-42,44,45,50) and were conducted in the United States (35-42,44,45,48-50). All interventions had weight management and/or nutrition knowledge gain as the primary intervention objective(s). All but two studies (35,37) were published after 2009, indicating that this is an evolving area of research. The studies meeting selection criteria included RCTs (n=8) (37,40,41,43,45,47,49,50), a non-RCT (n=1) (35), a randomized comparison study (n=1) (38), a case-control study (n=1) (34), pre- and post-intervention studies (n=4) (36,39,42,48), a cross-sectional study (n=1) (46), and a mixed method study (n=1) (44).

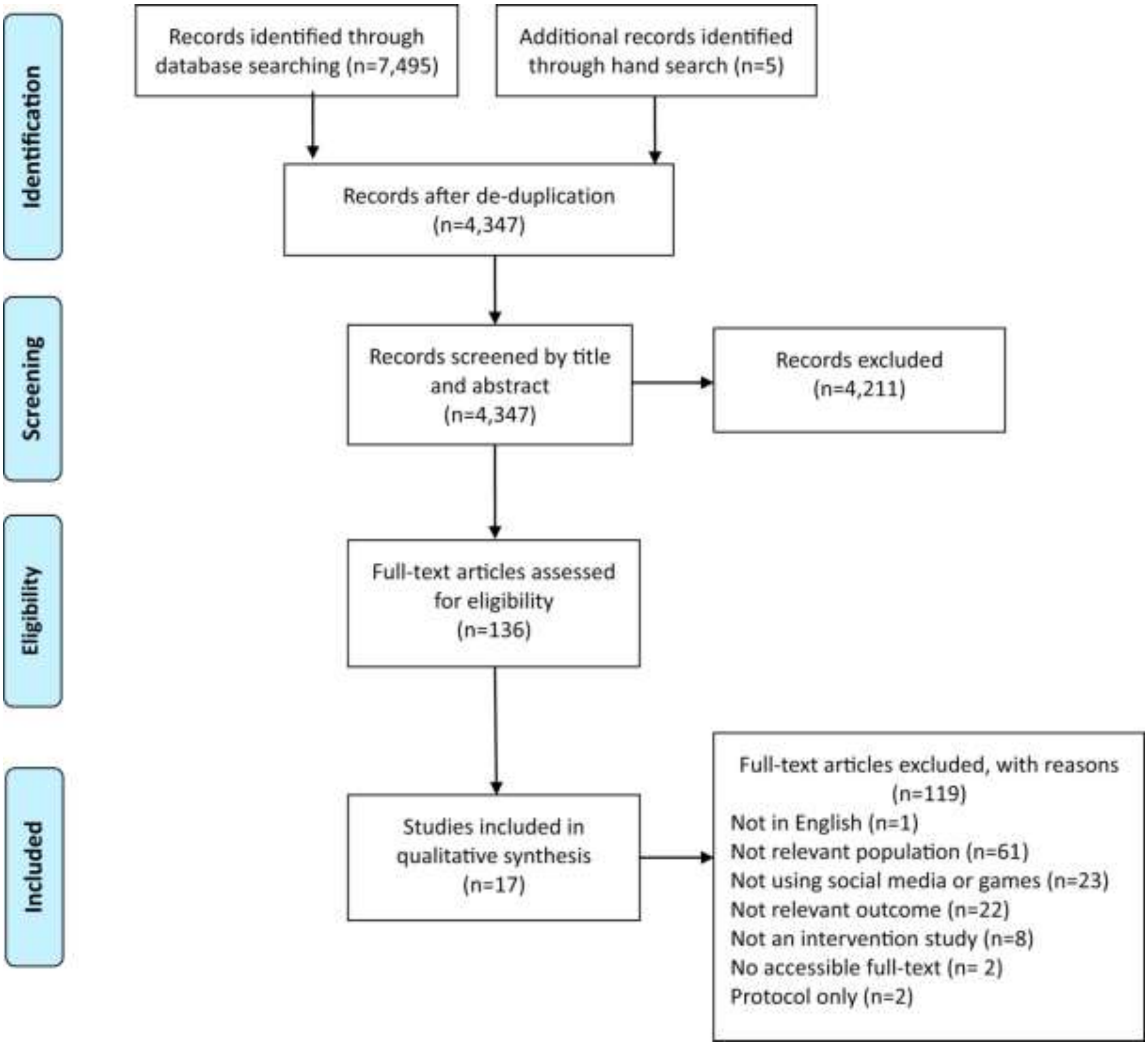

Figure 5.1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram indicating the number of records screened, included, and excluded in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults.

Table 5.2. Overview of social media-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults. Details include the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used and results.

Author(s), year, country, citation	Study Design	Theoretical Framework/ BCTs[a]	Population		Outcome measures	Results
			N (Study arms)	Baseline Characteristics		
Cavallo et al, 2015, United States (48)	**Single group pre-post design** Social media used: Facebook *InShape*: group-based weight loss intervention Weeks 1-20: 5 face-to-face group education Weeks 2-20: weekly online questionnaires on F&V intake, PA, food record completion Weeks 5-20: Facebook page with moderator posts (~4/week), weekly self-monitoring statistics+ 8 web-based nutrition and PA lessons Duration: 5months, Follow-up duration[f]: nil	BCTs: goal setting, self-monitoring, feedback, education and social support	N=40 (N/A[b])	BMI[c] > 27.5 kg/m^2 *Gender:* Female intervention *Age:* mean 30 years	**Primary:** Weight and blood pressure measured by trained personnel **Secondary:** F&V[d] intake measured by validated Block rapid food screener, self-efficacy for healthy lifestyle measured using self-report single item question	Outcomes from baseline to post-intervention (at 5 months) for study completers(n=12): **Weight:** Mean -1.3 ±4.4 kg reduction (no statistical analyses conducted) **F&V:** Mean change 0.5 ±1.5 servings/day (no statistical analyses conducted) **Self-efficacy:** post intervention self-efficacy NR[e]
Dagan et al, 2015, United States (49)	**RCT[g]** Social media used: Facebook *Food Hero*: Players feed virtual character according to their own nutritional needs and complete a set of virtual sport challenges. Intervention[h]: use "social version": user can see other players' scores, including Facebook friends. Control[i]: "private version": users see own score Duration: 2 weeks, Follow up duration: nil	NR	N=63 (I:30, C:33)	*Gender:* 36.5% male *Age:* mean 30.2 years	**Primary:** Nutrition knowledge measured using quiz and menu-assembly scores **Secondary:** Self-reported desire to improve eating habits	**Knowledge:** Quiz score from baseline to day 14 higher in I vs C (*P*=.02) (scores NR). From baseline to day 12, I menu-assembly scores improved (z score +0.18), C scores deteriorated (z score -0.26). **Desire to improve eating habits:** Post game motivation, 43% of respondents high, 38% moderate (no significant differences between I and C)
Gow et al, 2010, United States (40)	**RCT**; Social media used: discussion board Multi-component weight management I_1: Personalized feedback e-mails I_2: Weekly online education session guided by clinician, access to discussion board I_3: Combination of I_1& I_2, C: no intervention Duration: 6 wks, Follow up duration: 3 months	SCT[j]	N=159, **(**I_1:40; I_2:39; I_3:40; C:40)	First year college students *Gender:* 26% male *Age:*<22 years old (mean age NR)	**Primary:** BMI calculated from measured height and weight **Secondary:** F&V, fat intake measured by validated Block Food Screener	Post intervention (at 6 wks[k]): **BMI:** Mean BMI decreased for I_3 (-0.25 kg/m^2) compared to C (+0.18 kg/m^2) ($p<0.05$). I_1 and I_2 did not differ to control ($p>0.05$). **F&V and fat intake:** No significant differences between groups *(continued on next page)*

Table 5.2. Overview of social media-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults. Details include the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used and results.

Author(s), year, country, citation	Study Design	Theoretical Framework/ BCTs[a]	Population		Outcome measures	Results
			N (Study arms)	Baseline Characteristics		
Greene et al, 2012, United States (41)	**RCT**; social media used: Internet forum Multi-component nutrition and physical activity online program I: Weekly lessons of different activities, including quizzes, and forum C: no intervention received. Duration: 10 wks**,** Follow-up duration:15 months	SCT, TTM[l]	N=1689, **(**I: 830 C: 859)	College-age students (18-20 years) *Gender:*47% male *Age:* mean 18.1 years	**Primary:** F&V intake (measured using validated 2-item & National Cancer Institute screener), BMI (calculated from weight and height measured by trained personnel)	Post intervention (10 wks) change in: **Weight/BMI:** No significant differences between I and C (P:NR) **F & V intake:** Increased F&V intake from baseline by approximately 1 cup in I, decreased intake in C. I intake sig higher ($p<0.001$) than C at 15-months.
Harvey-Berino et al, 2012, United States (42)	**Single-group pre-post design** Social media used: Online chat& Internet forum Multi-component web-based weight management program. Program consisted of discussion board and weekly hourly online education as university coursework. Duration: one university semester, Follow-up duration: nil	SCT	N= 336, (N/A)	College-age students *Gender:*13% male *Age:* mean NR, targeted college students	**Primary:** Weight (self-report) BMI (calculated from self-report height and weight)	**Weight/BMI:** Weight loss post intervention among participants who set weight loss as goal ($n=145$, $p<0.001$) (2.7% loss of baseline weight for overweight participants, and 3.0% loss of baseline weight for obese participants)
Hebden et al, 2014, Australia (43)	**RCT**; social media used: Internet forum Multi-component mobile phone-based weight loss intervention I: received printed dietary & PA[m] information, text messages reminders, e-mails, and access to smart phone app & internet forum. C: received printed dietary & PA information Duration: 12 weeks**,** Follow-up duration: nil	TTM	N= 51, **(**I: 26; C:25)	University staff or students BMI 24-31.9 kg/m^2 *Gender:*20% male *Age:* mean I: 22.6 years; C: 23.1 years	**Primary:** Weight/BMI (calculated from weight and height measured by trained personnel) **Secondary:** F&V, SSB[n] & takeaway intake (measured using validated Australian national survey questions)	Post intervention (12 weeks): **Weight/BMI:** No significant differences between groups but decrease from baseline in I (-1.60 ± 2.58 kg, $p=0.004$ & -0.58 ± 0.90 kg/m^2, $p=0.003$), and C (-1.41 ± 2.86 kg, $p=0.021$ & -0.58 ± 0.90 kg/m^2, $p=0.003$). **F&V**, **take-away SSB intake:** Non-significant group differences between I & C after adjusting for baseline. *(continued on next page)*

Table 5.2. Overview of social media-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults. Details include the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used and results

Author(s), year, country, citation	Study Design	Theoretical Framework/ BCTs[a]	Population		Outcome measures	Results
			N (Study arms)	Baseline Characteristics		
Mackert et al, 2012[o], United States (50)	**RCT** *Study 1:* Twitter messages to promote multi-vitamin use. Intervention: received 9 twitter messages, C: no intervention received, Duration: NR *Study 2:* Investigated re-tweeting of messages. I: Received best rated multi-vitamin message C: Received a random multi-vitamin twitter message, Duration: NR	Theory of Planned Behavior	Study 1 N=259, (I:144; C:151) Study 2N=154, (I:78; C:76)	College-age *Gender:*0% male *Age:* mean 21.8 years *Gender:*0% male *Age:* mean 21.1 years	**Primary:** *Study 1:*attitudes and beliefs, intentions towards multivitamin intake (measured using self-report scales and questionnaires) **Secondary:** *Study 2:* motivation to re-tweet measured using likert scale	Post intervention: **Attitudes/beliefs**: Between groups, No-significant differences in beliefs or attitudes towards multivitamin intake (p=0.06), or intention to take multivitamins (p=0.09). **Re-tweeting:** Motivation to re-tweet low among I, mean score 3.2 out of 7. Motivation for C was NR
Merchant et al[p], 2014, United States (44)	**Mixed methods study** Social media used: Facebook Engagement evaluation of a dietitian-guided, Facebook weight loss program (*ThreeTwoMe*) I: On top of Facebook interaction, received co-intervention materials including website, blog, and mobile application. Duration: 21 months**,** Follow-up duration: N/A	Theory of Reasoned Action, SCT, CT[q], OC[r], Theories of Social Comparison, and Social Support	N=404, (N/A)	College students aged 18-35 years BMI 25-40 kg/m^2 *Gender:*% NR *Age:* mean NR	**Primary:** Engagement with Facebook posts (measured through likes, comments or shares)	**Engagement:** At 21 months, of the 1816 Facebook posts made, 72.96% were liked/commented/shared at least once. Most popular were polls, photos, then videos. Engagement rate varied, from 0 to 653 interactions per person. 53% of participants were minimally active,23.4% highly active
Napolitano et al, 2013, United States (45)	**RCT,** Social media used: Facebook Weight loss program delivered via a private Facebook group I_1:Facebook-only group I_2: Facebook Plus (multicomponent- Facebook + weekly personalized feedback, pedometer text messages, and a support buddy) Control: no intervention received Duration: 8 wks**,** Follow-up duration: 4&8 wks	BCTs: Goal setting, self-monitoring, and social support	N=52, (I_1:17; I_2:18; C: 17)	University students BMI 25-50 kg/m^2 *Gender:*13.5% male *Age:* 20.47 years	**Primary:** Weight loss after 8 wks (in person measure). **Secondary:** Weight self-efficacy (measured using validated 20-item WEL[s] Questionnaire), Adapted social support (measured using 48-item social support questionnaire).	**Weight:** At week 8, greater weight loss from baseline in I_2 (-2.4 ± 2.5 kg) compared to I_1 (-0.63 ± 2.4 kg) and C (0.24 ±2.6 kg) (p< 0.05). No significant differences from baseline between I_1 and C (p: NR) **Secondary:** No significant differences within or among groups on changes in any of the measures. *(continued on next page)*

Table 5.2. Overview of social media-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults. Details include the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used and results.

Author(s), year, country, citation	Study Design	Theoretical Framework/ BCTs[a]	Population: N (Study arms)	Population: Baseline Characteristics	Outcome measures	Results
NSW Food Authority 2013, Australia (46)	**Cross-sectional** Social media used: Facebook and Youtube Kilojoule menu labelling campaign with web-site, smartphone app, Facebook page and YouTube videos. Duration: 12 month study period Follow-up duration: 6 months post implementation	Knowledge-Attitude-Behavior Model	N = varied with sample; each sample ~130-230 (N/A)	Frequent consumers of fast-food outlets aged 18-24 years *Gender:*% NR *Age:* mean NR	**Primary:** Awareness and understanding of kJ[t] labelling and information and anticipated change in purchasing behaviour (kJs) measured using online survey	At 6 months post implementation: **Awareness:** increased significantly from baseline (p=NR) **Understanding:** No significant change in understanding meaning of kJs from baseline (p=NR) **Anticipated purchasing behaviour:** Non-significant increase in % anticipating to choose lower kJ food
Partridge et al, 2015, Australia (47)	**RCT,** Social media used: Internet Blog Multi-component weight loss intervention. Intervention: Received printed dietary booklet, 8 text messages weekly, 1 e-mail weekly, 5 tailored coaching calls, smart phone application, website and a community blog. Control: Received printed dietary & PA information and 4 text messages Duration:12 wks, Follow-up duration:6 months	TTM BCTs: goal setting, monitoring and feedback	N=250, (**I**:125; C:125)	BMI 25-31.9kg/m^2, or 23-24.9 kg/m^{2}with weight gain >2 kg in last 12 months *Gender:*38.7% male *Age:* 27.7 years	**Primary:** Weight/BMI **Secondary:** F&V intake and weekly SSB and takeaway consumption	At 12 weeks (post intervention): **Weight:** I 2.2kg lower in adjusted body weight compared to C (p=0.005) **F&V**: Increase % consuming ≥4 serves/day from baseline greater in I (+19.6%) than C (+8%) (p=0.009). No significant difference in fruit intake (p=0.18) between groups **SSB**: 92.7% consumed <500ml Compared to 72% in C (p=0.002) **Take-away:** consumption ≤once/week increased by 40% in I vs 16% in C (p=0.01).

[a]BCT= Behavior change techniques; [b]N/A=not available [c]BMI= body mass index; [d]F&V=fruit and vegetables; [e]NR= not reported; [f] time between intervention cessation and follow-up time point; [g]RCT=randomized controlled trial,[h]I=intervention; [i]C=control; [h]RCT=randomized controlled trial; [j]SCT= social cognitive theory [k]wks=weeks; [l]TTM=transtheoretical model; [m]PA=physical activity; [n]SSB=sugar sweetened beverages; [o]Two sub-studies with different features of population were conducted in this study; [p]sub-study examining engagement of intervention arm of SMART study (EARLY trials, final results not yet available); [q]CT= control theory [r]OC= operant conditioning; [s] WEL= Weight Efficacy Lifestyle; [t] Kj= kilojoule

Table 5.3. Overview of game-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults. Details include the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used and results.

Author(s), year, country, citation	Study Design	Theoretical Framework/ BCTs[a]	Population		Outcome measures	Results
			N (Study arms)	Baseline Characteristics		
Lee et al, 2010, Korea (34)	**Case-control study** Mobile game application (*Smart Diet*) Weight control mobile app with calorie calculator, meal planner and diet quiz game. Intervention details and Control arm NR[c] Duration NR, Follow-up duration[b]: NR	NR	N=36 (I[d]:19; C[e]:17)	Volunteers from an obesity clinic *Gender:* % NR *Age:* mean I: 28.2 years; C: 29.5 years	**Primary:** Body composition (weight, fat mass and BMI[f], measured in clinic using Inbody system[g])	**Body composition:** Decreases in weight (1.9 kg), fat mass (1.2kg) and BMI (0.8kg/m^2) post intervention among I ($p<0.05$); no significant changes in C ($p>0.05$)
Miller & Lindberg, 2007, United States (35)	**Non-RCT[h]** Web-based computer game I: Played educational game on GI [i] : Each level presented 5 foods with various GI values, foods to be "consumed" by dragging to animated mouth or discarded in trash can. C: Viewed information from a website concerning healthy eating Duration: One time play 25.3 minutes to complete the game, Follow-up duration: nil	Theory of planned behaviour (knowledge, self-efficacy, and behavioral intention)	N=67 (I:30; C:35)	*Gender:* 43% male *Age:* mean I: 20.5 years; C: 20.2	**Primary:** Nutrition and GI knowledge obtained (measured using 9-item multiple-choice test, pre-tested for reliability) **Secondary:** Self-efficacy for selecting lower GI foods (16-item instrument pre-tested for reliability and internal consistency)	**Nutrition Knowledge:** Higher gain of knowledge from baseline among I (mean +2.8 ±1.8) than C (mean +0.9 ±1.5) ($p<0.001$) post game play. **Self-efficacy:** Higher gain in mean self-efficacy scores from baseline among I (+2.8±1.8) than C (+1.7 ±1.9) ($p<0.01$) post game play
Miskovsky, 2012, United States (36)	**Single-group pre- & post- study** Web-based game (*Nutrition Jeopardy*) The game had single Jeopardy-style questions and a final Jeopardy-style question. Topics included my pyramid, fruits and vegetables, healthy snacks, advertising, and nutrition. Duration: NR, Follow-up duration: nil	Pender Model of Health promotion which integrates expectancy value model of human motivation and the SCT	N=106 (N/A[j])	College freshmen *Gender:* 53% male *Age:* mean 21.7 years	**Primary:** Nutrition knowledge (measured using validated self-report General Nutrition Questionnaire) and self-efficacy (measured using validated 11 item General Nutrition Self-efficacy Questionnaire)	**Nutrition Knowledge:** No significant post-intervention changes in nutrition knowledge ($p=0.49$) compared to baseline, but significant increase in nutrition knowledge related to expert advice ($p=0.0039$) (scores NR) **Self-efficacy:** No significant changes post-intervention in self-efficacy ($p=0.48$)

(continued on next page)

Table 5.3. Overview of game-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults. Details include the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used and results.

Author(s), year, country, citation	Study Design	Theoretical Framework/ BCTs[a]	Population		Outcome measures	Results
			N (Study arms)	Baseline Characteristics		
Orji et al, 2012, United States & Canada (39)	**Single-group pre- & post- study** Virtual reality mobile game application (*LunchTime*) with link to Facebook Multi-player interactive game mimicking restaurants visits, to learn to select healthy options in line with dietary goal. Duration: 10 days, Follow-up duration: nil	TTM[k], Goal setting theory, social learning theory, KAB[m] model & reinforcement theory	N=6 (N/A)	Participants aged 19-40 years *Gender:* 50% male *Age:* mean NR	**Primary:** Nutrition knowledge and healthy eating attitude measured using a survey, healthy eating attitude ranked on scale of 1-5, with 5 indicating positive attitude	Post-intervention (10 days): **Nutrition knowledge:** Increased from baseline by mean score of 2.1±0.5 (no statistical analysis conducted) **Healthy eating attitude:** Increased from baseline by 2.3 (baseline=1.9, post=4.2) (no statistical analysis)
Peng, 2009, United States (37)	**RCT** Virtual reality computer game (*RightWay Café*) Mimics eating in university cafeteria environment. I: played the game once C: no intervention received Duration: One-time play Follow-up duration: 1 month	Health belief model, SCT[n], Situated learning theory, Theory of reasoned action, Entertainment education theory and BCTs: instilling intrinsic motivation,	N=40 (NR)	Undergraduate students *Gender:* 20% male *Age:* mean 20 years	**Primary**: Nutrition knowledge (using author created questionnaire), self-efficacy for eating healthy (using modified 14-item self-efficacy of healthy eating scale pre-tested for reliability), perceived benefits of healthy eating (using 5-item scale created by authors pre-tested for reliability) & intention to eat healthier food (using 10-item scale created by authors)	Differences from baseline to post-test (after game play): **Nutrition knowledge:** Greater gain in score in I (+5.8) vs. C (+0.19) ($p< 0.05$). Not significant at 1 month follow-up **Self-efficacy:** Greater improvement in score for I (+0.77) vs. C (+0.01) ($p<0.01$). Maintained for I and decrease for C 1 month follow-up. **Perceived benefit:** Greater improvement in perceived benefits of health eating in I (+0.58) vs. C (+0.09) ($p< 0.01$). I also showed greater perceived benefits at 1 month follow-up than C ($p< 0.05$). **Intention:** Greater intention to eat healthy ($p<0.001$) in I vs. C. Baseline results and follow-up NR. *(continued on next page)*

Table 5.3. Overview of game-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults. Details include the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used and results.

Author(s), year, country, citation	Study Design	Theoretical Framework/ BCTs[a]	Population: N (Study arms)	Population: Baseline Characteristics	Outcome measures	Results
Sullivan et al, 2013, United States (38)	**Randomized comparison study** Virtual reality computer game (*Second Life*) Weight loss & weight maintenance game. Interaction between players and clinicians in virtual clinics, homes, grocery stores. Intervention$_1$: interaction via game only Intervention$_2$ attended face-to-face clinic for 3 months, then interaction via game for 6months Duration: 9 months, Follow-up duration: nil	BCTs: Experimental learning	N=20 (I_1: 10 ; I_2:10)	Overweight or obese subjects *Gender:* 15% male *Age:* mean 31.1 years	**Primary:** Weight (measured in clinic by trained personnel), Fruit and vegetable intake (Self reported) **Secondary:** qualitative rating of, adequacy of training, ease of communication & engagement	**Weight:** Weight loss from baseline at 3-month assessment for both groups (I_1 10.8 ±3.5% and I_2 7.6± 5.1%). At 9 months, I_2 regained weight by a mean of 13.6%, while I_1 lost additional weight by a mean of 3.7% (p: NR) **Fruit and Vegetable intake:** At 9 months, Sig. higher consumption of fruits in I_1 (2.7± 0.7 servings/day) compared to I_2 (1.9 ±0.4 servings/day) ($p<0.05$), and higher but non-significant increase in vegetable intake ($p=0.07$) between groups.

[a] BCT= behaviour change techniques; [b]time between intervention cessation and follow-up time point; [c]NR=not reported; [d]I=intervention; [e]C=control; [f] BMI=body mass index; [g]Body composition analyzer; [h]RCT= Randomized controlled trials; [i] GI= glycemic index; [j]N/A=not available; [k]TTM= transtheoretical model; [m]KAB=knowledge attitude behaviour; [n]SCT= social cognitive theory

5.6.3 Intervention Strategies

Social Media−Based Interventions

Among the 11 social media−based studies (40-47,50), Internet forums/blogs (n=5) (40-43,47) and Facebook (n=5) (43-46,48,49) were the most commonly used modalities. Others included chat rooms (42) (n=1), Twitter (50) (n=1), and YouTube (46) (n=1) (Table 5.2). One study (50) investigated the effect of social media on attitudes to multivitamins. Dagan and colleagues (49) used gamification techniques in their social media intervention. They compared the effect of sharing game progress on social media on improvements in knowledge and engagement. The remaining studies were designed as multicomponent interventions, with social media utilized as one of the strategies, without isolating its effect on the outcomes. Other intervention components used in these studies included e-mail, websites, text messages, and face-to-face or phone coaching. Napolitano and colleagues (45), compared the effect of social media (Facebook) alone to the effect of social media (Facebook) as part of the multi-component intervention in their three-arm RCT (Table 5.2).

Game-Based Interventions

For the six game-based interventions (34-39), three were virtual reality (VR) games (37-39), two web-based games (35,36), and one a mobile application game (34) (Table 5.3). The three VR games each presented a virtual dining experience, which aimed to promote knowledge gain and behavior change. Strategies used included the direct provision of food knowledge information, real-time education and training, personalized goal-setting and task selection, instant dynamic feedback corresponding to game performance, and trial and error exploration. The mobile application game used a quiz to improve nutrition knowledge in conjunction with other functions, such as a calorie calculator and diet planner. One of the web-based games used levels and a point system to encourage play (35), while the other did not specify gamification techniques (36) (Table 5.3). The Facebook study by Dagan and colleagues (49), used gaming strategies, such as progress monitoring and feedback on performance with a numerical score presented on a leader board in the social media condition (Table 5.2).

5.6.4 Outcome Measures

Social Media-Based Interventions

Knowledge and Attitude Change

Two studies measured knowledge gain (46,49). The New South Wales Food Authority campaign resulted in a significant improvement in understanding of kilojoule requirements, but this did not translate to changes in anticipated kilojoule intake (46). The study by Dagan and colleagues (49) found social media had positive effects on nutrition knowledge, with greater improvements in the intervention arm (Table 5.2). There were no significant changes in attitudes toward multivitamin intake after exposure to the Twitter intervention (50).

Weight/BMI Change

Seven studies measured changes in weight and/or BMI as their primary outcome (40-43,45,47,48). With the exception of studies by Hebden and colleagues (43) and Cavallo and colleagues (48), all others reported positive outcomes for weight and/or BMI, with significant reductions in the intervention arm relative to control. The pre–post study by Cavallo and colleagues observed a 1.3 kg mean weight loss from baseline; however, the sample was too small for statistical analyses. Notably, positive outcomes were only observed in the multicomponent group in the study by Napolitano and colleagues (45), and not the Facebook-only group (Table 5.2).

Dietary Behavior Change

Five interventions also measured changes in fruit and vegetable intake (Table 5.2) (40,41,43,47,48). One demonstrated a significant increase in intake by 1 cup in the intervention arm (41). The multi-component study by Partridge and colleagues (47) produced a positive outcome for vegetable intake but changes between intervention and control were nonsignificant for fruit. The remaining three studies also increased intake, but outcomes were not statistically significant (40,43,48).

User Engagement

Eight studies reported participant engagement with the social media components (41,43-49). Methods used to measure engagement varied, including numbers of "likes," "shares," or comments on social media posts. Overall engagement was low, and interaction declined over time (44,48,50). The study by Dagan and colleagues (49), demonstrated engagement was higher in the social media arm compared to the control arm. Although a high engagement rate was reported in the study by Merchant and colleagues (44), with participants interacting with 73% of Facebook posts, 81% of these interactions were made by the more highly active participants. Engagement with other social media platforms was much lower than that reported in the Facebook studies. In the Twitter intervention, only one participant "retweeted" the multivitamin messages (50). Furthermore, the popularity of forums/blogs was low, with only 6.4% of participants engaging with the blog in the study by Partridge and colleagues (47), and only 2 of 51 participants replying to forum posts in the study by Hebden and colleagues (43). Forums were also ranked as the least motivating strategy of the Project Webhealth intervention (51).

Game-Based Interventions

Knowledge and Attitude Change

Three game-based interventions reported positive outcomes for post-game knowledge of nutrition or healthy eating concepts (35-37). While the study by Orji and colleagues (39) also reported positive improvements in nutrition knowledge scores, statistical significance of these results was not assessed. Three studies also measured the change in self-efficacy to make healthier food choices (35,36) and to engage in healthier eating habits (37), with two reporting positive outcomes (35,37) (Table 5.3).

Weight/BMI Change

Two studies measured weight changes and found significant decreases in body weight (34,38). In the study by Sullivan and colleagues (38), this positive change was sustained in the game-only intervention arm (Table 5.3). Lee and colleagues (34) found significant decreases in weight, fat mass, and BMI among the intervention arm only.

Dietary Behavior Change

Only one game-based study assessed behavioral outcomes. The study by Sullivan and colleagues (38) explored whether VR gaming could improve fruit and vegetable intake, with outcomes indicating that the game-only intervention arm had significantly higher fruit intake at 9 months compared to the game and face-to-face study group. Group differences at baseline were not reported (Table 5.3).

User Engagement

Engagement rates were not well documented across studies. The time spent interacting with gaming platforms varied between studies. Dagan and colleagues (49) reported the intervention participants (social media arm) spent more time playing than the control (non−social media arm). This was also observed in the study by Miller and Lindberg (35), where game players spent almost double the amount of time interacting with the gaming platform when compared to the control. The Smart Diet app study found a majority of users interacted with the platform once per week, with only 8% using it daily (34).

5.6.5 Delivery Mode

Nine social media studies were multi-component interventions implemented in conjunction with other non−social media components (Table 5.2). Positive changes were generally reported by these interventions (40-48), whereas no significant changes were observed in the social media−only study (50). This finding is in line with the results of the RCT by Napolitano and colleagues (45), which indicated a significant weight loss in the Facebook Plus multi-component intervention arm, but not the Facebook-only arm when compared with the control (Table 5.2). The game-based studies were delivered as stand-alone interventions, with the exception of the study by Sullivan and colleagues (38), which compared game exposure against a combined face-to-face and gaming intervention, finding greater weight maintenance in the game-alone setting (Table 5.3).

5.6.6 Duration and Intensity

Game-based studies were short, with participants generally required to use the game on one occasion (n=3) (35-37) (Table 5.3). Despite their short duration, these studies indicated positive improvements in knowledge post-game interaction. However, due to lack of follow-up, little is known about maintenance or if the acquired knowledge translates to behavior change. Social media–based interventions ranged in duration from 2 weeks to 21 months (Table 5.2). The frequency of participants-and-facilitator interactions varied among studies, from daily to weekly, but all generally encouraged participant engagement in daily intervention-related activities (eg, food dairy, step count). There was no clear link between intervention intensity and efficacy as findings varied.

5.6.7 Behavioral Theory

With the exception of two interventions (34,49), the reviewed studies were theoretical (35,37-44,46,47,50) or evidence-based (36,45) in their design. Due to the large variety of behavioral models adopted, no single specific theory or model could be identified as more effective. Social cognitive theory was most commonly applied within the social media–based interventions, that found positive behavioral and weight outcomes (40-42,45). The four game-based interventions (35-38) with positive outcomes reported using behavior change theories, such as the Health Belief Model, Social Cognitive Theory, or Theory of Planned Behavior.

5.6.8 Quality Assessment and Risk of Bias

Tables 5.4 and 5.5 provide a summary of the quality rating for each study. Only one study (47) was free from risk of bias regarding blinding. The studies that reported attrition had low dropout rates (37,40,43,47), but the majority (n=13) (34,35,37-42,45,46,48-50) did not report the attrition rate or reasons for withdrawal. Seven studies (33-36,39,41,44,46,48) were non-randomized designs. Of the nine RCTs (37,38,40,41,43-45,47,49,50), only three described a randomization method (40,43,47). Common factors that compromised study quality included noncomparable study groups, low validity and reliability of methods of outcome measurement, and failure to perform intention-to-treat analysis. Due to the low quality and high risk of bias in the included studies, we interpret the evidence with caution.

Table 5.4 Quality assessment[a] of social media−based studies (n=11) using the Quality Criteria Checklists for Primary Research developed by the Academy of Nutrition and Dietetics (33)

First Author, Year	***Cavallo 2016***	***Dagan 2015***	***Gow et al 2010***	***Greene et al 2012***	***Harvey-Berino et al. 2012***	***Hebden et al 2013***	***Mackert et al 2012***	***Merchant et al 2014***	***Napolitano et al 2013***	***NSW[b] Food Authority, 2013***	***Partridge et al 2015***
VALIDITY QUESTIONS											
1. Was the research question clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the selection of study subjects/patients free from bias?	Unclear	Unclear	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes	Unclear	Yes
3. Were study groups comparable?	N/A[c]	Yes	Yes	No	N/A	Yes	Unclear	Unclear	Unclear	N/A	Yes
6. Were intervention procedures and any comparison(s) described in detail?	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	N/A	Yes
7. Were outcomes clearly defined and measurements valid and reliable?	Yes	No	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Unclear	Yes
4. Was method of handling withdrawals described?	No	Unclear	Yes	Unclear	N/A	Yes	Unclear	Unclear	Yes	N/A	Yes
5. Was blinding used to prevent bias?	Unclear	No	Unclear	Unclear	N/A	No	No	No	Unclear	N/A	Yes
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
9. Were conclusions supported by results with biases and limitations taken into consideration?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
10. Is bias due to study's funding or sponsorship unlikely?	Unclear	Unclear	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes	Unclear	Yes
Negative/Neutral/Positive **(N/0/P)**	0	0	P	0	0	P	0	0	0	0	P

a Rating criteria: if most (six or more) of the answers to the validity questions are "no," the report should be designated negative. If answers to validity criteria questions 2, 3, 6, and 7 do not indicate that the study is exceptionally strong, the report should be designated neutral. If most answers to the above validity questions are "yes" (including criteria 2, 3, 6, 7 and at least one additional "yes"), the report should be designated positive. b NSW=New South Wales. c NA=not available.

Table 5.5: Quality Assessment[a] of Game-based studies (n=6) using the Quality Criteria Checklists for Primary Research developed by the Academy of Nutrition and Dietetics (33)

First Author, Year	***Lee et al, 2010***	***Miller & Lindberg, 2007***	***Miskovsky, 201***	***Orji et al, 2012***	***Peng, 2009***	***Sullivan et al, 2013***
VALIDITY QUESTIONS						
1. Was the research question clearly stated?	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
2. Was the selection of study subjects/patients free from bias?	*Unclear*	*No*	*No*	*No*	*No*	*Yes*
3. Were study groups comparable?	*No*	*No*	*No*	*N/A*[b]	*No*	*Unclear*
6. Were intervention procedures and any comparison(s) described in detail?	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*
7. Were outcomes clearly defined and the measurements valid and reliable?	*Yes*	*Yes*	*Unclear*	*No*	*Unclear*	*Yes*
4. Was method of handling withdrawals described?	*Unclear*	*Unclear*	*No*	*No*	*Yes*	*N/A*
5. Was blinding used to prevent introduction of bias?	*Unclear*	*Unclear*	*No*	*N/A*	*N/A*	*Unclear*
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	*Yes*	*Yes*	*No*	*No*	*Yes*	*Yes*
9. Were conclusions supported by results with biases and limitations taken into consideration?	*Yes*	*Yes*	*Unclear*	*No*	*Yes*	*Yes*
10. Is bias due to study's funding or sponsorship unlikely?	*Unclear*	*Unclear*	*Unclear*	*Yes*	*Yes*	*Unclear*
Negative/Neutral/Positive **(N/0/P)**	***0***	***0***	***N***	***0***	***0***	***0***

a Rating criteria: if most (six or more) of the answers to the validity questions are "no," the report should be designated negative. If answers to validity criteria questions 2, 3, 6, and 7 do not indicate that the study is exceptionally strong, the report should be designated neutral. If most answers to the above validity questions are "yes" (including criteria 2, 3, 6, 7 and at least one additional "yes"), the report should be designated positive. b NA=not available..

5.8 Discussion

This review has highlighted the increased use of social media and emerging use of experimental games in nutrition interventions. Despite the growing body of evidence, very few studies have examined the isolated effect of social media on nutrition outcomes and the longer-term implications of game play on behavior and health. Furthermore, measurement of participant engagement and process evaluations of the interventions were not well executed. Due to the overall low quality of the studies, particularly among the gaming interventions, our capacity to draw any definite conclusions on the efficacy of strategies was limited. Therefore, we emphasize the gaps in the literature and identify opportunities for the development of future interventions.

Among the reviewed social media–based studies, Facebook and blogs/forums were the most frequently used platforms. However, blogs/forums were consistently ranked the least popular when used within multicomponent interventions. A majority of these multi-component studies measured the overall efficacy of their intervention, with few evaluating the sole impact of social media. Consequently, we cannot determine whether the positive outcomes recorded are related to participation in a healthy lifestyle intervention or directly attributable to the social media strategies. Dagan and colleagues (49), demonstrated that social networking alone was associated with greater improvements in nutrition knowledge, and desire to develop better eating habits, but did not measure the impact on behavioral or weight outcomes. Napolitano and colleagues (45) found that social media alone was not as effective for weight loss as when it was combined with other components. To confidently establish the efficacy of social media for improving nutrition outcomes in young adults, further research isolating the effects of social networking strategies on dietary behavior is warranted. The Multiphase Optimization Strategy or the Sequential Multiple Assignment Randomized Trials setup (52) may assist with designing these factorial studies (53).

VR gaming was the most commonly implemented strategy among game-based studies. The popularity of VR gaming is increasing (54,55) and may have the potential to effectively engage young adults in nutrition education. Gaming has been adopted for behavior change in several other clinical areas (56-63); however, its ability to maintain engagement in nutrition interventions could not be determined. In addition, while VR gaming was found to support improvements in knowledge (37,39), tools used to measure this change were not validated. Furthermore, only one intervention measured weight or behavioral outcomes (38). Thus, the implications of these short-lived games on behavior and health over time are unknown. There is a need for future interventions to explore long-term outcomes linked to game play, with an opportunity to explore the impact of repeat game play, while also measuring participant interaction to ascertain the efficacy of games in maintaining engagement.

Engagement with social media–based studies was predominantly low (41,43,46-48,50). The complex nature of measuring engagement with social media content is acknowledged in the literature (64). Among the challenges is capturing participants who “lurk,” which refers to participants who view content shared without actively engaging with it (65,66). This means that metrics such as “likes,” “comments,” or “shares,” may underestimate engagement. With this in mind, researchers should consider study designs that better compare the impact of social networking on engagement. As demonstrated in the study by Dagan and colleagues (49), exposing the intervention arm to social networking had a positive impact on time interaction and engagement with the nutrition game compared to the non−social control group. More studies of similar design are required. Furthermore, while RCTs are considered higher-level evidence, the role of ecological designs should not be neglected. There is value in reflecting engagement behavior as influenced by the "peering effect," (67,68) whereby peers act as "socialization agents" that affect desire to interact and can promote imitation behavior of their counterparts (69). This peering effect may enhance the efficacy and dissemination of nutrition information via social media in broader settings.

These studies were mainly based on behavioral theory, in contrast to previous literature suggesting a lack of consideration of theoretical frameworks in intervention design (18). There were, however, large variations in the theories applied; Social Cognitive Theory aiming to improve self-efficacy and attitudes was most commonly adopted. While behavior change techniques, such as goal setting and feedback, were used in multi-component interventions, they were rarely used in the gaming interventions, indicating an opportunity to transform games from an interface for awareness raising and knowledge gain to a platform for behavior change. With few studies using valid and reliable measures of outcomes, there is a need for future interventions to consider use of reliable tools and methods, with less reliance on nonvalidated self-report measures.

5.7.1 Strengths and Limitations

To our knowledge, this is the first systematic review to evaluate the use of gaming in nutrition interventions among young adults. While we used the PRISMA guidelines and a comprehensive search strategy, including conference proceedings and gray literature, publication bias remains possible, as some studies may have been missed. Although most game-based interventions had a well-described in-game design theory, most did not report their intervention procedures in detail, particularly eligibility criteria, sample selection methods, and methods used for measuring outcomes. Due to the heterogeneity in study design, intervention methodologies, and outcome measures, we decided not to attempt to combine the results of the reviewed studies, by effect size. Furthermore, we acknowledge that the majority of studies were implemented on convenience samples of college students, who generally have a lower income for food expenses, and might obtain most food on campus (70). While the diversity of tertiary educated individuals is expanding, lower socioeconomic populations remain under-represented in college and university settings (71,72). In addition, most studies were conducted in the United States, with a small sample size and a large proportion of white participants. Therefore, the results of these interventions may not be representative of the broader young adult population. We suggest researchers include young adults from more diverse, social, educational, economic, and ethnic backgrounds. Overall, the quality of evidence was low, with few studies measuring outcomes over longer durations. To gain a greater understanding of the efficacy of social media and gaming strategies for nutrition intervention, further studies using robust designs and power-based calculation for sample sizes are necessary.

5.7.2 Conclusions

Social media and gaming offer a new dimension for nutrition interventions, with the current body of evidence indicating potential positive impacts on improving knowledge and attitudes. However, the implications of social media and gaming strategies in the longer-term and for influencing behavior and health outcomes could not be determined. Further research using high-quality, low risk of bias study designs, with adequately power-based sample sizes is required. Valid and reliable methods for assessing outcomes must be considered and reported. Interventions that follow changes in behavior, nutrition, and health outcomes over longer periods are needed. In addition, reporting of user engagement may be important to determine the dose–response relationship. Addressing the opportunities for future research identified in this review will provide a stronger evidence base of the most effective way to disseminate nutrition education and interventions using these novel strategies. If effectiveness is demonstrated then social media and gaming technologies applied to public health campaigns may appeal to the tech-savvy generation of young adults.

5.9 References

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5.10 Conclusion to chapter.

The studies summarised in this review confimed that the integration of gaming components and social media in nutrition interventions is its infancy. Overall the evidence suggested that using these delivery strategies may have positive implications on nutrition knowledge and attitudes. However, the research exploring implications for vegetable intake or other dietary behaviours is limited. In summary, this review highlighted an opportunity to develop and test a program using a low risk of bias study design to determine the effectiveness of social media and mobile gaming as strategies to deliver behaviour change interventions to young adults.

Appendix 5

Appendix 5.1

Social media and game-based nutrition interventions targeted at young adults: excluded studies with reasons (n=119).

Not Relevant Population (n=61)

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Intervention Did Not Use Social Media or Games (n=23)

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Not Relevant Outcome (n=22)

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Appendix 5.2

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A Narrative Review of Social Media and Game-Based Nutrition Interventions Targeted at Young Adults

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ABSTRACT

The increased popularity of social media and mobile gaming among young adults provides an opportunity for innovative nutrition programs. This review evaluated the efficacy of these strategies in interventions targeted at 18- to 35-year-olds. The protocol was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Ten scientific databases, information technology conference proceedings, and gray literature were searched. Two reviewers conducted screening, data extraction, and quality assessments. Interventions were included if they used social media or electronic games. Comparisons were made pre- to post-intervention, or between intervention and control arms. Outcomes of interest included change in nutrition knowledge, attitudes, behavior, or weight and/or body composition. Eleven social media–based (randomized controlled trials [RCT] n=7) and six game-based [RCT n=1]) interventions were included. Overall quality of studies was low. Social media–based strategies included forum/blogs (n=5), Facebook (n=5), Twitter (n=1), YouTube (n=1), and chat rooms (n=1). Eight (RCT n=6) of 11 social media–based studies demonstrated improvements in outcomes. Findings suggested that social media may be more effective when combined with other strategies. Virtual reality games (n=3), web-based games (n=2), and a mobile application (n=1) were used in the gaming interventions. While a significant increase in knowledge was reported by three gaming studies (RCT=1), two used non-validated tools and longer-term measures of weight and behavioral outcomes were limited. The use of social media and gaming for nutrition promotion is in its infancy. Preliminary evidence suggests that these strategies have some utility for intervening with young adults. Further research using high-quality study designs is required, with measurement of outcomes over longer time periods. The systematic review protocol is registered with PROSPERO (registration number: CRD42015025427).
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OPTIMIZING NUTRITION IS ESSENTIAL IN THE PREvention of chronic diseases and the maintenance of good health and well-being.[1] "Young adulthood," defined as 18 to 35 years old, is a transitional stage during which individuals gain independence and are likely to form life-long eating habits.[2] This population group is generally unware of, or less concerned with, the relationship between diet and health.[2-4] Their typical diet is high in sodium, sugar-sweetened beverages, and foods prepared outside the home, and is low in fruits and vegetables.[5-9] Such dietary patterns increase disease risk factors,[10-12] yet population-wide nutrition campaigns do not usually target young adults.[13] An opportunity exists for interventionists to positively influence nutrition habits during young adulthood to reduce future disease burden.

The current generation of young adults has grown up alongside rapid progression in technology. Conventional methods of communication technology have changed and young adults commonly read material on, and share information through, social media sites, such as Facebook, YouTube, and Twitter.[14] The popularity of social media has created a wide-reaching communication platform for health promotion and an opportunity to facilitate lifestyle behavior change. Using social media channels for the delivery of health information may reduce the time burden of traditional interventions, such as in-person or group consultations. Previous systematic reviews have explored the effectiveness of social media–based interventions in children, adolescents, and adults,[15-19] but not in young adults specifically. Of concern in these studies was the absence of high-quality study designs using behavioral theory-based frameworks.[17,18]

In addition to the well-known social media channels mentioned, there is an increasing trend toward gaming in health interventions.[20] Gamification, also known as experimental or serious games, is defined as the use of game components in a non-game context to motivate users.[21] One component of games is the concept of rewards that promote continuous participation.[22] Such a concept can be used not only for engagement, but also as a technique for behavior change. Rewards have been shown to reinforce positive behaviors enabling change,[23] habit formation, and maintenance of new behaviors.[24] Given the popularity of social media[25] and gaming[26] among young adults, appropriate application of these strategies provides a potentially more accessible and flexible method to disseminate dietary behavior change interventions.

The primary aim of this systematic review was to evaluate the efficacy of social media and game-based interventions in nutrition promotion and behavior modification. More-specific objectives were to describe the social media and gaming nutrition campaigns/interventions, according to content, strategies, duration, and frequency of contact; and assess the efficacy of the social media– and game-based strategies in supporting changes in weight or body composition and/or dietary behavior change and enhancing engagement with the intervention.

METHODS

Design

This systematic review was conducted based on the methods described in the Cochrane Guidelines for Systematic Reviews of Health Promotion and Public Health Interventions[27] and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol.[28] The review protocol was registered with PROSPERO (registration number: CRD42015025427).

Definitions

In this review, the following definitions were assumed: Social media are Internet-based platforms that allow the publication of information and interaction between the content creator and recipients.[29] Popular social media platforms include blogs/forums, chat rooms, Facebook, Instagram, Twitter, and YouTube. Other electronic technologies that involve little or no interaction among users were excluded under this definition. For instance, text messages and websites solely for information-delivery purposes were not categorized as social media. Gamification (experimental or serious games) is the use of game components in a non-game context (eg, nutrition education) to motivate users.[21] This review focused on game-based interventions delivered via digital sources. Young adults were defined as those aged 18 to 35 years, based on the National Institutes of Health cut point.[30]

Search Strategy

A comprehensive search strategy was developed in consultation with two experienced librarians and was used to identify eligible articles from the following electronic databases: CINAHL, the Cochrane Library, Embase, Lilacs, MEDLINE, PubMed, PyschINFO, Science Direct, Scopus, and Web of Science. Reference lists, government reports, and unpublished proceedings from information technology and computer–human interaction conferences were hand searched to obtain additional articles relevant to the review topic. These included the Ubiquitous Computing (UbiComp) Conference; the Computer Human Interaction Conference; and the Conference on User Modelling, Adaptation and Personalization held in the past 5 years (2011 to 2015). Databases were searched from 1990 to March 2016. This period was chosen to reflect the advent of social media.[31] A combination and broad coverage of search terms and MEDLINE thesaurus Medical Subject Headings (MeSH) were selected, including young adults, social media, blogging, telemedicine, experimental game, serious game, gamification, diet, obesity, weight loss, and body mass index (BMI, calculated as kg/m^2). Appropriate indexation, truncations, and synonyms were used for each database to maximize sensitivity. The search strategy is presented in Table 1 (available at www.andjrnl.org) with results from one database, MEDLINE included.

Study Selection

Studies were downloaded to Endnote X7 citation management software[32] and duplicates removed before screening. Two reviewers independently screened the articles by title and abstract, then by full text to determine eligibility. A third reviewer was consulted for articles with uncertainties. There was no limitation on country of publication, but non-English publications were excluded. Articles with no accessible full text were excluded after attempts to contact authors and retrieve them using library request were unsuccessful.

Participants

Articles were included if interventions were targeted at young adults aged 18 to 35 years. A more lenient criterion was applied for the game-based studies due to the minimal availability of articles and, as such, studies were included if the majority of participants ($\geq$90%) fell within the age range of 18 to 35 years and mean age was younger than 35 years. Study participants had to be generally healthy, nonpregnant, and have no illnesses that could impact normal dietary behavior. There were no limitations concerning sex, ethnicity, education, or socioeconomic status.

Interventions

Eligible articles made use of social media– or electronic-based experimental games to promote good nutrition. These digital strategies were either the main component of an intervention or used as one part of a combination of intervention strategies.

Comparisons

Comparisons varied based on study type and included pre- and post-intervention, or intervention and control arm.

Outcomes

The outcomes of interest included nutrition knowledge; attitude or behavior change; and/or change in weight, fat mass, and BMI. Outcomes pertaining to user engagement were also of interest, including frequency of interaction with or usage of social media or gaming program components.

Study Designs

To improve the comprehensiveness of the review, and considering that such social media and gaming strategies are not commonly trialed using a controlled experimental design, no limitation was placed on study design.

Data Extraction

Data were extracted from eligible studies to a data extraction sheet. Information collected included study details (author, date, country of publication, and study type), participant descriptors (age range, population/sample size, and characteristics), study design, intervention features (mode of delivery, theory applied, and duration and follow-up period), level of engagement with the program, and outcomes and the methods and/or tools used to measure change. Behavior change theories and techniques were extracted when explicitly mentioned by the authors within the article and no interpretation or coding of possible techniques was applied by the reviewers.

Data Analysis and Synthesis

The study characteristics were discussed narratively and tabulated to allow comparison and qualitative evaluation of intervention design, participant characteristics, social media/gaming strategies, and intervention outcome(s). Studies that reported a statistically significant change with respect to the comparison group (ie, baseline to post intervention for pre- and post- studies) and intervention arm to control for randomized controlled trials (RCTs) were considered as having a positive outcome.

Quality and Risk of Bias Assessment

Two independent reviewers rated the included studies for quality and risk of bias using the Quality Criteria Checklists for Primary Research developed by the Academy of Nutrition and Dietetics.[33] This tool was chosen due to its suitability for evaluating different study designs. Components assessed included selection bias, blinding, comparability of study groups, rate of withdrawal and dropouts, methods of data collection and statistical analysis, and specification of funding. A positive, negative, or neutral rating was given to each study. Positive or high-quality ratings were reserved for studies that provided a clear description of the intervention and met six or more of the assessment criteria. A neutral or medium-quality rating was designated to studies that met main criteria, but were not completely free from bias, and a negative rating allocated to studies that failed on six or more domains.[30] Any discrepancies in the assessment were resolved by discussion with a third reviewer.

RESULTS

Study Selection and Outcome Reporting

A total of 7,495 records were identified through database searching. A total of 17 studies (6 game-based,[34-39] and 11 social media–based[40-50]) met the eligibility criteria. The reasons for exclusion by full text were recorded (see Figure 1, available online at www.andjrnl.org). The detailed study selection process is illustrated in Figure 2. The included studies were heterogeneous in their design and outcome reporting, preventing the pooling of findings. As a result, outcomes and study details have been collated using tables and described narratively according to strategies used; outcomes assessed; and intervention design components, including behavior change theory, duration, and intensity.

Study Characteristics

Tables 2 and 3 present the key characteristics of the included social media– and game-based studies, respectively. Across the 16[34-45,47-50] studies that specified sample size, a total of 3,732 participants were included, with 73% females. The majority of studies targeted college students[35-37,40-42,44,45,50] and were conducted in the United States.[35-42,44,45,48-50] All interventions had weight management and/or nutrition knowledge gain as the primary intervention objective(s). All but two studies[35,37] were published after 2009, indicating that this is an evolving area of research. The studies meeting selection criteria included RCTs (n=8),[37,40,41,43,45,47,49,50] a non-RCT (n=1),[35] a randomized comparison study (n=1),[38] a case-control study (n=1),[34] pre- and post-intervention studies (n=4),[36,39,42,48] a cross-sectional study (n=1),[46] and a mixed method study (n=1).[44]

INTERVENTION STRATEGIES

Social Media–Based Interventions

Among the 11 social media–based studies,[40-47,50] Internet forums/blogs (n=5)[40-43,47] and Facebook (n=5)[43-46,48,49] were the most commonly used modalities. Others included chat rooms[42] (n=1), Twitter[50] (n=1), and YouTube[46] (n=1) (Table 2). One study[50] investigated the effect of social media on attitudes to multivitamins. Dagan and colleagues[49] used gamification techniques in their social media intervention. They compared the effect of sharing game progress on social media on improvements in knowledge and engagement. The remaining studies were designed as multicomponent interventions, with social media utilized as one of the strategies, without isolating its effect on the outcomes. Other intervention components used in these studies included e-mail, websites, text messages, and face-to-face or phone coaching. Napolitano and colleagues,[45] compared the effect of social media (Facebook) alone to the effect of social media (Facebook) as part of the multi-component intervention in their three-arm RCT (Table 2).

Game-Based Interventions. For the six game-based interventions,[34-39] three were virtual reality (VR) games,[37-39] two web-based games,[35,36] and one a mobile application game[34] (Table 3). The three VR games each presented a virtual dining experience, which aimed to promote knowledge gain and behavior change. Strategies used included the direct provision of food knowledge information, real-time education and training, personalized goal-setting and task selection, instant dynamic feedback corresponding to game performance, and trial and error exploration. The mobile application game used a quiz to improve nutrition knowledge in conjunction with other functions, such as a calorie calculator and diet planner. One of the web-based games used levels and a point system to encourage play,[35] while the other did not specify gamification techniques[36] (Table 3). The Facebook study by Dagan and colleagues,[49] used gaming strategies, such as progress monitoring and feedback on performance with a numerical score presented on a leader board in the social media condition (Table 2).

OUTCOME MEASURES

Social Media-Based Interventions

Knowledge and Attitude Change. Two studies measured knowledge gain.[46,49] The New South Wales Food Authority campaign resulted in a significant improvement in understanding of kilojoule requirements, but this did not translate to changes in anticipated kilojoule intake.[46] The study by Dagan and colleagues[49] found social media had positive

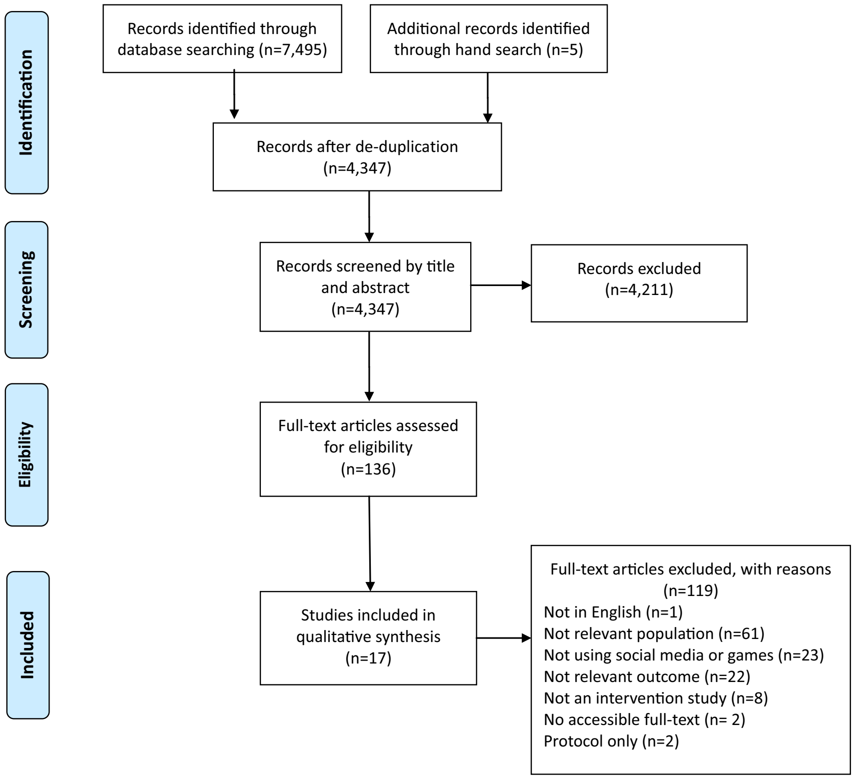

Figure 2. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram indicating the number of records screened, included, and excluded in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults.

effects on nutrition knowledge, with greater improvements in the intervention arm (Table 2). There were no significant changes in attitudes toward multivitamin intake after exposure to the Twitter intervention.[50]

Weight/BMI Change. Seven studies measured changes in weight and/or BMI as their primary outcome.[40-43,45,47,48] With the exception of studies by Hebden and colleagues[43] and Cavallo and colleagues,[48] all others reported positive outcomes for weight and/or BMI, with significant reductions in the intervention arm relative to control. The pre−post study by Cavallo and colleagues observed a 1.3-kg mean weight loss from baseline; however, the sample was too small for statistical analyses. Notably, positive outcomes were only observed in the multicomponent group in the study by Napolitano and colleagues,[45] and not the Facebook-only group (Table 2).

Dietary Behavior Change. Five interventions also measured changes in fruit and vegetable intake (Table 2).[40,41,43,47,48] One demonstrated a significant increase in intake by 1 cup in the intervention arm.[41] The multicomponent study by Partridge and colleagues[47] produced a positive outcome for vegetable intake but changes between intervention and control were nonsignificant for fruit. The remaining three studies also increased intake, but outcomes were not statistically significant.[40,43,48]

User Engagement. Eight studies reported participant engagement with the social media components.[41,43-49] Methods used to measure engagement varied, including numbers of "likes," "shares," or comments on social media posts. Overall engagement was low, and interaction declined over time.[44,48,50] The study by Dagan and colleagues,[49] demonstrated engagement was higher in the social media arm compared to the control arm. Although a high engagement rate was reported in the study by Merchant and colleagues,[44] with participants interacting with 73% of Facebook posts, 81% of these interactions were made by the more highly active participants. Engagement with other social media platforms was much lower than that reported in the Facebook studies. In the Twitter intervention, only one participant "retweeted" the multivitamin messages.[50] Furthermore, the popularity of forums/blogs was low, with only 6.4% of participants engaging with the blog in the study by Partridge and colleagues,[47] and only 2 of 51 participants replying to forum posts in the study by Hebden and colleagues.[43] Forums were also ranked as the least motivating strategy of the Project Webhealth intervention.[51]

Game-Based Interventions

Knowledge and Attitude Change. Three game-based interventions reported positive outcomes for post-game knowledge of nutrition or healthy eating concepts.[35-37] While the study by Orji and colleagues[39] also reported positive improvements in nutrition knowledge scores, statistical significance of these results was not assessed. Three studies also measured the change in self-efficacy to make healthier food choices[35,36] and to engage in healthier eating habits,[37] with two reporting positive outcomes[35,37] (Table 3).

Table 2. Overview of social media–based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results

			Population			
Author(s), year, country	**Study design**	**Theoretical framework/BCTs[a]**	**n (study arms)**	**Baseline characteristics**	**Outcome measures**	**Results**
Cavallo and colleagues, 2015, United States[48]	Single group pre–post design Social media used: Facebook InShape: group-based weight-loss intervention wk 1 to 20: 5 face-to-face group education wk 2 to 20: weekly online questionnaires on F/V[b] intake, PA,[c] food record completion wk 5 to 20: Facebook page with moderator posts (∼4/wk), weekly self-monitoring statistics+ 8 web-based nutrition and PA lessons Duration: 5 mo, follow-up duration[d]: nil	BCTs: goal setting, self-monitoring, feedback, education and social support	40 (NA[e])	BMI[f]: >27.5 Female intervention Mean age: 30 y	Primary: weight and blood pressure measured by trained personnel Secondary: F/V intake measured by validated Block rapid food screener, self-efficacy for healthy lifestyle measured using self-report single-item question	Outcomes from baseline to post-intervention (at 5 mo) for study completers (n=12): Weight: mean -1.3 ± 4.4 kg reduction in weight (no statistical analyses conducted) F/V: mean change in servings/d 0.5 ± 1.5 (no statistical analyses conducted) Self-efficacy: post-intervention self-efficacy NR[g]
Dagan and colleagues, 2015, United States[49]	RCT[h] Social media used: Facebook Food Hero: players feed virtual character according to their own nutritional needs and complete a set of virtual sport challenges. I: use "social version": user can see other players' scores, including Facebook friends. C: "private version": users see own score Duration: 2 wk, Follow-up duration: nil	NR	63 (I[i]: 30, C[j]: 33)	36.5% male Mean age: 30.2 y	Primary: nutrition knowledge measured using quiz and menu-assembly scores Secondary: self-reported desire to improve eating habits	Knowledge: quiz score from baseline to day 14 higher in I vs C (*P*=0.02) (scores NR). From baseline to day 12, I menu-assembly scores improved (*z*-score +0.18), C scores deteriorated (*z*-score −0.26). Desire to improve eating habits: post-game motivation, 43% of respondents high, 38% moderate (no significant differences between I and C)

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Table 2. Overview of social media–based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

Author(s), year, country	Study design	Theoretical framework/BCTs[a]	Population: n (study arms)	Population: Baseline characteristics	Outcome measures	Results
Gow and colleagues, 2010, United States[40]	RCT; social media used: discussion board Multi-component weight management I_1: personalized feedback e-mails I_2: weekly online education session guided by clinician, access to discussion board I_3: combination of I_1 and I_2 and 2 C: no intervention Duration: 6 wk, follow-up duration: 3 mo	SCT[k]	159, (I_1: 40; I_2: 39; I_3: 40; C: 40)	First-year college students 26% male Age: <22 y (mean age: NR)	Primary: BMI calculated from measured height and weight Secondary: F/V, fat intake measured by validated Block Food Screener	Post intervention (at 6 wk): BMI: mean BMI decreased for I_3 (−0.25) compared with C (+0.18) ($P<0.05$). I_1 and I_2 did not differ to control ($P>0.05$). F/V and fat intake: no significant differences between groups
Greene and colleagues, 2012, United States[41]	RCT; social media used: Internet forum Multi-component nutrition and physical activity online program I: weekly lessons of different activities, including quizzes, and forum C: no intervention received Duration: 10 wk, follow-up duration: 15 mo	SCT, TTM[l]	1,689 (I: 830; C: 859)	College-aged students (18 to 20 y) 47% male Mean age: 18.1 y	Primary: F/V intake (measured using validated 2-item and National Cancer Institute screener), BMI (calculated from weight and height measured by trained personnel)	Post-intervention (10 wk) change in: Weight/BMI: no significant differences between I and C (*P* value NR) F/V intake: increased F/V intake from baseline by approximately 1 cup in I, decreased intake in C. I intake significantly higher ($P<0.001$) than C at 15 mo

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Table 2. Overview of social media–based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

Author(s), year, country	Study design	Theoretical framework/BCTs[a]	Population: n (study arms)	Population: Baseline characteristics	Outcome measures	Results
Harvey-Berino and colleagues, 2012, United States[42]	Single-group pre-post design Social media used: online chat and Internet forum Multi-component web-based weight-management program. Program consisted of discussion board and weekly hourly online education as university coursework. Duration: one university semester, follow-up duration: nil	SCT	336 (NA)	College-aged students 13% male Mean age: NR, targeted college students	Primary: weight (self-report) BMI (calculated from self-report height and weight)	Weight/BMI: weight loss post intervention among participants who set weight loss as goal (n=145, $P<0.001$) (2.7% loss of baseline weight for overweight participants, and 3.0% loss of baseline weight for obese participants)
Hebden and colleagues, 2014, Australia[43]	RCT; social media used: Internet forum Multi-component mobile phone-based weight loss intervention I: received printed dietary and PA information, text messages reminders, e-mails, and access to smart phone app and Internet forum. C: received printed dietary and PA information Duration: 12 wk, follow-up duration: nil	TTM	51 (I: 26; C:25)	University staff or students BMI: 24 to 31.9 20% male Mean age I: 22.6 y; C: 23.1 y	Primary: weight/BMI (calculated from weight and height measured by trained personnel) Secondary: F/V, SSB[m] and takeaway intake (measured using validated Australian national survey questions)	Post intervention (12 wk): Weight/BMI: no significant differences between groups but decrease from baseline in I (-1.60 ± 2.58 kg; $P=0.004$ and -0.58 ± 0.90; $P=0.003$), and C (-1.41 ± 2.86 kg; $P=0.021$ and -0.58 ± 0.90; $P=0.003$). F/V, takeaway SSB intake: nonsignificant group differences between I & C after adjusting for baseline.

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RESEARCH

Table 2. Overview of social media–based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

			Population			
Author(s), year, country	**Study design**	**Theoretical framework/BCTs**[a]	**n (study arms)**	**Baseline characteristics**	**Outcome measures**	**Results**
Mackert and colleagues, 2012[n], United States[50]	RCT Study 1: Twitter messages to promote multivitamin use. I: received 9 Twitter messages, C: no intervention received, duration: NR Study 2: investigated retweeting of messages. I: received best-rated multivitamin message C: received a random multivitamin twitter message, duration: NR	Theory of Planned Behavior	Study 1: 259 (I: 144; C: 151) Study 2: 154 (I: 78; C: 76)	College-aged 0% male Mean age: 21.8 y 0% male Mean age: 21.1 y	Primary: Study 1: attitudes and beliefs, intentions toward multivitamin intake (measured using self-report scales and questionnaires) Secondary: Study 2: motivation to retweet measured using Likert scale	Post intervention: attitudes/beliefs: between groups, no significant differences in beliefs or attitudes toward multivitamin intake (P=0.06), or intention to take multivitamins (P=0.09). Retweeting: motivation to retweet low among I, mean score 3.2 out of 7. Motivation for C was NR
Merchant and colleagues,[o] 2014, United States[44]	Mixed methods study Social media used: Facebook Engagement evaluation of a registered dietitian nutritionist–guided, Facebook weight-loss program (ThreeTwoMe) I: On top of Facebook interaction, received co-intervention materials including website, blog, and mobile application. Duration: 21 mo, follow-up Duration: NA	Theory of Reasoned Action, SCT, CT,[p] OC,[q] Theories of Social Comparison, and Social Support	404 (NA)	College students aged 18 to 35 y BMI: 25 to 40 Sex: % NR Age: mean NR	Primary: Engagement with Facebook posts (measured through likes, comments, or shares)	Engagement: At 21 mo, of the 1,816 Facebook posts made, 72.96% were liked/commented/shared at least once. Most popular were polls, photos, then videos. Engagement rate varied, from 0 to 653 interactions per person; 53% of participants were minimally active, 23.4% highly active

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Table 2. Overview of social media–based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

			Population			
Author(s), year, country	**Study design**	**Theoretical framework/BCTs[a]**	**n (study arms)**	**Baseline characteristics**	**Outcome measures**	**Results**
Napolitano and colleagues, 2013, United States[45]	RCT, social media used: Facebook weight-loss program delivered via a private Facebook group I_1: Facebook-only group I_2: Facebook Plus (multicomponent-Facebook+weekly personalized feedback, pedometer text messages, and a support buddy) C: no intervention received Duration: 8 wk, follow-up Duration: 4 and 8 wk	BCTs: goal setting, self-monitoring, and social support	52 (I_1: 17; I_2: 18; C: 17)	University students BMI: 25 to 50 13.5% male Age: 20.47 y	Primary: weight loss after 8 wk (in person measure). Secondary: weight self-efficacy (measured using validated 20-item WEL[r] Questionnaire), adapted social support (measured using 48-item social support questionnaire).	Weight: At wk 8, greater weight loss from baseline in I_2 (−2.4±2.5 kg) compared to I_1 (−0.63±2.4 kg) and C (0.24±2.6 kg) ($P<0.05$). No significant differences from baseline between I_1 and C (*P* value NR) Secondary: no significant differences within or among groups on changes in any of the measures.
NSW Food Authority 2013, Australia[46]	Cross-sectional Social media used: Facebook and YouTube Kilojoule menu labeling campaign with website, smartphone app, Facebook page and YouTube videos. Duration: 12-mo study period Follow-up duration: 6 mo post implementation	Knowledge–Attitude–Behavior Model	Varied with sample; each sample ~130 to 230 (NA)	Frequent consumers of fast-food outlets aged 18 to 24 y Sex: % NR Age: mean NR	Primary: awareness and understanding of kJ[s] labeling and information and anticipated change in purchasing behavior (kJs) measured using online survey	At 6 mo post implementation: Awareness: increased significantly from baseline (*P*=NR) Understanding: no significant change in understanding meaning of kJs from baseline (*P*=NR) Anticipated purchasing behavior: nonsignificant increase in % anticipating to choose lower kJ food

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Table 2. Overview of social media−based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

			Population			
Author(s), year, country	Study design	Theoretical framework/BCTs[a]	n (study arms)	Baseline characteristics	Outcome measures	Results
Partridge and McGeechan, 2015, Australia[47]	RCT, social media used: Internet blog multi-component weight-loss intervention. I: Received printed dietary booklet, 8 text messages weekly, 1 e-mail weekly, 5 tailored coaching calls, smart phone application, website and a community blog. C: Received printed dietary and PA information and 4 text messages Duration:12 wk, follow-up duration: 6 mo	TTM BCTs: goal setting, monitoring, and feedback	250 (I: 125; C: 125)	BMI 25 to 31.9 or 23-24.9 with weight gain >2 kg in last 12 mo 38.7% male Age: 27.7 y	Primary: weight/BMI Secondary: F/V intake and weekly SSB and takeaway consumption	At 12 k (post intervention): Weight: I was 2.2 kg lower in adjusted body weight compared to C (P=0.005) F/V: increase % consuming ≥4 servings/d from baseline greater in I (+19.6%) than C (+8%) (P=0.009). No significant difference in fruit intake (P =0.18) between groups SSB: 92.7% consumed <500 mL compared with 72% in C (P=0.002) Takeaway: consumption once/wk or less increased by 40% in I vs 16% in C (P=0.01).

[a]BCT=behavior change techniques.
[b]F/V=fruits and vegetables.
[c]PA=physical activity.
[d]Time between intervention cessation and follow-up time point.
[e]NA=not available.
[f]BMI=body mass index; calculated as kg/m^2.
[g]NR=not reported.
[h]RCT=randomized controlled trial.
[i]I=intervention.
[j]C=control.
[k]SCT=Social Cognitive Theory.
[l]TTM=Transtheoretical Model.
[m]SSB=sugar sweetened beverages.
[n]Two sub-studies with different features of population were conducted in this study.
[o]Sub-study examining engagement of intervention arm of Sequential Multiple Assignment Randomized Trial study (early trials, final results not yet available).
[p]CT=control theory.
[q]OC=operant conditioning.
[r]WEL=Weight Efficacy Lifestyle.
[s]kJ=kilojoule.

Weight/BMI Change. Two studies measured weight changes and found significant decreases in body weight.[34,38] In the study by Sullivan and colleagues,[38] this positive change was sustained in the game-only intervention arm (Table 3). Lee and colleagues[34] found significant decreases in weight, fat mass, and BMI among the intervention arm only.

Dietary Behavior Change. Only one game-based study assessed behavioral outcomes. The study by Sullivan and colleagues[38] explored whether VR gaming could improve fruit and vegetable intake, with outcomes indicating that the game-only intervention arm had significantly higher fruit intake at 9 months compared to the game and face-to-face study group. Group differences at baseline were not reported (Table 3).

User Engagement. Engagement rates were not well documented across studies. The time spent interacting with gaming platforms varied between studies. Dagan and colleagues[49] reported the intervention participants (social media arm) spent more time playing than the control (non–social media arm). This was also observed in the study by Miller and Lindberg,[35] where game players spent almost double the amount of time interacting with the gaming platform when compared to the control. The Smart Diet app study found a majority of users interacted with the platform once per week, with only 8% using it daily.[34]

Delivery Mode

Nine social media studies were multi-component interventions implemented in conjunction with other non–social media components (Table 2). Positive changes were generally reported by these interventions,[40-48] whereas no significant changes were observed in the social media–only study.[50] This finding is in line with the results of the RCT by Napolitano and colleagues,[45] which indicated a significant weight loss in the Facebook Plus multi-component intervention arm, but not the Facebook-only arm when compared with the control (Table 2). The game-based studies were delivered as stand-alone interventions, with the exception of the study by Sullivan and colleagues,[38] which compared game exposure against a combined face-to-face and gaming intervention, finding greater weight maintenance in the game-alone setting (Table 3).

Duration and Intensity

Game-based studies were short, with participants generally required to use the game on one occasion (n=3)[35-37] (Table 3). Despite their short duration, these studies indicated positive improvements in knowledge post-game interaction. However, due to lack of follow-up, little is known about maintenance or if the acquired knowledge translates to behavior change. Social media–based interventions ranged in duration from 2 weeks to 21 months (Table 2). The frequency of participants-and-facilitator interactions varied among studies, from daily to weekly, but all generally encouraged participant engagement in daily intervention-related activities (eg, food dairy, step count). There was no clear link between intervention intensity and efficacy as findings varied.

Behavioral Theory

With the exception of two interventions,[34,49] the reviewed studies were theoretical[35,37-44,46,47,50] or evidence-based[36,45] in their design. Due to the large variety of behavioral models adopted, no single specific theory or model could be identified as more effective. Social cognitive theory was most commonly applied within the social media–based interventions, that found positive behavioral and weight outcomes.[40-42,45] The four game-based interventions[35-38] with positive outcomes reported using behavior change theories, such as the Health Belief Model, Social Cognitive Theory, or Theory of Planned Behavior.

Quality Assessment and Risk of Bias

Tables 4 and 5 (both available online at www.andjrnl.org) provide a summary of the quality rating for each study. Only one study[47] was free from risk of bias regarding blinding. The studies that reported attrition had low dropout rates,[37,40,43,47] but the majority (n=13)[34,35,37-42,45,46,48-50] did not report the attrition rate or reasons for withdrawal. Seven studies[33-36,39,41,44,46,48] were non-randomized designs. Of the nine RCTs,[37,38,40,41,43-45,47,49,50] only three described a randomization method.[40,43,47] Common factors that compromised study quality included noncomparable study groups, low validity and reliability of methods of outcome measurement, and failure to perform intention-to-treat analysis. Due to the low quality and high risk of bias in the included studies, we interpret the evidence with caution.

DISCUSSION

This review has highlighted the increased use of social media and emerging use of experimental games in nutrition interventions. Despite the growing body of evidence, very few studies have examined the isolated effect of social media on nutrition outcomes and the longer-term implications of game play on behavior and health. Furthermore, measurement of participant engagement and process evaluations of the interventions were not well executed. Due to the overall low quality of the studies, particularly among the gaming interventions, our capacity to draw any definite conclusions on the efficacy of strategies was limited. Therefore, we emphasize the gaps in the literature and identify opportunities for the development of future interventions.

Among the reviewed social media–based studies, Facebook and blogs/forums were the most frequently used platforms. However, blogs/forums were consistently ranked the least popular when used within multicomponent interventions. A majority of these multi-component studies measured the overall efficacy of their intervention, with few evaluating the sole impact of social media. Consequently, we cannot determine whether the positive outcomes recorded are related to participation in a healthy lifestyle intervention or directly attributable to the social media strategies. Dagan and colleagues,[49] demonstrated that social networking alone was associated with greater improvements in nutrition knowledge, and desire to develop better eating habits, but did not measure the impact on behavioral or weight outcomes. Napolitano and colleagues[45] found that social media alone was not as effective for weight loss as when it was combined with other components. To confidently establish the efficacy of social media for improving nutrition outcomes in young

Table 3. Overview of game-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results

			Population			
Author(s), year, country, citation	Study design	Theoretical framework/BCTs[a]	n(study arms)	Baseline characteristics	Outcome measures	Results
Lee and colleagues, 2010, Korea[34]	Case-control study Mobile game application (Smart Diet) Weight-control mobile app with functions such as calorie calculator, meal planner, and diet quiz game. Intervention details of I[b] and C[c] NR[d] Duration NR, follow-up duration[e]: NR	NR	36 (I: 19; C: 17)	Volunteers from an obesity clinic % male NR Mean age: I: 28.2 y C: 29.5 y	Primary: body composition (weight, fat mass and BMI,[f] measured in clinic using Inbody system[g])	Body composition: decreases in weight (1.9 kg), fat mass (1.2 kg) and BMI (0.8) post intervention among I ($P<0.05$); no significant changes in C ($P>0.05$)
Miller and Lindberg, 2007, United States[35]	Non-RCT[h] Web-based computer game I: played educational game on GI[i] : each level presented 5 foods with various GI values, foods to be "consumed" by dragging to animated mouth or discarded in trash can. C: viewed information from a website concerning healthy eating Duration: one-time play 25.3 min to complete the game, follow-up duration: nil	Theory of Planned Behavior (knowledge, self-efficacy, and behavioral intention)	67 (I: 30; C: 35)	43% male Mean age: I: 20.5 y C: 20.2 y	Primary: nutrition and GI knowledge obtained (measured using 9-item multiple-choice test, pretested for reliability) Secondary: self-efficacy for selecting lower GI foods (16-item instrument pretested for reliability and internal consistency)	Nutrition knowledge: higher gain of knowledge from baseline among I mean $+2.8\pm1.8$ than C mean $+0.9\pm1.5$ ($P<0.001$) post game play Self-efficacy: higher gain in mean self-efficacy scores from baseline among I: $+2.8\pm1.8$ than C: $+1.7\pm1.9$ ($P<0.01$) post game play

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Table 3. Overview of game-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

			Population			
Author(s), year, country, citation	**Study design**	**Theoretical framework/BCTs**[a]	**n(study arms)**	**Baseline characteristics**	**Outcome measures**	**Results**
Miskovsky, 2012, United States[36]	Single-group pre- and post-study Web-based game (Nutrition Jeopardy) The game had single *Jeopardy!*[j]-style questions and a final *Jeopardy!*-style question. Topics included my pyramid, fruits and vegetables, healthy snacks, advertising, and nutrition. Duration: NR, follow-up duration: nil	Pender Model of Health promotion that integrates expectancy value model of human motivation and the SCT	106 (NA[k])	College freshmen 53% male Mean age: 21.7 y	Primary: nutrition knowledge (measured using validated self-report General Nutrition Questionnaire) and self-efficacy (measured using validated 11 item General Nutrition Self-efficacy Questionnaire)	Nutrition knowledge: no significant post-intervention changes in nutrition knowledge (P=0.49) compared to baseline, but significant increase in nutrition knowledge related to expert advice (P=0.0039) (scores NR) Self-efficacy: no significant changes post-intervention in self-efficacy (P=0.48)
Orji and colleagues, 2012, United States and Canada[39]	Single-group pre- and post-study Virtual reality mobile game application (LunchTime) with link to Facebook Multi-player interactive game mimicking restaurants visits, to learn to select healthy options in line with dietary goal. Duration: 10 d, follow-up duration: nil	TTM[l], Goal Setting Theory, Social Learning Theory, KAB[m] Model and Reinforcement Theory	6 (NA)	Participants aged 19 to 40 y 50% male Mean age: NR	Primary: nutrition knowledge and healthy eating attitude measured using a survey, healthy eating attitude ranked on scale of 1 to 5, with 5 indicating positive attitude.	Post-intervention (10 d): nutrition knowledge: increased from baseline by mean score of 2.1$\pm$0.5 (no statistical analysis conducted) Healthy eating attitude: increased from baseline by 2.3 (baseline=1.9, post=4.2) (no statistical analysis)

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Table 3. Overview of game-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

Author(s), year, country, citation	Study design	Theoretical framework/BCTs[a]	Population: n(study arms)	Population: Baseline characteristics	Outcome measures	Results
Peng, 2009, United States[37]	RCT Virtual reality computer game (RightWay Café) Mimics eating in university cafeteria environment. I: played the game once C: no intervention received Duration: One-time play Follow-up duration: 1 mo	Health Belief Model, SCT[n], Situated Learning Theory, Theory of Reasoned Action, Entertainment Education Theory and BCTs: instilling intrinsic motivation	40 (NR)	Undergraduate students 20% male Mean age: 20 y	Primary: nutrition knowledge (using author created questionnaire), self-efficacy for eating healthy (using modified 14-item self-efficacy of healthy eating scale pretested for reliability), perceived benefits of healthy eating (using 5-item scale created by authors pretested for reliability) and intention to eat healthier food (using 10-item scale created by authors)	Differences from baseline to post-test (after game play): N=nutrition knowledge: greater gain in score in I (+5.8) vs C (+0.19) ($P<0.05$). Not significant at 1-mo follow-up Self-efficacy: greater improvement in score for I (+0.77) vs C (+0.01) ($P<0.01$). Maintained for I and decrease for C 1-mo follow-up. Perceived benefit: greater improvement in perceived benefits of health eating in I (+0.58) vs C (+0.09) ($P<0.01$). I also showed greater perceived benefits at 1-mo follow-up than C ($P<0.05$). Intention: greater intention to eat healthy ($P<0.001$) in I vs C. Baseline results and follow-up NR.

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Table 3. Overview of game-based studies included in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults, including the design, intervention description, duration, theoretical framework, population characteristics, number of participants, outcomes, measures used, and results (*continued*)

			Population			
Author(s), year, country, citation	**Study design**	**Theoretical framework/BCTs[a]**	**n(study arms)**	**Baseline characteristics**	**Outcome measures**	**Results**
Sullivan and colleagues, 2013, United States[38]	Randomized comparison study Virtual-reality computer game (Second Life) Weight-loss and weight-maintenance game. Interaction between players and clinicians in virtual clinics, homes, grocery stores. I_1: interaction done via the game only I_2: attended face-to-face clinic in first 3 mo, then interaction via game for rest of the study Duration: 9 mo, follow-up duration: nil	BCTs: experimental learning	20 (I_1: 10; I_2:10)	Overweight or obese subjects 15% male Mean age: 31.1 y	Primary: weight (measured in clinic by trained personnel), fruit and vegetable intake (self-reported) Secondary: qualitative rating of, adequacy of training, ease of communication and engagement	Weight: weight loss from baseline at 3-mo assessment for both groups (I_1 10.8%±3.5% and I_2 7.6%±5.1%). At 9 mo, I_2 regained weight by a mean of 13.6%, while I_1 lost additional weight by a mean of 3.7% (P=NR) Fruit and vegetable intake: At 9 mo, significantly higher consumption of fruits in I_1 2.7±0.7 servings/d compared with I_2 1.9±0.4 servings/d ($P<0.05$), and higher but nonsignificant increase in vegetable intake ($P=0.07$) between groups.

[a]BCT=behavior change techniques.
[b]I=intervention.
[c]C=control.
[d]NR=not reported.
[e]Time between intervention cessation and follow-up time point.
[f]BMI=body mass index; calculated as kg/m^2.
[g]Body composition analyzer.
[h]RCT=randomized controlled trials.
[i]GI=Glycemic Index.
[j]Production company: Sony Pictures Television.
[k]NA=not available.
[l]TTM=Transtheoretical Model.
[m]KAB=knowledge–attitude–behavior.
[n]SCT=Social Cognitive Theory.

adults, further research isolating the effects of social networking strategies on dietary behavior is warranted. The Multiphase Optimization Strategy or the Sequential Multiple Assignment Randomized Trials setup[52] may assist with designing these factorial studies.[53]

VR gaming was the most commonly implemented strategy among game-based studies. The popularity of VR gaming is increasing[54,55] and may have the potential to effectively engage young adults in nutrition education. Gaming has been adopted for behavior change in several other clinical areas[56-63]; however, its ability to maintain engagement in nutrition interventions could not be determined. In addition, while VR gaming was found to support improvements in knowledge,[37,39] tools used to measure this change were not validated. Furthermore, only one intervention measured weight or behavioral outcomes.[38] Thus, the implications of these short-lived games on behavior and health over time are unknown. There is a need for future interventions to explore long-term outcomes linked to game play, with an opportunity to explore the impact of repeat game play, while also measuring participant interaction to ascertain the efficacy of games in maintaining engagement.

Engagement with social media–based studies was predominantly low.[41,43,46-48,50] The complex nature of measuring engagement with social media content is acknowledged in the literature.[64] Among the challenges is capturing participants who "lurk," which refers to participants who view content shared without actively engaging with it.[65,66] This means that metrics such as "likes," "comments," or "shares," may underestimate engagement. With this in mind, researchers should consider study designs that better compare the impact of social networking on engagement. As demonstrated in the study by Dagan and colleagues,[49] exposing the intervention arm to social networking had a positive impact on time interaction and engagement with the nutrition game compared to the non–social control group. More studies of similar design are required. Furthermore, while RCTs are considered higher-level evidence, the role of ecological designs should not be neglected. There is value in reflecting engagement behavior as influenced by the "peering effect,"[67,68] whereby peers act as "socialization agents" that affect desire to interact and can promote imitation behavior of their counterparts.[69] This peering effect may enhance the efficacy and dissemination of nutrition information via social media in broader settings.

These studies were mainly based on behavioral theory, in contrast to previous literature suggesting a lack of consideration of theoretical frameworks in intervention design.[18] There were, however, large variations in the theories applied; Social Cognitive Theory aiming to improve self-efficacy and attitudes was most commonly adopted. While behavior change techniques, such as goal setting and feedback, were used in multi-component interventions, they were rarely used in the gaming interventions, indicating an opportunity to transform games from an interface for awareness raising and knowledge gain to a platform for behavior change. With few studies using valid and reliable measures of outcomes, there is a need for future interventions to consider use of reliable tools and methods, with less reliance on nonvalidated self-report measures.

Strengths and Limitations

To our knowledge, this is the first systematic review to evaluate the use of gaming in nutrition interventions among young adults. While we used the PRISMA guidelines and a comprehensive search strategy, including conference proceedings and gray literature, publication bias remains possible, as some studies may have been missed. Although most game-based interventions had a well-described in-game design theory, most did not report their intervention procedures in detail, particularly eligibility criteria, sample selection methods, and methods used for measuring outcomes. Due to the heterogeneity in study design, intervention methodologies, and outcome measures, we decided not to attempt to combine the results of the reviewed studies, by effect size. Furthermore, we acknowledge that the majority of studies were implemented on convenience samples of college students, who generally have a lower income for food expenses, and might obtain most food on campus.[70] While the diversity of tertiary educated individuals is expanding, lower socioeconomic populations remain under-represented in college and university settings.[71,72] In addition, most studies were conducted in the United States, with a small sample size and a large proportion of white participants. Therefore, the results of these interventions may not be representative of the broader young adult population. We suggest researchers include young adults from more diverse, social, educational, economic, and ethnic backgrounds. Overall, the quality of evidence was low, with few studies measuring outcomes over longer durations. To gain a greater understanding of the efficacy of social media and gaming strategies for nutrition intervention, further studies using robust designs and power-based calculation for sample sizes are necessary.

CONCLUSIONS

Social media and gaming offer a new dimension for nutrition interventions, with the current body of evidence indicating potential positive impacts on improving knowledge and attitudes. However, the implications of social media and gaming strategies in the longer-term and for influencing behavior and health outcomes could not be determined. Further research using high-quality, low risk of bias study designs, with adequately power-based sample sizes is required. Valid and reliable methods for assessing outcomes must be considered and reported. Interventions that follow changes in behavior, nutrition, and health outcomes over longer periods are needed. In addition, reporting of user engagement may be important to determine the dose–response relationship. Addressing the opportunities for future research identified in this review will provide a stronger evidence base of the most effective way to disseminate nutrition education and interventions using these novel strategies. If effectiveness is demonstrated then social media and gaming technologies applied to public health campaigns may appeal to the tech-savvy generation of young adults.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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Table 1. Database search strategy including search terms and the number of articles retrieved from MEDLINE (conducted on August 26, 2015) to be screened for inclusion in the narrative review to determine the effectiveness of social media and gaming interventions for improving nutrition outcomes in young adults

Search ID	Search terms[a]	Results
1	gamification.mp.	22
2	'experimental game*'.mp.	32
3	'serious game*'.mp.	81
4	gaming.mp.	1,017
5	1 or 2 or 3 or 4	1,131
6	internet/or blogging/or social media/	56,115
7	Internet/	54,297
8	Games, Experimental/	1,529
9	Telemedicine/	12,686
10	Diet/	117,136
11	Obesity/	137,649
12	Overweight/	14,494
13	Weight Loss/	26,796
14	Body Mass Index/	89,887
15	Adult/or Young Adult/	4,225,899
16	10 or 11 or 12 or 13 or 14	317,842
17	weight loss.mp. or Weight Loss/	63,988
18	Internet/or internet.mp.	67,062
19	16 or 17	347,557
20	social media.mp. or Social Media/	2,550
21	6 or 7 or 8 or 9 or 18 or 20	80,883
22	5 or 21	81,680
23	15 and 19 and 22	637
24	Limit 23 to (yr="1990 -Current" and ("adult (19 to 44 years)" or "young adult and adult (19-24 and 19-44)") and english and humans)	612

[a]Modifiers are * (search term as major focus of articles), .mp (multiple purpose search including all fields: title, original title, abstract, subject heading, name of substance, and registry word fields), and/(valid controlled vocabulary term that has been searched in the subject headings field of the database).

Supplementary Material

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Figure 1. Social media and game-based nutrition interventions targeted at young adults: excluded studies with reasons (n=119).

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Figure 1. *(continued)* Social media and game-based nutrition interventions targeted at young adults: excluded studies with reasons (n=119).

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Figure 1. *(continued)* Social media and game-based nutrition interventions targeted at young adults: excluded studies with reasons (n=119).

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Figure 1. *(continued)* Social media and game-based nutrition interventions targeted at young adults: excluded studies with reasons (n=119).

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Figure 1. *(continued)* Social media and game-based nutrition interventions targeted at young adults: excluded studies with reasons (n=119).

Table 4. Quality assessment[a] of social media–based studies (n=11) using the Quality Criteria Checklists for Primary Research developed by the Academy of Nutrition and Dietetics[33]

	Author(s), Year										
Validity questions	**Cavallo and colleagues, 2016[48]**	**Dagan and colleagues, 2015[49]**	**Gow and colleagues, 2010[40]**	**Greene and colleagues, 2012[41]**	**Harvey-Berino and colleagues, 2012[42]**	**Hebden and colleagues, 2014[43]**	**Mackert and colleagues, 2012[50]**	**Merchant and colleagues, 2014[44]**	**Napolitano and colleagues, 2013[45]**	**NSW[b] Food Authority, 2013[46]**	**Partridge and McGeechan, 2015[47]**
1. Was the research question clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the selection of study subjects/patients free from bias?	Unclear	Unclear	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes	Unclear	Yes
3. Were study groups comparable?	NA[c]	Yes	Yes	No	NA	Yes	Unclear	Unclear	Unclear	NA	Yes
6. Were intervention procedures and any comparison(s) described in detail?	Unclear	Unclear	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	NA	Yes
7. Were outcomes clearly defined and measurements valid and reliable?	Yes	No	Yes	Yes	No	Yes	Unclear	Unclear	Yes	Unclear	Yes
4. Was method of handling withdrawals described?	No	Unclear	Yes	Unclear	NA	Yes	Unclear	Unclear	Yes	N/A	Yes
5. Was blinding used to prevent bias?	Unclear	No	Unclear	Unclear	NA	No	No	No	Unclear	N/A	Yes
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Unclear	Yes	Yes

(*continued on next page*)

Table 4. Quality assessment[a] of social media–based studies (n=11) using the Quality Criteria Checklists for Primary Research developed by the Academy of Nutrition and Dietetics[33] (*continued*)

	Author(s), Year										
Validity questions	**Cavallo and colleagues, 2016[48]**	**Dagan and colleagues, 2015[49]**	**Gow and colleagues, 2010[40]**	**Greene and colleagues, 2012[41]**	**Harvey-Berino and colleagues, 2012[42]**	**Hebden and colleagues, 2014[43]**	**Mackert and colleagues, 2012[50]**	**Merchant and colleagues, 2014[44]**	**Napolitano and colleagues, 2013[45]**	**NSW[b] Food Authority, 2013[46]**	**Partridge and McGeechan, 2015[47]**
9. Were conclusions supported by results with biases and limitations taken into consideration?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
10. Is bias due to study's funding or sponsorship unlikely?	Unclear	Unclear	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes	Unclear	Yes
Negative/Neutral/Positive (N/0/P)	0	0	P	0	0	P	0	0	0	0	P

[a]Rating criteria: if most (six or more) of the answers to the validity questions are "no," the report should be designated negative. If answers to validity criteria questions 2, 3, 6, and 7 do not indicate that the study is exceptionally strong, the report should be designated neutral. If most answers to the above validity questions are "yes" (including criteria 2, 3, 6, 7 and at least one additional "yes"), the report should be designated positive.
[b]NSW=New South Wales.
[c]NA=not available.

Table 5. Quality assessment[a] of game-based studies (n=6) using the Quality Criteria Checklists for Primary Research developed by the Academy of Nutrition and Dietetics[33]

	Author(s), Year					
Validity questions	**Lee and colleagues, 2010[34]**	**Miller and Lindberg, 2007[35]**	**Miskovsky, 2012[36]**	**Orji and colleagues, 2012[39]**	**Peng, 2009[37]**	**Sullivan and colleagues, 2013[38]**
1. Was the research question clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes
2. Was the selection of study subjects/ patients free from bias?	Unclear	No	No	No	No	Yes
3. Were study groups comparable?	No	No	No	NA[b]	No	Unclear
6. Were intervention procedures and any comparison(s) described in detail?	No	Yes	No	Yes	No	Yes
7. Were outcomes clearly defined and the measurements valid and reliable?	Yes	Yes	Unclear	No	Unclear	Yes
4. Was method of handling withdrawals described?	Unclear	Unclear	No	No	Yes	NA
5. Was blinding used to prevent introduction of bias?	Unclear	Unclear	No	NA	NA	Unclear
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?	Yes	Yes	No	No	Yes	Yes
9. Were conclusions supported by results with biases and limitations taken into consideration?	Yes	Yes	Unclear	No	Yes	Yes
10. Is bias due to study's funding or sponsorship unlikely?	Unclear	Unclear	Unclear	Yes	Yes	Unclear
Negative/neutral/positive (N/0/P)	0	0	N	0	0	0

[a]Rating criteria: If most (six or more) of the answers to the above validity questions are "no," the report should be designated negative. If answers to validity criteria questions 2, 3, 6, and 7 do not indicate that the study is exceptionally strong, the report should be designated neutral. If most answers to the above validity questions are "yes" (including criteria 2, 3, 6, 7, and at least one additional "yes"), the report should be designated positive.
[b]NA=not available.

Chapter 6: The development of a social-media and gamified smartphone intervention to promote vegetable intake in young adults

6.1 Introduction to chapter

This chapter describes the theoretical framework "COM-B" which informed the development of a program using social media and smartphone apps (with and without gaming elements) to promote vegetable intake in young adults. The COM-B system is at the centre of the Behaviour Change Wheel framework which encapsulates 19 theories of behaviour change shown to be effective for supporting changes in lifestyle habits. Previous vegetable interventions have been primarily based on Social Cognitive Theory, Transtheoretical Model and Theory of Planned Behaviour. The COM-B model is relatively new and has not been tested in many nutrition interventions. As such we have chosen to apply this comprehensive model to test its effectiveness in improving vegetable intake. An overview of the behavioural determinants, the relevant behaviour change techniques that shaped the intervention functions and features along with evidence supporting their use are presented in this chapter.

6.2 Introduction

The research presented in this thesis thus far has established that young adults are the poorest consumers of vegetables among the Australian adult population. Researchers have intervened in an attempt to improve vegetable consumption; however the majority of interventions have been delivered in the United States within tertiary education settings using face-to-face contact or online learning modules, limiting their applicability to the broader young adult population (1). Furthermore, very few interventions have been delivered using modern communication technologies such as mobile applications and social media as delivery platforms (2). To effectively engage young adults, researchers need to design interventions using appealing and motivating strategies based on behavioural theory and choose delivery modes that will engross young adults in carrying out the behaviour. Smartphones may serve as an effective, age-appropriate platform for dissemination of such an intervention.

Smartphones are currently the most widely owned, indispensable devices across developed countries, with penetration exceeding 85% within the Australian population (3). Young adults are leading this market, with 95% of 18-34 year olds in Australia owning a smartphone in 2016 (4). Alongside the rapid rise in smartphone ownership has been a growth in the number of software applications (“apps”) programmed for use on these portable mobile devices (3). Searching for health information is one of the most frequently reported uses of smartphones, with 77% of young adults consulting their smartphone for health facts (5). Approximately 24% of young adults are also downloading commercial apps from the health/fitness category to track behaviours such as physical activity, weight loss or diet (calorie counting) (6).

Furthermore, 91% of smartphone owners use their device for entertainment and game playing (7).

With the digital-era evolving rapidly, new strategies to increase engagement are continuously emerging. Of increasing popularity is the use of social media, a group of online applications driven by the sharing of user-generated content. These social media platforms are commonly accessed through smartphones. In 2018, young adults were reported to be the most frequent users of multiple social media platforms (8). Despite the popularity of these platforms, my research thus far has indicated that use of social media to improve nutrition behaviours in young adults specifically is limited (2). Preliminary reports are encouraging (9, 10), but challenges lie in maintaining participation and minimising attrition (11). Continued research is required to assess whether engagement can be enhanced when social media is combined with other novel strategies.

One such strategy is gamification. Gamification involves the application of game concepts in a non-game context to motivate participants, with the aim of educating or promoting behaviour change (12). This differs slightly from serious gaming that is usually regulated by a framework, or rules, which dictate the players experience within the game world, usually with the objective of teaching a certain behaviour (13). Both serious gaming and gamification can educate in a fun and engaging way, provide the opportunity to practice a healthy lifestyle skill to increase self-efficacy (14) or integrate behaviour change strategies such as goal and reward setting (15, 16). Interventions which employ gamification may use game elements such as challenges, level progression, rewards and leader boards to enhance user engagement and reinforce desired behaviours.

A meta-analysis of gamified interventions found that serious games have small but positive effects on health behaviours, particularly knowledge (17). Researchers have applied gamification techniques within interventions with adults and children (16, 17). The mean age of players of digital games is 30 and approximately 63% are under the age of 36 (18). However, the use of gaming for nutrition promotion with young adults is limited. The available evidence indicates that these interventions are typically delivered as serious games in the form of a video or computerized game (2, 19-22). An opportunity exists to study the effect of incorporating gaming techniques within modern dietary intervention platforms such as smartphone applications. A recent study compared a gamified self-monitoring app against a waitlist control and found that participants who received the app treatment had greater improvements in vegetable intake (23). These adults were recruited as part of a larger weight loss trial where face-to-face counselling and other strategies for behaviour change were applied. Thus the implications of the app specifically on vegetable intake could not be readily discerned. Nonetheless, using gaming strategies has been established as means to increase reach and adoption of computer-tailored interventions targeted at young adults (24). The portable nature of gamified apps makes them convenient, further increasing opportunity for engagement.

The effectiveness of interventions delivered using modern information and communication technology is dependent on the incorporation of techniques to support behavior change (25). Most researchers employ some behavior change techniques (2, 26), with self-monitoring combined with feedback most frequently acknowledged as an essential strategy for behavior change (27, 28).

To establish the efficacy of behaviour change techniques applied in any nutrition intervention, it is first essential to describe the theoretical framework and then select the behaviour change techniques for the intervention. This chapter aims to provide a detailed record of the process undertaken to select the target behaviours, allocate the appropriate behaviour change techniques and determine the modes of delivery using the COM-B model.

6.3 Methods and Discussion

Intervention development process

The development of this program comprised three stages; (1) selecting the target behaviours and specifying what needed to change (2) deciding on intervention functions and features and relevant behaviour change techniques, and (3) testing the acceptability and feasibility of the proposed program components with a sample of the target audience and refining appropriately.

Theoretical Framework

The program presented in this thesis is based on The Behaviour Change Wheel by Professor Susan Michie and Colleagues. The intervention integrates key behaviour change techniques selected to address the components of behaviour change as outlined in the COM-B model (Capability, Opportunity and Motivation) (29)**.** The COM-B model is the core of The Behaviour Change Wheel which was developed through expert consensus and a validation process (29). COM-B is underpinned by The Theoretical Domains Framework (TDF) which includes 14 factors based on 19 theories of behaviour change that are related to one of the three categories which predict performance of a behaviour (Capability, Opportunity and

Motivation) (30). These categories are broken down further into more specific behavioural determinants. For example, capability comprises both being physically able to perform the behaviour (i.e. skills) and being psychologically equipped with the necessary knowledge. With regards to opportunity, this is broken down into physical opportunity such as triggers within the environment and social opportunity such as cultural norms. Finally, motivation comprises both automatic motivation such as habitual responses and reflective motivation which includes self-evaluation of progress with the target behaviour.

There is a second layer within the Behaviour Change Wheel which details the processes by which an intervention might change behaviour. These processes are categorised under nine "intervention functions", namely; Education, Persuasion, Incentivisation, Coercion, Training, Enablement, Modeling, Environmental Restructuring and Restrictions. The intervention functions have been associated with a taxonomy of 93 behaviour change techniques (31) which drive the behaviour change. Definitions of the intervention functions are provided in Appendix 6.1. The outer layer of the wheel details the seven policy categories that may be drawn upon beyond the intervention setting to support environmental restructuring related to the behaviour. This chapter details the development of an intervention for improving the vegetable intake of young adults underpinned by the COM-B model and the relevant intervention functions as described in the Behaviour Change Wheel.

Stage 1: Selecting the target behaviors and specifying what needs to change

This program aims to support improvements in vegetable consumption in young adults. Prior research has revealed that young adults lack skills for cooking meals containing vegetables (physical capability) (32, 33). Additionally, their ability to plan for meals containing vegetables and knowledge of daily recommendations and serving sizes is poor (psychological capability) (33, 34). Thus, this program will provide tools and resources to improve these specified skills and knowledge. Young adults are also faced with unique challenges related to social influences, independence in food selection within a food environment saturated with processed foods and psychological factors such as increased stress due to transition to work. These factors may all impact their motivation to select healthy foods. As such it is essential that the program included elements that address motivation.

Stage 2: Deciding on intervention functions and features and relevant behaviour change techniques

A review on the mediators of successful interventions indicated the importance of a systematic approach to selecting behaviour change techniques (35). Abraham and Michie's Taxonomy of Behaviour Change Techniques was consulted to systematically match the proposed intervention features with relevant behaviour change techniques (36).

Research has shown that goal setting, self-monitoring and the provision of feedback are successful strategies for supporting young adults to maintain motivation and improving self-efficacy for practicing healthful lifestyle behaviours(37-39). Thus, as the core of this program, a goal setting and self-monitoring app with feedback on vegetable intake was developed. The purpose of this app is to increase the opportunity for self-evaluation. A second version of the app was developed and incorporated rewards as incentivisation.

Social support has also been recognised as an effective motivator for behaviour change as it provides empowerment and positive peer pressure (40). Therefore providing social support was proposed as another main feature of the intervention. Given the established lack of understanding of daily recommendations and serving sizes among young adults and their low level of skills related to planning and preparing to include vegetables in their diet, building knowledge and skills were also selected as key intervention functions. Table 6.1 provides a summary of the intervention functions and suggested strategies to achieve behaviour change. A description of the main intervention features and evidence to support their use are detailed below:

Feature 1: Building knowledge (Education)

Poor knowledge of vegetable serving sizes is a barrier to adequate consumption (41), with lack of clarity or over-estimation of what constitutes a serve contributing to complacency about the need to increase intake (42). Other research has shown that correct recognition of serving sizes is correlated with actual intake and meeting daily vegetable recommendations (43, 44). Thus improving consumer knowledge may have implications for intake by allowing for more accurate self-assessment and tracking, in turn motivating and enhancing frequency of consumption. In order to achieve this, an infographic was proposed to educate participants on vegetable serving sizes and recommended intakes (see Figure 6.1).

An additional feature proposed for inclusion was a mobile app based quiz to provide an opportunity to further enhance knowledge (Figure 6.2). Badges or points were proposed as rewards for selecting the correct answers to multiple choice questions on vegetable names, categories and serving sizes.

Feature 2: Goal setting, self-monitoring and rewards (Enablement and Incentivisation)

Defined goals and tracking intake can support behaviour change and facilitate self-awareness (32, 45). This is especially important for young adults who struggle with self-regulation and planning (33, 46). While self-monitoring dietary behaviours can be burdensome, research indicates greater adherence to use of smartphone self-monitoring apps than traditional paper-based methods (47). These technologies also allow the provision of feedback in real time which is beneficial for progression toward the behaviour of interest (27, 48, 49).

Given the success of goal setting and personalised feedback for improving fruit and vegetable intake in young adults (1), a smartphone app “VeggieTracker” was developed by dietitians and experts in computer human interaction for goal setting, self-monitoring and the provision of feedback. In keeping with control theory, previous research has indicated that people value having a comparator to work towards based on a credible source (50, 51). Thus, users are provided with a benchmark (5 and 6 serves of vegetables per day for women and men respectively) based on the recommended daily intake in order to improve their understanding of the final target and self-assess progress (52). The app provides instruction on setting a realistic goal based on usual intake. Feedback as weekly and monthly progress is available in a separate screen.

To determine if incentivisation using rewards and gamification offer additional motivation a second version of the app was developed with gaming components. Figure 6.3a shows the standard self-monitoring app prototype which featured only the goal setting and tracking components. Figure 6.3b shows the app prototype that used gaming elements, such as challenges and points and badges as rewards for goal attainment. Rewards are recognized as effective in enhancing self-regulation as they reinforce the desired behaviour (53, 54). The challenges were designed to be tailored to the user's intake and were provided on a weekly basis. For example, if a user reports only consuming vegetables at dinner, they will be prompted with a "meal time challenge", encouraging vegetables to be included in other meals such as breakfast, lunch or snacks. This particular challenge was based on my previous research (Chapter 2) demonstrating that consumption of vegetables across all meal occasions is associated with meeting vegetable recommendations (55).

Feature 3: Building skills and motivation for cooking (Training, Modelling)

Role modelling (demonstrating the desired behaviour) can be used to encourage performance of a health-related behaviour (56, 57). Thus, the third main feature of the intervention uses cooking demonstrations to address the low level of self-efficacy for food preparation (58), and lack of knowledge on how to prepare vegetables among young adults (32). The demonstrations are delivered through short videos narrated by a young adult and demonstrate basic cooking skills such as chopping and steaming. Money saving tips and ideas on how to substitute ingredients and modify recipes to include vegetables are also included in the videos. Improving nutritional and culinary knowledge has been identified as an important predictor of vegetable consumption (59). The cooking demonstrations were optimised for smartphone delivery so they could be shared on the Facebook intervention page which is described in more detail below.

Feature 4: Providing social support (Persuasion)

Based on the Social Cognitive Theory (60), the provision of social support has been associated with improvements in nutrition outcomes in previous research (61, 62). Thus, the fourth main feature of the program uses a Facebook page to provide social support. The Facebook posts aim to enable and motivate young adults to consume more vegetables by persuading them that meal planning and cooking with vegetables is achievable and affordable. Skill mastery (providing the opportunity to practice and become competent in the behaviour) has been shown to encourage performance of health-related behaviours (56). So, posts that provide challenges encouraging participants to cook and upload a photograph of the final product to the Facebook page were proposed. Previous research has indicated that social encouragement and positive reinforcement for achievements (such as preparing a meal from scratch), can aid in behaviour change, especially in high stress or busy periods which are frequently encountered by young adults (63, 64). Other materials designed for delivery through the Facebook page included tips on purchasing vegetables in season to reduce costs, meal inspiration images and posts on the health benefits of vegetables. Credible sources such as the Australian Dietary Guidelines and Guide To Healthy Eating informed by extensive literature review (52, 65) were used by the candidate (an accredited practicing dietitian) to develop the material, ensuring quality of the information.

Stage 3: Testing the proposed program with a sample of the target audience.

The aforementioned program materials and smartphone app prototypes were tested for acceptability and relevance in focus groups with a sample of the target audience. A detailed explanation of the views and preferences of the young adults are summarised in Chapters 7 and 8 which follow.

Table 6.1: Application of COM-B Intervention functions within the vegetable intervention

Intervention function	Application within the intervention
Education	- Increasing knowledge of recommended daily vegetable intake and standard serving sizes using electronic resources. - Additional in-app quiz (gamified versions only).
Persuasion	- Providing social media posts that address the barriers to vegetable intake by providing tips on how to integrate vegetables into meals easily, quickly and at a low cost to create positive feelings about including vegetables in diet (re-framing beliefs)(social media only).
Incentivisation	- Providing badges or points as rewards for completing challenges and reaching goals (gamified versions only). - Using competitions to encourage participants to practice cooking dishes with vegetables (social media only).
Training	- Cooking videos as demonstration of skills for preparing meals with vegetables (social media only).
Environmental restructuring	- Facebook posts that encourage changing the physical context by placing healthy triggers in environment to encourage vegetable intake e.g. Place chopped vegetables on top shelf of fridge to prompt snacking (social media only).
Modeling	- Providing cooking videos narrated by a young adult to provide participants with a model to aspire to or imitate (social media only).
Enablement	- Self-monitoring progress against a goal and provision of feedback to build self-efficacy for vegetable intake (all versions) - Providing weekly challenges to increase the target behaviour by providing opportunities to increase vegetable intake (gamified versions only).

Figure 6.1: Proposed infographic (for delivery via email) to educate young adults on serving sizes and recommended intakes

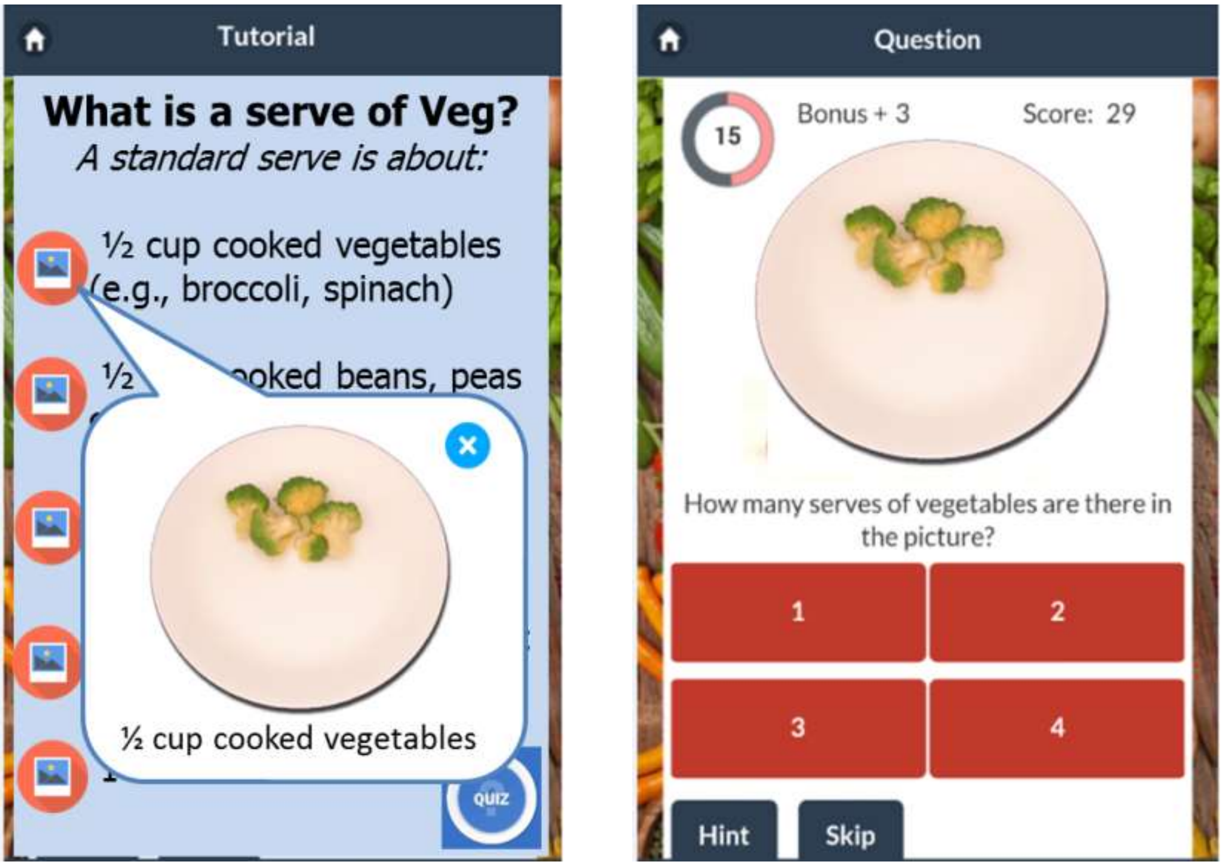

Figure 6.2: Wireframes of in app quiz for improving knowledge regarding vegetable serve

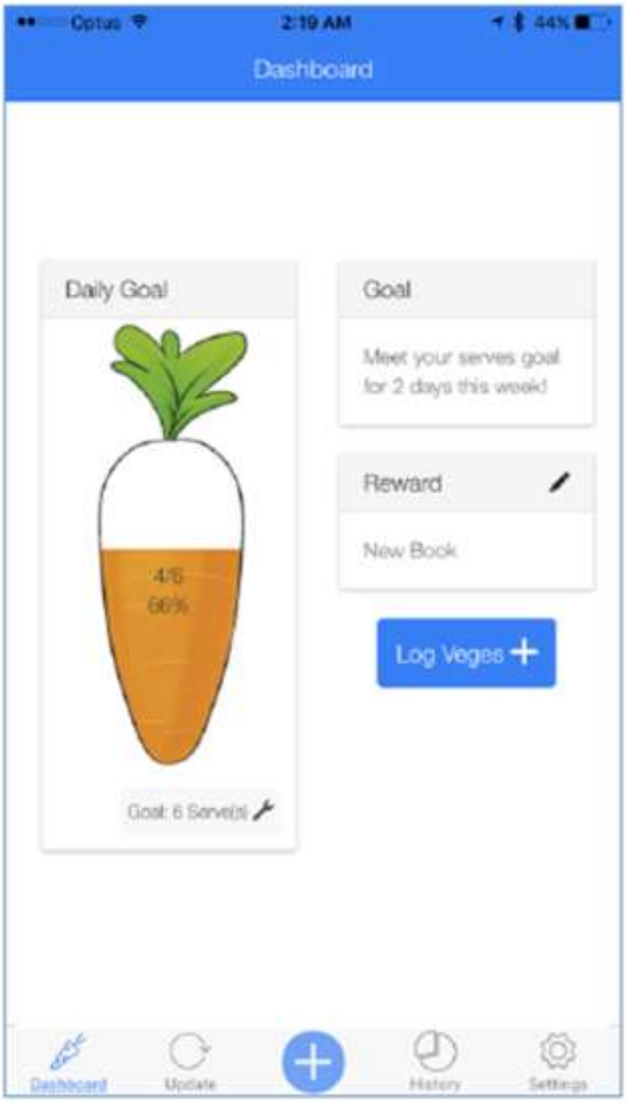

Figure 6.3a: Standard version of app

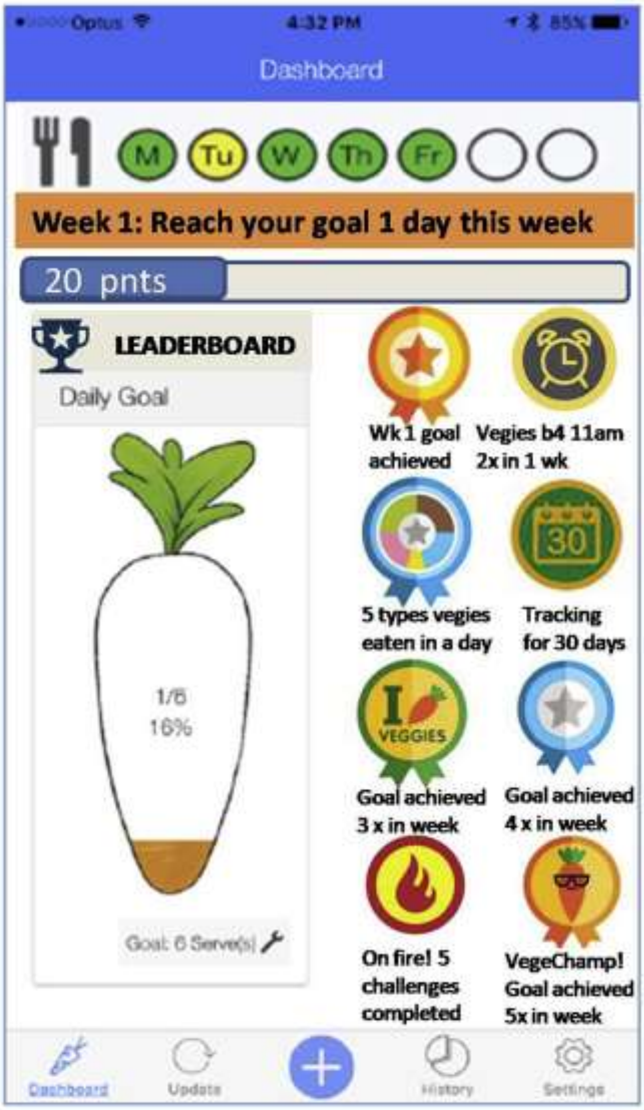

Figure 6.3b: Gamified version of app

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6.5 Conclusion to Chapter

This chapter described the process of applying the Behaviour Change Wheel as a theoretical framework for the development of a theory-based program to improve the vegetable intake of young adults. The key determinants of vegetable intake, namely physical and psychological capability, opportunity and motivation have been described and strategies to address the barriers and enablers to change outlined. In keeping with best practice, the material developed will be tested in focus groups with a representative sample of the target population to refine material design before inclusion in an intervention. This process is described in the chapter that follows.

Appendix 6

Appendix 6.1

Definitions of intervention functions (Table reproduced from; *The behaviour change wheel: A new method for characterising and designing behaviour change interventions, Michie et al, 2011)*

Intervention function	**Definition**
Education	Increasing knowledge or understanding
Persuasion	Using communication to induce positive or negative feelings or stimulate action
Incentivisation	Creating expectation of reward
Coercion	Creating expectation of punishment or cost
Training	Imparting skills
Restriction	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours)
Environmental restructuring	Changing the physical or social context
Modelling	Providing an example for people to aspire to or imitate
Enablement	Increasing means/reducing barriers to increase capability or opportunity[1]

[1]Capability beyond education and training; opportunity beyond environmental restructuring

Chapter 7: Exploring young adult perspectives on the use of gamification and social media in a smartphone platform for improving vegetable intake

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7.1 Publication details

This chapter presents the manuscript titled ‘Exploring young adult perspectives on the use of gamification and social media in a smartphone platform for improving vegetable intake’ published in *Appetite* 2018, Volume 120, pages 547-556, doi: 10.1016/j.appet.2017.10.016 (see *Appendix 7*). It has been reformatted but contains exactly the same text.

7.2 Author contribution

I Monica Marina Nour (the candidate) was the primary researcher involved in developing the research questions, the intervention material and producing the final manuscript for publication. The secondary author Ms Rouf assisted with conducting the focus groups through audio tapping and note taking. Senior author Allman-Farinelli supervised the project and edited the draft manuscript for publication.

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7.3 Introduction to chapter

This chapter provides details of research conducted using focus groups to explore the acceptability of the proposed researcher developed theory-based strategies and program materials detailed in the previous chapter. This formative research was conducted using the nominal group technique which is a coordinated variation of a focus group where participants partake in structured activities such as ranking pictures, statements or sample intervention materials according to personal preferences. The findings from this chapter were used to refine the program components and ensure the selected features are tailored to the needs of the target population.

7.4 Abstract

Young adults are the poorest consumers of vegetables. Social media and smartphones are frequently used by this demographic and could serve as an engaging medium for nutrition promotion. Five focus groups were conducted to capture participants' perceptions of a theory-based gamified self-monitoring app for improving vegetable intake of young adults. Ranking activities were used to gather feedback on preferences for social media posts. Data arising from group discussion were analysed using NVivo software using a deductive approach to group common ideas into themes. Thirty two participants (14 males) attended (mean age 23.1 (SD 2.7) years). Qualitative analyses of open discussion revealed two major themes regarding preferred features for a smartphone app; (1) the use of visual guides for estimating quantities of vegetables and tracking progress, and (2) a simple interface. Gamification strategies such as earning badges were viewed more positively than the use of a self-reward framework. Social media posts which presented food pictures and recipes were ranked most motivating, while awareness-raising posts received lower scores. Participants indicated a preference for viewing but reluctance to post information onto social media. “Just in time” situational cues were ranked highly and the use of an “authoritative” tone was preferred and associated with credibility. Young adults also ranked messages containing “Gen Y” language highly, with a preference for those which were personally relevant. The proposed use of social media and mobile-gaming was seen as an acceptable approach for delivery of a program to improve vegetable intake. Materials should be visually appealing, simply designed, credible, and personally relevant to appeal to this population. This feedback may inform future mobile-phone based interventions targeting improved nutrition in young adults.

7.5 Introduction

Young adults aged 18–34 years are the poorest consumers of vegetables among Australian adults (Australian Health Survey, 2013). Increasing vegetable intake can reduce chronic disease risk (Oyebode, Gordon-Dseagu, Walker, & Mindell, 2014) and improve indicators of psychological well-being such as life-satisfaction and happiness (Mujcic, 2016; Nguyen, Ding, & Mihrshahi, 2017). However, the lower likelihood of chronic disease during this life stage, and competing priorities may reduce the motivation of young adults to engage in longer-term behaviour change (Bibbins-Domingo & Burroughs Peña, 2010).

Research highlights that young adults lack self-efficacy for practicing healthful dietary behaviours (Strong, Parks, Anderson, Winett, & Davy, 2008). Specific barriers to consuming vegetables include low levels of cooking literacy, the perceived cost of vegetables, the time/effort required to prepare them and their undesirable flavour (Brug, Debie, van Assema, & Weijts, 1995; Hartman, Wadsworth, Penny, van Assema, & Page, 2013; Soliah, Walter, & Antosh, 2006). A meta-regression of 122 studies showed that self-monitoring is one of the best predictors of change in eating habits (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). The process of monitoring can provide reflective insights on one's current behaviour, facilitating self-awareness, enhancing motivation for change (Li et al., 2011; Rapp & Tirassa, 2017) and increasing ability to achieve dietary goals (West et al., 2017). There is growing evidence to suggest that this process supports behaviour change (Kersten-van Dijk, Westerink, Beute, & IJsselsteijn, 2017; Lieffers & Hanning, 2012; West et al., 2017) and can also be useful in the maintenance phase for assessing divergence from the goal (Li et al., 2011). This may be particularly relevant to young adults who usually struggle with self-regulation (Strong et al., 2008). With 95% of 18–34 year olds owning a smartphone in 2016 (Poushter), mobile applications (apps) may be a suitable platform through which young adults can easily self-monitor their diet (McGloin & Eslami, 2015).

Social media and mobile-gaming may also serve as an engaging way to deliver nutrition interventions to young adults, with 91% of 18–29 year olds interacting on social networks and a further 91% of smartphone owners using their devices for gaming (Our Mobile Planet, 2013; Smith). Gamification, defined as the incorporation of game elements in a non-gaming context to evoke motivation (Cugelman, 2013), has been harnessed by researchers for the delivery of nutrition interventions (Nour, Yeung, Partridge, & Allman-Farinelli, 2017). Information sharing in online networks has also been proposed as a means to further promote positive health behaviours (Heaney & Israel, 2008, pp. 189–210). While evidence for use of these technologies is still emerging, some positive effects have been reported among young adults (Nour et al., 2017) and the general public (Hamari et al., 2014). A study by Orji, Vassileva, and Mandryk (2013) used a socially connected virtual reality mobile game app to effectively improve the knowledge and attitudes of young adults regarding selection of healthy options when eating out (Orji et al., 2013). Another study harnessed Facebook as a platform for the delivery of a group-based weight loss program, with improvements in fruit and vegetable intake observed post intervention (Cavallo et al., 2016).

Despite these positive outcomes, there is limited use of robust experimental designs (Seaborn & Fels, 2015) and many studies report low user engagement or drop-off in usage over time (Kelders, Kok, Ossebaard, & Van Gemert-Pijnen, 2012; Nour et al., 2017). Use of techniques for maintaining participant engagement is often neglected in intervention planning (Short, Rebar, Plotnikoff, & Vandelanotte, 2015) and future work should consider engagement in the design process to combat this.

Supported by the Elaboration Likelihood Model (Petty, Barden, & Wheeler, 2002), researchers in the field of engagement have highlighted the importance of persuasive design (Kelders et al., 2012; Short et al., 2015); whereby an individual is more likely to engage with and process intervention material when it is personally relevant. Focus groups provide valuable insights into the needs and expectations of users (Thompson, 2014). However, participant responses may sometimes result in incongruence between researcher learning objectives based on theory and the design elements participants suggest (Vasalou et al., 2012). For example, users may suggest a certain feature for inclusion in a smartphone intervention that is unlikely to support the intended change in behaviour. Contrastingly, involving the target population as “informants” who provide feedback on the relevance and motivational capacity of intervention strategies developed by professionals has been shown to enhance the effectiveness of digital interventions (DeSmet et al., 2016).

Our primary aim was to test the feasibility and acceptability of a theory-based smartphone intervention for young adults that combines social media, self-monitoring and mobile-gaming to address the most salient psycho-social and environmental determinants of vegetable intake reported in the literature including taste, cost, availability, knowledge and self-efficacy (Hartman et al., 2013). This formative research will inform the framing of the smartphone intervention by gathering prioritised, objective, and quantified feedback from the target group on the proposed content (behaviour change messages and social media posts). Perceptions of the planned approach which uses social media and a mobile-application will also be captured.

7.6 Methods

Development of intervention materials

The COM-B framework (Michie, van Stralen, & West, 2011) and Taxonomy of behaviour change techniques (Abraham & Michie, 2008) were used to translate the determinants of vegetable intake into context-specific behaviour change strategies for use in an intervention to improve vegetable consumption of young adults. The COM-B framework is a psychological model which supports the process of changing human behaviour by addressing the “prerequisites” for a given behaviour. This involves ensuring the individual is capable of physically performing the behaviour (i.e. they have the necessary skills) and is psychologically equipped with the necessary knowledge. The model also addresses the opportunity an individual has to engage in the behaviour, including physical opportunity such as triggers within the environment and social opportunity such as addressing cultural norms. Finally, instilling motivation by targeting reflective motivation such as one's beliefs and automatic motivation such as reflex and habitual responses is important (Michie et al., 2011).

We developed the prototype for a smartphone application (app) for monitoring vegetable intake. Research on self-regulation of health behaviours has indicated that goal setting is an important component of habit formation (Mann, De Ridder, & Fujita, 2013). Thus, on initial log in to the app, users are prompted to set a goal for daily vegetable serves. To cater to the experience level of non-expert trackers, simple visual representations of progress were used to minimise cognitive load and ensure easy interpretation of personal data (Rapp & Cena, 2016). As shown in the wire frames utilised for acceptability testing (Figure 7.1a–d), progress toward the personal goal can be reviewed through the carrot gauge which fills up as intake is entered (Figure 7.1a and b). A traffic light system is used to provide an overview of weekly achievements, where green indicates goal attainment and amber represents progress towards the intake goal (Figure 7.1a). Intake is tracked according to type of vegetable and the meal in which it is consumed (Figure 7.1c). Self-monitoring may be short-lived (Rapp, 2015), and users may struggle with maintaining personal data records as they forget to track or purposely skip entries (Rapp, 2017). For this reason, we proposed the use of gaming rewards such as points and badges to maintain engagement. In this virtual reward prototype (Figure 7.1a), achieving ones goal allows for the accumulation of points, rewarded with 'in app' badges. Experts in the field have questioned the effectiveness of these gamified rewards (Rapp, 2015), and highlighted the importance of using meaningful rewards that reflect user's needs and desires (Rapp, 2017). As such we also designed a self-elected reward prototype for testing (Figure 7.1b) in which users elect their own rewards to self-administer after completing each challenge level (e.g. level 1: meet your goal 2 times this week and reward with a new book). The reward app prototypes were compared against a standard app which only featured the goal setting and self-monitoring components

Additional components that could be integrated were also tested. This included a series of push notifications for delivery through the mobile app. Messages were one to two sentences long and addressed barriers such as taste, included tips on how to substitute vegetables into the diet, and provided motivational messages describing the health benefits of vegetables. Some messages used short hand writing known as "text talk", replacing words with characters to reduce length for delivery to the notifications screen. To test the acceptability of this style of writing we developed messages in both short hand and standard language. For example, *"RU adding Veg 2 ur diet? Make the change - replace those chips with Veggie* *sticks"* (short hand); *"Worried about the taste of vegetables? Up the flavour! Add some herbs and spices"* (standard).

Advertisements often manipulate the tone of voice in messages to influence engagement with brands, products or services (Delin, 2005). Previous research with high income university educated young adults suggested "substitution" and "empathetic" messages were most likely to persuade improvements in fruit and vegetable intake (Pollard et al., 2016). To explore this further using a more diverse sample of young adults, we designed messages based on the following five voice tones; empathetic, authoritative, solution-based, substitution-based, and generation Y ("Gen Y"), and asked participants to rank them according to how much they motivated vegetable consumption.

To determine the acceptability of social media in the intervention, a series of "mock" Facebook™ posts were developed and tested for engagement and motivation. These included competitions, money saving tips, links to additional resources and educational posts on serving sizes, recommended daily intake and health benefits of vegetables (See Figure 7.2 for examples).

Participants

A total of 32 young adults (14 male) attended 5 focus groups. Groups consisted of 4–12 participants recruited from the greater Sydney area, Australia. The mean age was 23.1 (SD 2.7) years. Participants came from a range of sociodemographic backgrounds as determined by the Socio-economic index for areas (SEIFA) (Table 7.1). Participants were recruited through flyers placed around university (college) and vocational college campuses, and advertisements on relevant community social media pages. Those who did not own a smartphone or who had a background in nutrition were excluded. Potential participants were scheduled into a focus group in their local area and offered a AUD $20 gift voucher for attendance.

Figure 7.1. a–d: Example prototypes of self-monitoring app with options for gaming strategies presented to focus group participants. Fig. 1a includes a point system, leader boards, badges and challenges (external reward system) and Fig1b uses self-elected rewards for progression through levels (intrinsic reward system). Fig. 1c and d shows the process of entering vegetable intake.

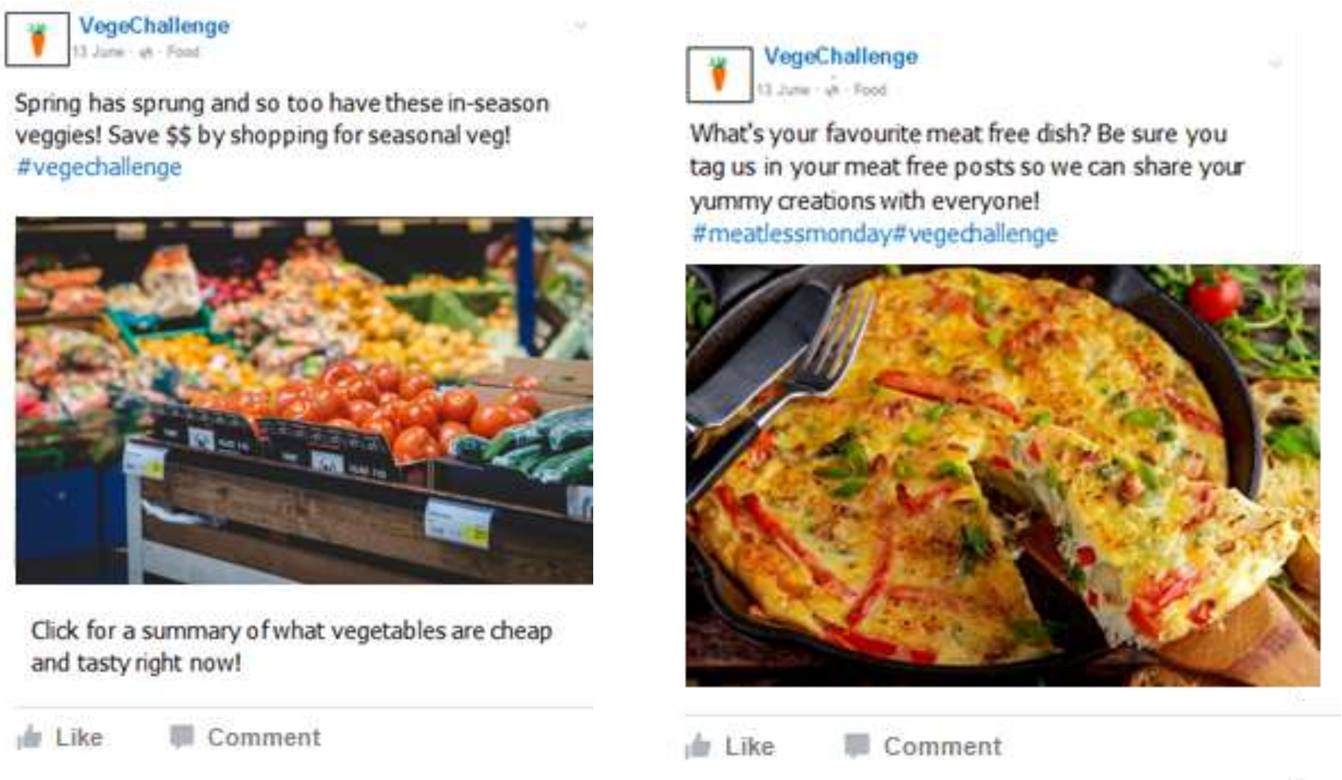

Figure 7.2. Mock Facebook posts presented to focus group participants for ranking.

Table 7.1. Characteristics of focus group participants n = 32.

Characteristics	**N**
Gender	
Male	14
Age, years	
18-24	22
25-30	10
SEIFA category	
1 (Lowest)	4
2	12
3	5
4	3
5 (Highest)	8
Occupation	
Student	18
Health worker	6
White collar	4
Blue collar	4

Study design

Materials and methods of the focus groups were approved by the Institutional Human Research Ethics Committee (approval number 2016/705). Consecutive sampling was used, whereby all eligible participants were included in the study sample until data saturation was achieved. Data saturation was determined when no new ideas were generated in the focus group session.

The methods proposed by Kruger and Casey (Krueger & Casey, 2014) and the consolidated criteria for reporting qualitative research (COREQ) 32 item checklist (Tong, Sainsbury, & Craig, 2007) were consulted for study design and reporting of findings. A mixed methods approach was utilised to gather both quantitative and qualitative data.

We applied a user-centred design philosophy in which the target audience (young adults) are directly involved in the design process by providing their preferences for and opinions on the relevance of the aforementioned theory-based pilot intervention materials. We used a deductive method of study whereby a pre-determined approach is tested for its acceptability (Harris, 2009). This method was selected to confirm if the proposed strategies for supporting improvements in vegetable intake are motivating and appropriately pitched to the target audience.

The nominal group technique (NGT) is a coordinated variation of the focus group technique where participants engage in structured activities such as ranking pictures, statements, or sample intervention materials. This was used to gather inductive input (Gallagher, Hares, Spencer, Bradshaw, & Webb, 1993; Harris, 2009) followed by discussion to achieve consensus on a given idea or research question (Castiglioni, Shewchuk, Willett, Heudebert, & Centor, 2008; Gallagher et al., 1993). The structured format of the NGT limits process loss and inefficiencies of open discussion or uncoordinated interactive group settings (Delbecq, Van de Ven, & Gustafson, 1975; Gallagher et al., 1993; Miller, Shewchuk, Elliot, & Richards, 2000).

Procedures

The 90 min focus groups were led by a female facilitator (MMN, Dietitian and PhD researcher). A moderator (AR, Dietitian and PhD researcher) took notes during open discussion and assisted with time-keeping and audio-taping. Upon arrival, participants were briefed with the focus group objectives. They were informed of the inadequate intake of vegetables in young Australians and the researchers' interests in using mobile technologies to support improved nutrition. Quantitative and qualitative data were collected in two phases.

Quantitative component

Once signed consent was obtained participants completed a demographic questionnaire (see Appendix 6.1) capturing age, gender, postcode (for categorising SEIFA), occupation, and use of health and gaming apps. Knowledge of vegetable serving sizes and recommendations were also measured through multiple choice questions (NSW Population Health Survey, 2014). Finally, participants were asked to identify and rank barriers to consuming vegetables and estimate their usual daily intake using validated images of serving sizes (Islam et al., 2013).

Next, participants were presented with a series of push notification messages and mock Facebook™ posts to rank according to how much they would motivate their consumption of vegetables. Preferences regarding frequency and timing of the notifications/posts were collected through a two-item question.

Qualitative component

To gather user feedback on the app prototype, a series of electronically drawn app screens known as wire frames (Figure 7.1a–d) were presented using PowerPoint. The facilitator provided verbal navigation through the app and the potential gaming strategies. Participants were invited to provide their opinions; including which gaming strategies would encourage engagement with the app. Open discussion was also used to test the acceptability of short hand writing known as "text talk" used in example messages. Pre-determined prompts were used to encourage discussion (see Table 7.2 for examples).

Table 7.2. Prompts to encourage discussion on the acceptability and feasibility of the mobile app.

Prompts used in focus group
What do you think of this design?
What aspects of the design need improvement?
Are there aspects you like or dislike?
Which aspects seem more motivating, selecting self-rewards or a virtual reward design?
Are there certain aspects of the virtual rewards that you like or dislike?
Which parts of the app design would be most motivating/useful to you?
Would you be motivated to play an educational game? If not, can you suggest other ways you would prefer to learn about vegetables?
Are there any other strategies that would motivate you to eat more vegetables that we haven't mentioned in these examples?
Suppose that you were in charge of developing this platform and could make one change that would make the program better. What would you do?

Finally, the NGT was used to gather opinions on the enablers to vegetable consumption. Feedback was collected using the following method: 1) 5 min of silent brainstorming during which each individual documented responses to the research question *"Eating healthy can be challenging, what would make it easier for you to eat more vegetables and choose healthier foods?"* 2) round-robin recording of ideas where participants were invited to share their most important "enabler" to consuming vegetables, 3) open discussion to clarify ideas raised and 4) voting on most relevant and motivating idea (Castiglioni et al., 2008).

Data collection and analysis

Both qualitative and quantitative data were collected simultaneously in October–November 2016. By the fifth focus group no new ideas were generated indicating theoretical saturation. The moderator made brief notes and discussions were audiotaped and later transcribed. Descriptive statistics were used to summarise demographic data, and knowledge, attitudes and behaviours related to vegetable consumption. The quantitative responses gathered through ranking activities and questionnaires were coded into a standardised Excel spread sheet (data entry checked by the moderator). Participants' names were replaced with unique ID numbers for anonymity. Scores were averaged to determine which Facebook™ posts and push notifications were preferred. The qualitative data analysis software NVivo11 (2015, version 11.0.0.317, QSR International Pty Ltd., Melbourne, Victoria, Australia) was used to conduct content analysis of audio transcripts by two authors trained in NVivo coding. Content analysis was chosen because of its systematic approach to categorising textual information to determine patterns in ideas and the frequency in which they appear (Hsieh & Shannon, 2005; Mays & Pope, 2007, pp. 82–101). This approach involved 1) determining coding categories a-priori based on the research question regarding barriers to vegetable intake as well as the questions on app design listed in Appendix 6.1, 2) reading the contents of transcripts to determine patterns in ideas 3) clustering comments with observed similarity using themes under each category, 4) tabulating the frequency in which comments within a theme appeared, 5) writing a descriptive explanation summarising each theme and 6) selecting quotes representative of the themes as well as opposing opinions, if exceptions arose.

7.7 Results

Use of health apps, social media and mobile games

Eleven of the 32 participants had used or were using apps for monitoring health outcomes at the time of the focus group. Exercise apps were used more frequently (8/11) than nutrition apps (4/11). Although nutrition apps were not widely used, 20 participants indicated interest in using the Vegetable tracker for self-monitoring vegetable intake. A smaller proportion (8/16) of young adults from the lowest SEIFA quintiles (quintile 1 and 2) were interested in using the app compared to those from SEIFA 4 and 5(8/11). All the young adults reported use of social media daily, with Facebook™ ranked as the most frequently visited platform, followed by Instagram™ and Youtube™. Only 9 of the participants reported playing games on their mobile devices with the average frequency of game play being one to two times per week. The young adults from the lower SEIFA quintiles were twice as likely to play games than those from quintile 4 and 5.

Knowledge, attitudes and behaviours related to vegetable consumption

Only 2 of the 32 respondents correctly identified a serving of vegetables as ½ a cup of cooked vegetables or 1 cup of raw vegetables. The mean self-reported vegetable intake was 2.5 serves per day, with those from higher SEIFA quintiles (quintile 4 and 5) reporting 1 serve greater intake than the lower SEIFA groups (1 and 2). Eleven participants reported primary responsibility for grocery shopping and cooking, with the remaining receiving assistance from a parent. Fewer young adults in the lowest SEIFA quintiles were responsible for the preparation of food (4/16, 25% vs 7/11, 64%). On average, the young adults ate 3.2 (range 0.5–14) meals prepared outside of home per week (including take-away and restaurant meals), with lower SEIFA participants consuming twice as many meals prepared outside their home as the higher SEIFA respondents.

Barriers and enablers of vegetable consumption

Respondents ranked the expense and time required to prepare vegetables as the greatest barriers to consumption. Lower SEIFA groups were twice as likely to report poor cooking skills as a barrier to vegetable consumption. Two major themes were derived from participant responses to the research question on enablers to vegetable intake; cooking guidance and tips on meal planning, purchasing and storage.

Cooking guidance

This theme reveals the overall low level of confidence among young adults for conceiving and preparing recipes. Half (16/32) of the participants identified that provision of recipes would enable them to consume more vegetables. Discussion revealed that recipes should provide tips on integrating vegetables into everyday foods such as a pasta dish, with inspiration on how to include them in all meals of the day. The lack of ability to conceive recipes was well summarised by *P19, FG3* who said they wanted "*More fun ways to cook tasty lunches and breakfast using veggies. I still don't know how to use it in brekkie apart from making an omelette"*. The inclusion of a searchable database of recipes within the app was favoured. However, some respondents felt that recipes alone wouldn't enable them to cook with vegetables and suggested cooking videos demonstrating preparation methods would be helpful; "*I would much prefer cooking videos to follow that show how to prepare the vegetables and new ways of eating vegetables that isn't just salad*" *P8 FG2*.

Meal planning, purchasing and storage

The gap in knowledge of young adults on how to plan meals, where to shop on a budget and how to appropriately store vegetables to maximise shelf-life were the main findings exemplifying this theme. Twelve respondents indicated that tips on where to purchase vegetables at a low cost would be a significant enabler. Many also (10/32) identified that having pre-prepared meals would support healthier eating but didn't know which foods stored well (*"Having access to healthy options like frozen meals to take to work so I don't buy unhealthy food and telling us which food can be frozen for later" P3 FG2*). Overall concern regarding the fast spoilage of vegetables was raised in three of the five focus groups, with the young adults indicating a need for education on storage and tips to reduce waste.

Motivation for improving vegetable intake

Motivation to increase vegetable intake was greater among young adults from higher SEIFA areas (mean score 4 out of 5 vs. 3 out of 5). Themes around immediate versus long term health benefits emerged. Long term implications of poor health due to inadequate vegetable intake was not a motivator, as one participant explained; *"you wouldn't be motivated to eat more vegetables at this age unless you got something"*[referring to having a health problem] *P31 FG 5.* It was apparent that immediate health outcomes such as improvements in appearance were more relevant. One male commented; "*you could have different body types on the app if you want to get lean, get bulk or get fit, you select the type of physique that you want and the app helps you in that way" P30 FG 5*.

Feedback on pilot intervention material

Responses from participants gathered through ranking activities and thematic analysis of open discussion are summarised below;

Design of application

Two main themes regarding the app design emerged through qualitative data analysis1) the importance of a simple interface and 2) the use of visual guides for estimating serving sizes, identifying categories and tracking progress. Comments included; *"The pictures of the vegetable serves and categories would really help, because I don't know the names of veggies"P11 FG2* and*"I like having the carrot fill up as a visual aid and seeing what I have eaten on previous days through the graphs" p23 FG3.*

An interface that is quick and easy to use was valued by participants who indicated that intuitive features and functions would encourage them to continue using the app. For example, the young adults preferred the option to click on pictures to log vegetables consumed rather than entering exact quantities in grams. Five participants identified that tracking of foods in detail discourages continued use of commercial apps they have downloaded in the past. This is well summarised by a female participant who stated that,*"It looks quicker and easier to use than my fitness pal because instead of calorie counting you're* *just looking at pictures of portions of food which to me is more realistic and easy to use" P1 FG1*.

Some participants expressed interest in tracking other health related goals such as mood and weight so they could link improvements in vegetable intake to changes in these health outcomes. However, this was not favoured by all, especially if it compromised the simplicity of the app, with participant 21 FG 3 summarising this idea with the statement; *"I like that the app is just targeted at vegetables, it is not even including fruit … adding other things like weight makes it complicated. I would feel more motivated tracking one thing*"*P21 FG3.*

Reward framework and gaming strategies

The goal setting and self-monitoring framework was well received by majority of the young adults. However, use of self-rewards was not perceived as an appropriate approach to motivate increased vegetable intake by all participants; with some expressing that these types of rewards require effort and self-regulation which they felt they were lacking. Comments included; *"For me I have poor discipline, and so do most of my friends. So self-rewards wouldn't be motivating, I would do them regardless of achieving my goal" P29 FG5*, and *"Our generation is lazy, no-one is going to be motivated to set their own rewards, it's just easier to have it done for you, like the badges" P24 FG4.* While the badges were seen to be a motivating reward by most, some felt that their novelity would decline overtime; "*After a while the badges might get boring. You would need to have enough rewards to keep going and keep people motivated for the whole time" P17 FG3*.

In line with the desire for a simple interface, participants expressed the importance of using one to two gaming reward strategies rather than a combination as pictured in the example prototypes which was described as “cluttered”. A quiz was seen as a fun way to learn vegetables serving sizes; however most indicated that using this feature should be optional, with some preferring a simple ‘in app’ infographic. Challenges were perceived positively by majority as they provided motivation to try vegetables in new ways. The points and leader board were favoured by some and were described as an opportunity for positive peer rivalry which may be encouraging, but only if participants were competing against friends in their network (*“I like the leaderboard. If I was playing with my friends, we would all probably be eating more to beat each other”P19 FG3*). Others did not like the leader board and were concerned by the potential for participants to cheat by entering false data.

Push notifications and appropriate message tone

Discussion and ranking activities regarding push notifications centred on three main components: tone of messages, frequency of delivery, and customisation. Participants said push notifications sent too frequently would discourage app use. Some perceived notifications would be more helpful if provided in a timely fashion when one was struggling to reach a goal. As one participant said; *“If you're mid-way through the day and you didn't log anything or eat any vegetables it would be helpful if the app notified you to tell you haven't been eating vegetables”P32 FG5.*

Fifteen of the 19 respondents wanting to receive notifications indicated a preference to modify the timing and frequency to suit their schedule. The top three ranked messages were the shortest of the examples and provided meal inspiration or used situational cues centred on including vegetables at different meal times such as, *"There is always room for more Veg! Try smashed avo on toast for breakie"*. Open discussion reaffirmed the importance of succinct messages, as stated by participant 29 FG5, *"You should keep the notifications simple without a lot of writing otherwise I wouldn't read it"*.

Discussion regarding the appropriate tone to use in messages indicated that "text talk" was not acceptable. Comments revealed that this style of writing reduced the credibility of the information and was less persuasive. Authoritative toned messages were ranked the most persuasive for motivating behaviour change (Table 7.3). This was followed by Gen Y messages. Participants commented that "Gen Y" slang such as "munchies" was relatable and somewhat comical, with suggestions made to further incorporate humour through use of memes. The solution focused messages were also ranked highly, while substitution messages were ranked poorly. This was further supported in open discussion, well summarised by participant 8 FG2 who stated "*If I want hot chips, telling me to swap it for salad won't convince me against buying my chips, maybe you could say share a chips with a friend and also get a salad on the side."*

Table 7.3 Participant rating of persuasiveness of different tonal messages for motivating improvements in vegetable intake (n = 32).

Tone of Voice	**Example message**	**Rated as most likely to motivate vegetable intake (n)**
Authoritative	*You need 5 serves of Veg a day for optimal health. If you're not quite there, it's time to make a change and look after yourself!*	11
Empathetic	*We know you might not like the taste of vegetables, but adding herbs and spices or eating them with dip can boost their flavour*	1
Gen Y	*3pm munchies got you eating fatty snacks? Adding extra veg to your lunch can keep you fuller for longer to curb those junk food cravings*	9
Solution	*To help you reach 5 a day, have some veg between meals by packing a veggie snack bag. Try cherry tomatoes or carrot and cucumber sticks*	8
Substitution	*5 a day can be challenging if you eat out a lot. Why not swap those hot chips for a salad to up your vegetable intake.*	3

Social media for delivery of health information

The latter part of the focus groups explored opinions regarding the integration of social media into the smartphone intervention. Thematic analysis revealed young adults use social media to search for recipes, look at food pictures and cooking videos. This corroborated the results obtained from the ranking activity. Mock posts that presented food pictures and recipe ideas were ranked as the most motivating, while awareness raising posts received lower scores (Table 7.4). There was a preference towards viewing materials on social media with reluctance to post onto social networking pages. Mock posts providing emotional support that required interaction such as voting polls were rated lowest (Table 7.4). Despite reluctance to interact on a social media page, a theme emerged for the impact of "social interaction" on motivation. Participants suggested that integration of an ‘in app’ news feed for sharing tips, recipes and food pictures with others using the app would be appropriate. Having this feature was linked to continued use of the app. Comments included; *“It would be great to have a newsfeed on the app where you can post pictures of healthy food” P1 FG 1,* and *“If the app was more communal, like you could share tips between friends then I would be more likely to use it”P24 FG4.*

Table 7.4. Participant rating (from 1 to 10) of example Facebook™ mock posts based on how much motivation they instil to consume vegetables (lower scores indicate higher motivation) (n = 32).

Classification	*Meal inspiration image*	*Health benefits*	*Socia/emotional support voting poll*	*Awareness raising blog post*
Mock post screenshot				
Score	2.6	5.6	8.0	8.9

7.8 Discussion

This formative research captured the attitudes and behaviours of young adults regarding vegetables, and their preferences for strategies that could be incorporated into a mobile phone based intervention. Feedback indicated preference for a simple and visually appealing self-monitoring interface that uses gaming reward mechanisms for motivation. Social support was favoured; however, the young adults were reluctant to actively interact on social media. In line with existing literature (Bibbins-Domingo & Burroughs Peña, 2010; Goodman & Sheeshka, 2016), there was a preference for intervention material focusing on immediate advantages of behaviour change as opposed to longer-term health benefits.

While recent data indicates an increasing use of health apps among smartphone owners (Tseng, 2016), only one in eight of the focus group participants reported using nutrition apps for self-monitoring. Nonetheless, the interest expressed for use of the proposed vegetable tracking app suggests there is an opportunity for researchers to disseminate nutrition interventions using apps. Thematic analyses of feedback highlighted that these apps should be simple in their design and use visual aids for self-monitoring. Ease of use and having a visually appealing interface have been described as important features for continued app use in other formative studies (Mitchell et al., 2016; Tang, Abraham, Stamp, & Greaves, 2015).

Participants were interested in the use of goal setting, self-monitoring and rewards to support behaviour change. As recognised in the literature, the young adults expressed lack of self-discipline (Strong et al., 2008), and most preferred having a designated reward such as badges. However, this was not the case for all with a select few indicating preference for self-elected rewards. Challenges were overall well received regardless of the reward preference and were seen as a motivating way to encourage users to try vegetables in new ways. Gaming experts have reported that challenges can motivate continued use of an app if they reinforce the users' understanding of the apps goals (Zichermann & Cunningham, 2011). With mobile gaming found to be higher in the young adults from lower SEIFA groups, integrating such strategies may maximise engagement of this demographic who self report a lower level of motivation to improve vegetable intake. Considering the differences recorded in preferences for rewards, researchers may consider offering users a personalised approach to selecting their ideal reward/gaming elements. This approach has been suggested to be superior over a "one-size-fits all" design (Busch et al., 2015).

Further comparison of responses by SEIFA revealed that having poor cooking skills was more frequently reported as a barrier to vegetable consumption among the lower SEIFA participants, the majority of which resided in their family home and ate twice as many meals outside of home. These results are in agreement with a recent US study conducted with 19–24 year olds indicating that the majority (74.1%) of this demographic living at home have limited to no cooking abilities (Wilson, Matthews, Seabrook, & Dworatzek, 2017). Studies in Australia and the US have trialled cooking classes and web-based demonstrations with positive effects found on cooking confidence and vegetable intake (Flego et al., 2014; Levy & Auld, 2004). This evidence, along with the desire for instructional cooking videos and recipes expressed by the young adults, highlights the relevance of practical skill development strategies in nutrition interventions. The COM-B framework which integrates capacity building strategies (C) with the provision of opportunity (O) to apply learned skills and support to increase motivation (M) was used to inform the intervention content tested in these focus groups and appears to be an appropriate means for instigating behaviour change (Michie et al., 2011).

As demonstrated in other Australian (Pollard, Daly, & Binns, 2009) and international (Rooney et al., 2017) surveys, knowledge of vegetable serving sizes and recommended daily intake was poor among respondents. Participants indicated support for use of a quiz or infographic within the app for building their knowledge. Previous research with young adults found that one time quiz play was not effective in improving nutrition knowledge (Miskovsky, 2012), so future studies intending to use such a feature may consider allowing users continued access to support learning. Furthermore, it is important that infographics are evidence-based and supported by behaviour change theory. A recent content analysis of online nutrition infographics revealed that inclusion of health behaviour theories such as self-regulation/self-control results in greater engagement (likes and comments). The infographics with greater health behaviour theory were more likely to contain a larger amount of text and photographs of real people (Wilkinson, Strickling, Payne, Jensen, & West, 2016).

Previous research has highlighted the importance of personalised feedback and reminders for maintaining user engagement with online programs (Alkhaldi et al., 2016; Crutzen et al., 2010). Our study, in line with other literature (Fukuoka, Kamitani, Bonnet, & Lindgren, 2011), found that users would prefer to alter the timing and frequency of such messages to suit their personal schedule. A recent study conducted with high income university educated young adults (Pollard et al., 2016) found they disliked authoritative and Gen Y toned messages. Contrastingly, in our study using a more generalizable sample of young adults, respondents preferred messages with an authoritative tone balanced by “comical” messages using Gen Y “slang”. It is possible that these variations are due to demographic differences. Our sample had representation from low socioeconomic strata, whereas their population included a majority of tertiary educated young adults in high paying employment. Another possibility could be factors such as perceived self-control and barriers. Furthermore, we found that the young adults disliked messages which suggested vegetables as a substitution for unhealthy foods. Prior work suggests that any mention of unhealthy foods may be counteractive and encourage further consumption (Woolford et al., 2011). As found in another smartphone intervention with young adults (Partridge et al., 2016), short, simple situational cues and tips, commonly referred to in literature as "just in time" messages (Fukuoka et al., 2011) were preferred instead. Research confirms that use of such event-based cues can support behaviour change (Nguyen et al., 2012) and assist with automaticity and habit formation (Stawarz et al., 2015), with a call for apps to go beyond self-monitoring by providing real-time habit support. Overall, it is expected that messages that resonate with certain individuals or groups may be of no value to others. In addressing these differences, researchers should always attempt to capture perspectives of the specific target audience during the design of public health messages.

Importantly, it was noted that the young adults were less motivated by the longer term health implications of improving vegetable intake. Other researchers have used the term "young invincibles" to describe this demographic who are more concerned with immediate and personally relevant outcomes of behaviours (Bibbins-Domingo & Burroughs Peña, 2010; Goodman & Sheeshka, 2016). This group expressed preference for messages centred on benefits such as improvements in skin (females) or body shape (males). Thus, future nutrition interventions should consider pitching the benefits of behaviour change in an age-appropriate manner.

Finally, findings indicated that social media could serve as an acceptable support platform in nutrition interventions with young adults. Participants preferred meal inspiration posts and recipe ideas, especially those with attractive food images. The young adults ranked awareness-raising and emotional support posts low. This contrasts to a recent study which explored the most popular Facebook posts on pages of 20 Australian public health organisations and found that emotionally appealing posts and those providing factual information had greater user engagement (Kite, Foley, Grunseit, & Freeman, 2016). However, only one of these Facebook pages was nutrition related and the age group interacting with the posts cannot be discerned. Furthermore, although research has suggested the development of active social media communities whereby users share new content to assist in improving engagement (Korda & Itani, 2013), the young adults of this study expressed reluctance to interact by posting on social networking sites themselves but were interested in viewing content created by others. These contrasting findings emphasise the importance of acceptability testing of intervention materials with a sample of the intended target audience.

Strengths and limitations

While researchers have examined the use of online platforms for behaviour change (Crutzen et al., 2010), few have explored preferences regarding nutrition specifically (Goodman & Sheeshka, 2016), with this paper being the first to report on preferences for an intervention targeted at increasing vegetable consumption. The focus groups gathered opinions from a broad range of young adults from Sydney. The demographic extended beyond the student population typically surveyed in studies with young adults. However, the findings may not be generalizable to other age groups or to all young adults, especially those from other countries with different cultures.

Conclusion and practical implications

Overall, a socially connected smartphone app is an acceptable medium for the delivery of a nutrition intervention to young adults. To specifically support improvements in vegetable intake, this population requires instructional guidance for skill development through situational cues, recipes and cooking demonstrations. The findings presented here may serve as a guide to researchers designing mobile phone based interventions aiming to improve other nutrition habits of young adults. The paper can provide a framework for exploring the inclusion of gaming and social technologies; and/or a summary of elements most likely to be accepted by this age group.

Young adults want nutrition apps that are simple in their design and use visual aids for self-monitoring. Gamification principles such as badges could help in maintaining motivation and engagement, but allowing users to personalise their rewards may be a more successful approach given the mixed response. Social media can serve as a platform for the delivery of support resources, however the credibility of the source of information must be well established and language to be used should be pre-tested with the target population. Researchers should also give careful consideration to what messages motivate behaviour change among their audience, and may need to focus on promotion of the immediate benefits as opposed to longer term implications in younger populations. Enlisting an expert from a nutrition/dietetics background for content development and a behavioural scientist for selection of relevant theory is recommended.

The findings from this study will be used to refine the design of our theory-based self-monitoring app developed specifically for young adults. To our knowledge, this will be the first smartphone intervention to combine social media and gaming to support improvements in vegetable intake in this population. The intervention will be piloted with evaluation of behavioural and psychological outcomes. User engagement will also be assessed to provide insight on the impact of these innovative strategies on behaviour.

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7.10 Conclusion to chapter

The formative research conducted in this chapter indicated positive support among young adults for the use of a goal setting and self-monitoring smartphone app with gamification for the delivery of a vegetable intervention. The goal and reward framework afforded by gamification was seen as a key motivator for their behaviour change. The findings also highlighted the need for additional support beyond the app such as instructional guidance for skill development through recipes and cooking demonstrations. Social media was seen as an acceptable platform for dissemination of support resources particularly if the information was seen as credible. Importantly, young adults indicated that they would most likely interact passively in social media interventions, whereby they view but will not post information. Findings from acceptability testing of the proposed intervention will guide the refinement of program material for future use in a factorial study that aims to determine which of the behaviour strategies (goal setting and self-monitoring via standard app vs. social support through social media vs. incentivisation through gamified app) have the most desirable impact on vegetable intake and engagement with the program.

Appendix 7

Appendix 7.1

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Exploring young adult perspectives on the use of gamification and social media in a smartphone platform for improving vegetable intake

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A B S T R A C T

Young adults are the poorest consumers of vegetables. Social media and smartphones are frequently used by this demographic and could serve as an engaging medium for nutrition promotion. Five focus groups were conducted to capture participants' perceptions of a theory-based gamified self-monitoring app for improving vegetable intake of young adults. Ranking activities were used to gather feedback on preferences for social media posts. Data arising from group discussion were analysed using NVivo software using a deductive approach to group common ideas into themes. Thirty two participants (14 males) attended (mean age 23.1 (SD 2.7) years). Qualitative analyses of open discussion revealed two major themes regarding preferred features for a smartphone app; (1) the use of visual guides for estimating quantities of vegetables and tracking progress, and (2) a simple interface. Gamification strategies such as earning badges were viewed more positively than the use of a self-reward framework. Social media posts which presented food pictures and recipes were ranked most motivating, while awareness-raising posts received lower scores. Participants indicated a preference for viewing but reluctance to post information onto social media. "Just in time" situational cues were ranked highly and the use of an "authoritative" tone was preferred and associated with credibility. Young adults also ranked messages containing "Gen Y" language highly, with a preference for those which were personally relevant. The proposed use of social media and mobile-gaming was seen as an acceptable approach for improving vegetable intake. Materials should be visually appealing, simply designed, credible, and personally relevant to appeal to this population. This feedback may inform future mobile-phone based interventions targeting improved nutrition in young adults.

1. Introduction

Young adults aged 18–34 years are the poorest consumers of vegetables among Australian adults (Australian Health Survey, 2013). Increasing vegetable intake can reduce chronic disease risk (Oyebode, Gordon-Dseagu, Walker, & Mindell, 2014) and improve indicators of psychological well-being such as life-satisfaction and happiness (Mujcic, 2016; Nguyen, Ding, & Mihrshahi, 2017). However, the lower likelihood of chronic disease during this life stage, and competing priorities may reduce the motivation of young adults to engage in longer-term behaviour change (Bibbins-Domingo & Burroughs Peña, 2010).

Research highlights that young adults lack self-efficacy for practicing healthful dietary behaviours (Strong, Parks, Anderson, Winett, & Davy, 2008). Specific barriers to consuming vegetables include low levels of cooking literacy, the perceived cost of vegetables, the time/effort required to prepare them and their undesirable flavour (Brug, Debie, van Assema, & Weijts, 1995; Hartman, Wadsworth, Penny, van Assema, & Page, 2013; Soliah, Walter, & Antosh, 2006). A meta-regression of 122 studies showed that self-monitoring is one of the best predictors of change in eating habits (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). The process of monitoring can provide reflective insights on one's current behaviour, facilitating self-awareness, enhancing motivation for change (Li et al., 2011; Rapp & Tirassa, 2017) and increasing ability to achieve dietary goals (West et al., 2017). There is growing evidence to suggest that this process supports behaviour change (Kersten-van Dijk, Westerink, Beute, & IJsselsteijn, 2017; Lieffers & Hanning, 2012; West et al., 2017) and can also be useful in the maintenance phase for assessing divergence from the goal (Li et al.,

Abbreviations: SEIFA, socioeconomic index for areas.

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2011). This may be particularly relevant to young adults who usually struggle with self-regulation (Strong et al., 2008). With 95% of 18–34 year olds owning a smartphone in 2016 (Poushter), mobile applications (apps) may be a suitable platform through which young adults can easily self-monitor their diet (McGloin & Eslami, 2015).

Social media and mobile-gaming may also serve as an engaging way to deliver nutrition interventions to young adults, with 91% of 18–29 year olds interacting on social networks and a further 91% of smartphone owners using their devices for gaming (Our Mobile Planet, 2013; Smith). Gamification, defined as the incorporation of game elements in a non-gaming context to evoke motivation (Cugelman, 2013), has been harnessed by researchers for the delivery of nutrition interventions (Nour, Yeung, Partridge, & Allman-Farinelli, 2017). Information sharing in online networks has also been proposed as a means to further promote positive health behaviours (Heaney & Israel, 2008, pp. 189–210). While evidence for use of these technologies is still emerging, some positive effects have been reported among young adults (Nour et al., 2017) and the general public (Hamari et al., 2014). A study by Orji, Vassileva, and Mandryk (2013) used a socially connected virtual reality mobile game app to effectively improve the knowledge and attitudes of young adults regarding selection of healthy options when eating out (Orji et al., 2013). Another study harnessed Facebook as a platform for the delivery of a group-based weight loss program, with improvements in fruit and vegetable intake observed post intervention (Cavallo et al., 2016).

Despite these positive outcomes, there is limited use of robust experimental designs (Seaborn & Fels, 2015) and many studies report low user engagement or drop-off in usage over time (Kelders, Kok, Ossebaard, & Van Gemert-Pijnen, 2012; Nour et al., 2017). Use of techniques for maintaining participant engagement is often neglected in intervention planning (Short, Rebar, Plotnikoff, & Vandelanotte, 2015) and future work should consider engagement in the design process to combat this.

Supported by the Elaboration Likelihood Model (Petty, Barden, & Wheeler, 2002), researchers in the field of engagement have highlighted the importance of persuasive design (Kelders et al., 2012; Short et al., 2015); whereby an individual is more likely to engage with and process intervention material when it is personally relevant. Focus groups provide valuable insights into the needs and expectations of users (Thompson, 2014). However, participant responses may sometimes result in incongruence between researcher learning objectives based on theory and the design elements participants suggest (Vasalou et al., 2012). For example, users may suggest a certain feature for inclusion in a smartphone intervention that is unlikely to support the intended change in behaviour. Contrastingly, involving the target population as "informants" who provide feedback on the relevance and motivational capacity of intervention strategies developed by professionals has been shown to enhance the effectiveness of digital interventions (DeSmet et al., 2016).

Our primary aim was to test the feasibility and acceptability of a theory-based smartphone intervention for young adults that combines social media, self-monitoring and mobile-gaming to address the most salient psycho-social and environmental determinants of vegetable intake reported in the literature including taste, cost, availability, knowledge and self-efficacy (Hartman et al., 2013). This formative research will inform the framing of the smartphone intervention by gathering prioritised, objective, and quantified feedback from the target group on the proposed content (behaviour change messages and social media posts). Perceptions of the planned approach which uses social media and a mobile-application will also be captured.

2. Methods

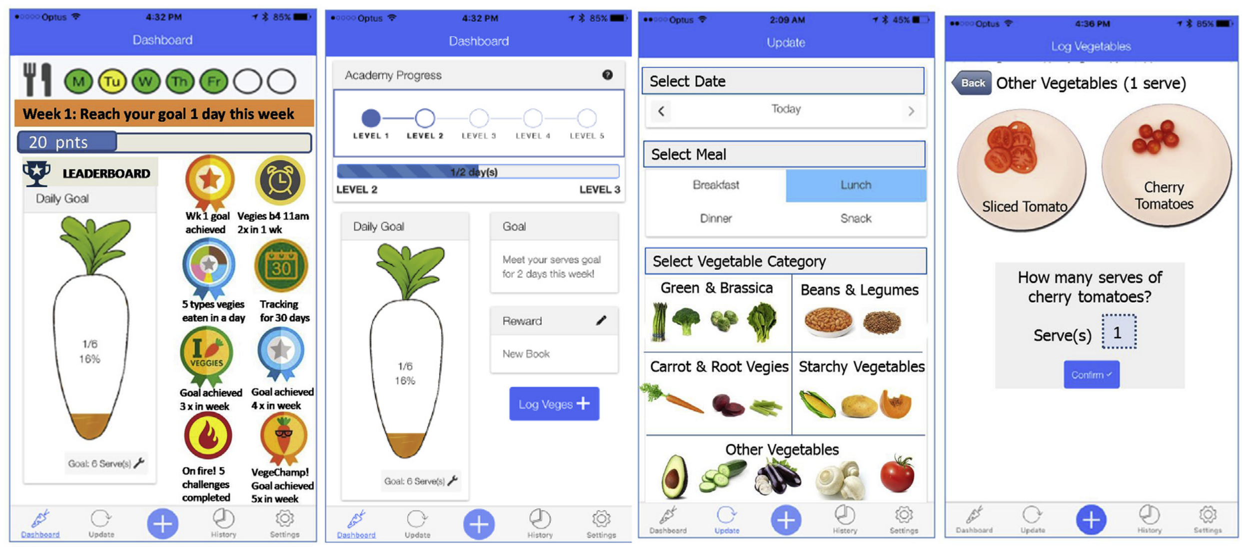
2.1. Development of intervention materials

The COM-B framework (Michie, van Stralen, & West, 2011) and Taxonomy of behaviour change techniques (Abraham & Michie, 2008) were used to translate the determinants of vegetable intake into context-specific behaviour change strategies for use in an intervention to improve vegetable consumption of young adults. The COM-B framework is a psychological model which supports the process of changing human behaviour by addressing the "pre-requisites" for a given behaviour. This involves ensuring the individual is capable of physically performing the behaviour (i.e. they have the necessary skills) and is psychologically equipped with the necessary knowledge. The model also addresses the opportunity an individual has to engage in the behaviour, including physical opportunity such as triggers within the environment and social opportunity such as addressing cultural norms. Finally, instilling motivation by targeting reflective motivation such as one's beliefs and automatic motivation such as reflex and habitual responses is important (Michie et al., 2011).

We developed the prototype for a smartphone application (app) for monitoring vegetable intake. Research on self-regulation of health behaviours has indicated that goal setting is an important component of habit formation (Mann, De Ridder, & Fujita, 2013). Thus, on initial log in to the app, users are prompted to set a goal for daily vegetable serves. To cater to the experience level of non-expert trackers, simple visual representations of progress were used to minimise cognitive load and ensure easy interpretation of personal data (Rapp & Cena, 2016). As shown in the wire frames utilised for acceptability testing (Fig. 1a–d), progress toward the personal goal can be reviewed through the carrot gauge which fills up as intake is entered (Fig. 1a and b). A traffic light system is used to provide an overview of weekly achievements, where green indicates goal attainment and amber represents progress towards the intake goal (Fig. 1a). Intake is tracked according to type of vegetable and the meal in which it is consumed (Fig. 1c). Self-monitoring may be short-lived (Rapp, 2015), and users may struggle with maintaining personal data records as they forget to track or purposely skip entries (Rapp, 2017). For this reason, we proposed the use of gaming rewards such as points and badges to maintain engagement. In this virtual reward prototype (Fig. 1a), achieving ones goal allows for the accumulation of points, rewarded with 'in app' badges. Experts in the field have questioned the effectiveness of these gamified rewards (Rapp, 2015), and highlighted the importance of using meaningful rewards that reflect user's needs and desires (Rapp, 2017). As such we also designed a self-elected reward prototype for testing (Fig. 1b) in which users elect their own rewards to self-administer after completing each challenge level (e.g. level 1: meet your goal 2 times this week and reward with a new book).

Additional components that could be integrated were also tested. This included a series of push notifications for delivery through the mobile app. Messages were one to two sentences long and addressed barriers such as taste, included tips on how to substitute vegetables into the diet, and provided motivational messages describing the health benefits of vegetables. Some messages used short hand writing known as "text talk", replacing words with characters to reduce length for delivery to the notifications screen. To test the acceptability of this style of writing we developed messages in both short hand and standard language. For example, *"RU adding Veg 2 ur diet? Make the change - replace those chips with Veggie sticks"* (short hand); *"Worried about the taste of vegetables? Up the flavour! Add some herbs and spices"* (standard).

Advertisements often manipulate the tone of voice in messages



a b c d

Fig. 1. a–d: Example prototypes of self-monitoring app with options for gaming strategies presented to focus group participants. Fig. 1a includes a point system, leader boards, badges and challenges (external reward system) and Fugire1b uses self-elected rewards for progression through levels (intrinsic reward system). Fig. 1c and d shows the process of entering vegetable intake.

to influence engagement with brands, products or services (Delin, 2005). Previous research with high income university educated young adults suggested "substitution" and "empathetic" messages were most likely to persuade improvements in fruit and vegetable intake (Pollard et al., 2016). To explore this further using a more diverse sample of young adults, we designed messages based on the following five voice tones; empathetic, authoritative, solution-based, substitution-based, and generation Y ("Gen Y"), and asked participants to rank them according to how much they motivated vegetable consumption.

To determine the acceptability of social media in the intervention, a series of "mock" Facebook™ posts were developed and tested for engagement and motivation. These included competitions, money saving tips, links to additional resources and educational posts on serving sizes, recommended daily intake and health benefits of vegetables (See Fig. 2 for examples).

2.2. Participants

A total of 32 young adults (14 male) attended 5 focus groups. Groups consisted of 4–12 participants recruited from the greater Sydney area, Australia. The mean age was 23.1 (SD 2.7) years. Participants came from a range of sociodemographic backgrounds as determined by the Socio-economic index for areas (SEIFA) (Table 1). Participants were recruited through flyers placed around university (college) and vocational college campuses, and advertisements on relevant community social media pages. Those who did not own a smartphone or who had a background in nutrition were excluded.

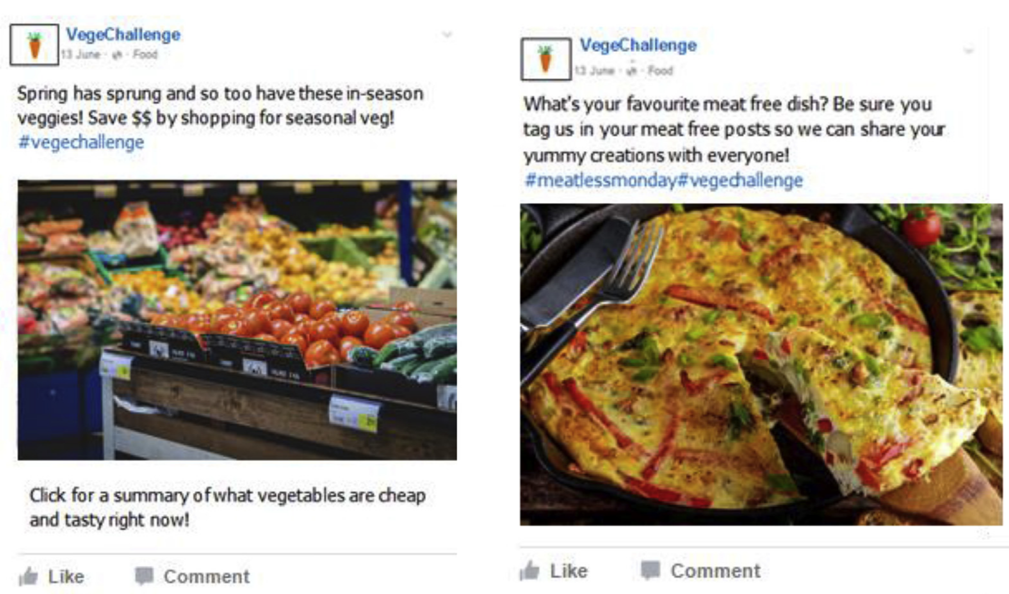


Fig. 2. Mock Facebook posts presented to focus group participants for ranking.

Table 1
Characteristics of focus group participants n = 32.

Characteristics	N
Gender	
Male	14
Age, years	
18-24	22
25-30	10
SEIFA category	
1 (Lowest)	4
2	12
3	5
4	3
5 (Highest)	8
Occupation	
Student	18
Health worker	6
White collar	4
Blue collar	4

Potential participants were scheduled into a focus group in their local area and offered a AUD $20 gift voucher for attendance.

2.3. Study design

Materials and methods of the focus groups were approved by the Institutional Human Research Ethics Committee (approval number 2016/705). Consecutive sampling was used, whereby all eligible participants were included in the study sample until data saturation was achieved. Data saturation was determined when no new ideas were generated in the focus group session.

The methods proposed by Kruger and Casey (Krueger & Casey, 2014) and the consolidated criteria for reporting qualitative research (COREQ) 32 item checklist (Tong, Sainsbury, & Craig, 2007) were consulted for study design and reporting of findings. A mixed methods approach was utilised to gather both quantitative and qualitative data.

We applied a user-centred design philosophy in which the target audience (young adults) are directly involved in the design process by providing their preferences for and opinions on the relevance of the aforementioned theory-based pilot intervention materials. We used a deductive method of study whereby a predetermined approach is tested for its acceptability (Harris, 2009). This method was selected to confirm if the proposed strategies for supporting improvements in vegetable intake are motivating and appropriately pitched to the target audience.

The nominal group technique (NGT) is a coordinated variation of the focus group technique where participants engage in structured activities such as ranking pictures, statements, or sample intervention materials. This was used to gather inductive input (Gallagher, Hares, Spencer, Bradshaw, & Webb, 1993; Harris, 2009) followed by discussion to achieve consensus on a given idea or research question (Castiglioni, Shewchuk, Willett, Heudebert, & Centor, 2008; Gallagher et al., 1993). The structured format of the NGT limits process loss and inefficiencies of open discussion or uncoordinated interactive group settings (Delbecq, Van de Ven, & Gustafson, 1975; Gallagher et al., 1993; Miller, Shewchuk, Elliot, & Richards, 2000).

2.4. Procedures

The 90 min focus groups were led by a female facilitator (MMN, Dietitian and PhD researcher). A moderator (AR, Dietitian and PhD researcher) took notes during open discussion and assisted with time-keeping and audio-taping. Upon arrival, participants were briefed with the focus group objectives. They were informed of the inadequate intake of vegetables in young Australians and the researchers' interests in using mobile technologies to support improved nutrition. Quantitative and qualitative data were collected in two phases.

2.5. Quantitative component

Once signed consent was obtained participants completed a demographic questionnaire (see supplementary file 1) capturing age, gender, postcode (for categorising SEIFA), occupation, and use of health and gaming apps. Knowledge of vegetable serving sizes and recommendations were also measured through multiple choice questions (NSW Population Health Survey, 2014). Finally, participants were asked to identify and rank barriers to consuming vegetables and estimate their usual daily intake using validated images of serving sizes (Islam et al., 2013).

Next, participants were presented with a series of push notification messages and mock Facebook™ posts to rank according to how much they would motivate their consumption of vegetables. Preferences regarding frequency and timing of the notifications/posts were collected through a two-item question.

2.6. Qualitative component

To gather user feedback on the app prototype, a series of electronically drawn app screens known as wire frames (Fig. 1a–d) were presented using PowerPoint. The facilitator provided verbal navigation through the app and the potential gaming strategies. Participants were invited to provide their opinions; including which gaming strategies would encourage engagement with the app. Open discussion was also used to test the acceptability of short hand writing known as "text talk" used in example messages. Predetermined prompts were used to encourage discussion (see Table 2 for examples).

Finally, the NGT was used to gather opinions on the enablers to vegetable consumption. Feedback was collected using the following method: 1) 5 min of silent brainstorming during which each individual documented responses to the research question *"Eating healthy can be challenging, what would make it easier for you to eat more vegetables and choose healthier foods?"* 2) round-robin recording of ideas where participants were invited to share their most important "enabler" to consuming vegetables, 3) open discussion to clarify ideas raised and 4) voting on most relevant and motivating idea (Castiglioni et al., 2008).

2.7. Data collection and analysis

Both qualitative and quantitative data were collected simultaneously in October–November 2016. By the fifth focus group no new ideas were generated indicating theoretical saturation. The moderator made brief notes and discussions were audiotaped and later transcribed. Descriptive statistics were used to summarise demographic data, and knowledge, attitudes and behaviours related to vegetable consumption. The quantitative responses gathered through ranking activities and questionnaires were coded into a standardised Excel spread sheet (data entry checked by the moderator). Participants' names were replaced with unique ID numbers for anonymity. Scores were averaged to determine which Facebook™ posts and push notifications were preferred. The qualitative data analysis software NVivo11 (2015, version 11.0.0.317, QSR International Pty Ltd., Melbourne, Victoria, Australia) was used to conduct content analysis of audio transcripts by two authors trained in NVivo coding. Content analysis was chosen because of its systematic approach to categorising textual information to determine patterns in ideas and the frequency in which they appear (Hsieh &

Table 2
Prompts to encourage discussion on the acceptability and feasibility of the mobile app.

Prompts used in focus group
What do you think of this design?
What aspects of the design need improvement?
Are there aspects you like or dislike?
Which aspects seem more motivating, selecting self-rewards or a virtual reward design?
Are there certain aspects of the virtual rewards that you like or dislike?
Which parts of the app design would be most motivating/useful to you?
Would you be motivated to play an educational game? If not, can you suggest other ways you would prefer to learn about vegetables?
Are there any other strategies that would motivate you to eat more vegetables that we haven't mentioned in these examples?
Suppose that you were in charge of developing this platform and could make one change that would make the program better. What would you do?

Shannon, 2005; Mays & Pope, 2007, pp. 82–101). This approach involved 1) determining coding categories a-priori based on the research question regarding barriers to vegetable intake as well as the questions on app design listed in Supplementary file 1, 2) reading the contents of transcripts to determine patterns in ideas 3) clustering comments with observed similarity using themes under each category, 4) tabulating the frequency in which comments within a theme appeared, 5) writing a descriptive explanation summarising each theme and 6) selecting quotes representative of the themes as well as opposing opinions, if exceptions arose.

3. Results

3.1. Use of health apps, social media and mobile games

Eleven of the 32 participants had used or were using apps for monitoring health outcomes at the time of the focus group. Exercise apps were used more frequently (8/11) than nutrition apps (4/11). Although nutrition apps were not widely used, 20 participants indicated interest in using the Vegetable tracker for self-monitoring vegetable intake. A smaller proportion (8/16) of young adults from the lowest SEIFA quintiles (quintile 1 and 2) were interested in using the app compared to those from SEIFA 4 and 5(8/11). All the young adults reported use of social media daily, with Facebook™ ranked as the most frequently visited platform, followed by Instagram™ and Youtube™. Only 9 of the participants reported playing games on their mobile devices with the average frequency of game play being one to two times per week. The young adults from the lower SEIFA quintiles were twice as likely to play games than those from quintile 4 and 5.

3.2. Knowledge, attitudes and behaviours related to vegetable consumption

Only 2 of the 32 respondents correctly identified a serving of vegetables as ½ a cup of cooked vegetables or 1 cup of raw vegetables. The mean self-reported vegetable intake was 2.5 serves per day, with those from higher SEIFA quintiles (quintile 4 and 5) reporting 1 serve greater intake than the lower SEIFA groups (1 and 2). Eleven participants reported primary responsibility for grocery shopping and cooking, with the remaining receiving assistance from a parent. Fewer young adults in the lowest SEIFA quintiles were responsible for the preparation of food (4/16, 25% vs 7/11, 64%). On average, the young adults ate 3.2 (range 0.5–14) meals prepared outside of home per week (including take-away and restaurant meals), with lower SEIFA participants consuming twice as many meals prepared outside their home as the higher SEIFA respondents.

3.3. Barriers and enablers of vegetable consumption

Respondents ranked the expense and time required to prepare vegetables as the greatest barriers to consumption. Lower SEIFA groups were twice as likely to report poor cooking skills as a barrier to vegetable consumption. Two major themes were derived from participant responses to the research question on enablers to vegetable intake; cooking guidance and tips on meal planning, purchasing and storage.

3.4. Cooking guidance

This theme reveals the overall low level of confidence among young adults for conceiving and preparing recipes. Half (16/32) of the participants identified that provision of recipes would enable them to consume more vegetables. Discussion revealed that recipes should provide tips on integrating vegetables into everyday foods such as a pasta dish, with inspiration on how to include them in all meals of the day. The lack of ability to conceive recipes was well summarised by *P19, FG3* who said they wanted "*More fun ways to cook tasty lunches and breakfast using veggies. I still don't know how to use it in brekkie apart from making an omelette*". The inclusion of a searchable database of recipes within the app was favoured. However, some respondents felt that recipes alone wouldn't enable them to cook with vegetables and suggested cooking videos demonstrating preparation methods would be helpful; "*I would much prefer cooking videos to follow that show how to prepare the vegetables and new ways of eating vegetables that isn't just salad*" *P8 FG2*.

3.5. Meal planning, purchasing and storage

The gap in knowledge of young adults on how to plan meals, where to shop on a budget and how to appropriately store vegetables to maximise shelf-life were the main findings exemplifying this theme. Twelve respondents indicated that tips on where to purchase vegetables at a low cost would be a significant enabler. Many also (10/32) identified that having pre-prepared meals would support healthier eating but didn't know which foods stored well (*"Having access to healthy options like frozen meals to take to work so I don't buy unhealthy food and telling us which food can be frozen for later"P3 FG2*). Overall concern regarding the fast spoilage of vegetables was raised in three of the five focus groups, with the young adults indicating a need for education on storage and tips to reduce waste.

3.6. Motivation for improving vegetable intake

Motivation to increase vegetable intake was greater among young adults from higher SEIFA areas (mean score 4 out of 5 vs. 3 out of 5). Themes around immediate versus long term health benefits emerged. Long term implications of poor health due to inadequate vegetable intake was not a motivator, as one participant explained; *"you wouldn't be motivated to eat more vegetables at this* *age unless you got something"* [referring to having a health problem] *P31 FG 5.* It was apparent that immediate health outcomes such as improvements in appearance were more relevant. One male commented; "*you could have different body types on the app if you want to get lean, get bulk or get fit, you select the type of physique that you want and the app helps you in that way" P30 FG 5*.

3.7. Feedback on pilot intervention material

Responses from participants gathered through ranking activities and thematic analysis of open discussion are summarised below;

3.8. Design of application

Two main themes regarding the app design emerged through qualitative data analysis 1) the importance of a simple interface and 2) the use of visual guides for estimating serving sizes, identifying categories and tracking progress. Comments included; *"The pictures of the vegetable serves and categories would really help, because I don't know the names of veggies"P11 FG2* and*"I like having the carrot fill up as a visual aid and seeing what I have eaten on previous days through the graphs" p23 FG3.*

An interface that is quick and easy to use was valued by participants who indicated that intuitive features and functions would encourage them to continue using the app. For example, the young adults preferred the option to click on pictures to log vegetables consumed rather than entering exact quantities in grams. Five participants identified that tracking of foods in detail discourages continued use of commercial apps they have downloaded in the past. This is well summarised by a female participant who stated that,*"It looks quicker and easier to use than my fitness pal because instead of calorie counting you're just looking at pictures of portions of food which to me is more realistic and easy to use" P1 FG1.*

Some participants expressed interest in tracking other health related goals such as mood and weight so they could link improvements in vegetable intake to changes in these health outcomes. However, this was not favoured by all, especially if it compromised the simplicity of the app, with participant 21 FG 3 summarising this idea with the statement; *"I like that the app is just targeted at vegetables, it is not even including fruit … adding other things like weight makes it complicated. I would feel more motivated tracking one thing"P21 FG3.*

3.9. Reward framework and gaming strategies

The goal setting and self-monitoring framework was well received by majority of the young adults. However, use of self-rewards was not perceived as an appropriate approach to motivate increased vegetable intake by all participants; with some expressing that these types of rewards require effort and self-regulation which they felt they were lacking. Comments included; *"For me I have poor discipline, and so do most of my friends. So self-rewards wouldn't be motivating, I would do them regardless of achieving my goal" P29 FG5*, and *"Our generation is lazy, no-one is going to be motivated to set their own rewards, it's just easier to have it done for you, like the badges" P24 FG4.* While the badges were seen to be a motivating reward by most, some felt that their novelity would decline overtime; "*After a while the badges might get boring. You would need to have enough rewards to keep going and keep people motivated for the whole time" P17 FG3*.

In line with the desire for a simple interface, participants expressed the importance of using one to two gaming reward strategies rather than a combination as pictured in the example prototypes which was described as "cluttered". A quiz was seen as a fun way to learn vegetables serving sizes; however most indicated that using this feature should be optional, with some preferring a simple 'in app' infographic. Challenges were perceived positively by majority as they provided motivation to try vegetables in new ways. The points and leader board were favoured by some and were described as an opportunity for positive peer rivalry which may be encouraging, but only if participants were competing against friends in their network (*"I like the leaderboard. If I was playing with my friends, we would all probably be eating more to beat each other"P19 FG3*). Others did not like the leader board and were concerned by the potential for participants to cheat by entering false data.

3.10. Push notifications and appropriate message tone

Discussion and ranking activities regarding push notifications centred on three main components: tone of messages, frequency of delivery, and customisation. Participants said push notifications sent too frequently would discourage app use. Some perceived notifications would be more helpful if provided in a timely fashion when one was struggling to reach a goal. As one participant said; *"If you're mid-way through the day and you didn't log anything or eat any vegetables it would be helpful if the app notified you to tell you haven't been eating vegetables"P32 FG5.*

Fifteen of the 19 respondents wanting to receive notifications indicated a preference to modify the timing and frequency to suit their schedule. The top three ranked messages were the shortest of the examples and provided meal inspiration or used situational cues centred on including vegetables at different meal times such as, *"There is always room for more Veg! Try smashed avo on toast for breakie"*. Open discussion reaffirmed the importance of succinct messages, as stated by participant 29 FG5, *"You should keep the notifications simple without a lot of writing otherwise I wouldn't read it"*.

Discussion regarding the appropriate tone to use in messages indicated that "text talk" was not acceptable. Comments revealed that this style of writing reduced the credibility of the information and was less persuasive. Authoritative toned messages were ranked the most persuasive for motivating behaviour change (Table 3). This was followed by Gen Y messages. Participants commented that "Gen Y" slang such as "munchies" was relatable and somewhat comical, with suggestions made to further incorporate humour through use of memes. The solution focused messages were also ranked highly, while substitution messages were ranked poorly. This was further supported in open discussion, well summarised by participant 8 FG2 who stated "*If I want hot chips, telling me to swap it for salad won't convince me against buying my chips, maybe you could say share a chips with a friend and also get a salad on the side.*"

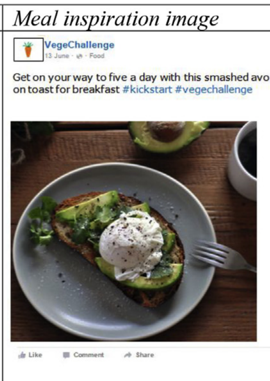
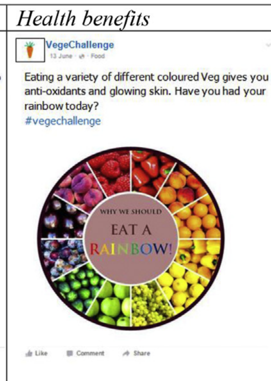
3.11. Social media for delivery of health information

The latter part of the focus groups explored opinions regarding the integration of social media into the smartphone intervention. Thematic analysis revealed young adults use social media to search for recipes, look at food pictures and cooking videos. This corroborated the results obtained from the ranking activity. Mock posts that presented food pictures and recipe ideas were ranked as the most motivating, while awareness raising posts received lower scores (Table 4). There was a preference towards viewing materials on social media with reluctance to post onto social networking pages. Mock posts providing emotional support that required interaction such as voting polls were rated lowest (Table 4). Despite reluctance to interact on a social media page, a theme emerged for the impact of "social interaction" on motivation. Participants suggested that integration of an 'in app' news feed for sharing tips, recipes and food pictures with others using the app would be

Table 3
Participant rating of persuasiveness of different tonal messages for motivating improvements in vegetable intake (n = 32).

Tone of Voice	Example message	Rated as most likely to motivate vegetable intake (n)
Authoritative	*You need 5 serves of Veg a day for optimal health. If you're not quite there, it's time to make a change and look after yourself!*	11
Empathetic	*We know you might not like the taste of vegetables, but adding herbs and spices or eating them with dip can boost their flavour*	1
Gen Y	*3pm munchies got you eating fatty snacks? Adding extra veg to your lunch can keep you fuller for longer to curb those junk food cravings*	9
Solution	*To help you reach 5 a day, have some veg between meals by packing a veggie snack bag. Try cherry tomatoes or carrot and cucumber sticks*	8
Substitution	*5 a day can be challenging if you eat out a lot. Why not swap those hot chips for a salad to up your vegetable intake.*	3

Table 4
Participant rating (from 1 to 10) of example Facebook™ mock posts based on how much motivation they instil to consume vegetables (lower scores indicate higher motivation) (n = 32).

<table>
<tr><th>Classification</th><th>Meal inspiration image</th><th>Health benefits</th><th>Socia/emotional support voting poll</th><th>Awareness raising blog post</th></tr>
<tr><td>Mock post screenshot</td>
<td>
</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Score</td><td>2.6</td><td>5.6</td><td>8.0</td><td>8.9</td></tr>
</table>

appropriate. Having this feature was linked to continued use of the app. Comments included; *"It would be great to have a newsfeed on the app where you can post pictures of healthy food" P1 FG 1,* and *"If the app was more communal, like you could share tips between friends then I would be more likely to use it"P24 FG4.*

4. Discussion

This formative research captured the attitudes and behaviours of young adults regarding vegetables, and their preferences for strategies that could be incorporated into a mobile phone based intervention. Feedback indicated preference for a simple and visually appealing self-monitoring interface that uses gaming reward mechanisms for motivation. Social support was favoured; however, the young adults were reluctant to actively interact on social media. In line with existing literature (Bibbins-Domingo & Burroughs Peña, 2010; Goodman & Sheeshka, 2016), there was a preference for intervention material focusing on immediate advantages of behaviour change as opposed to longer-term health benefits.

While recent data indicates an increasing use of health apps among smartphone owners (Tseng, 2016), only one in eight of the focus group participants reported using nutrition apps for self-monitoring. Nonetheless, the interest expressed for use of the proposed vegetable tracking app suggests there is an opportunity for researchers to disseminate nutrition interventions using apps. Thematic analyses of feedback highlighted that these apps should be simple in their design and use visual aids for self-monitoring. Ease of use and having a visually appealing interface have been described as important features for continued app use in other formative studies (Mitchell et al., 2016; Tang, Abraham, Stamp, & Greaves, 2015).

Participants were interested in the use of goal setting, self-monitoring and rewards to support behaviour change. As recognised in the literature, the young adults expressed lack of self-discipline (Strong et al., 2008), and most preferred having a designated reward such as badges. However, this was not the case for all with a select few indicating preference for self-elected rewards. Challenges were overall well received regardless of the reward preference and were seen as a motivating way to encourage users to try vegetables in new ways. Gaming experts have reported that challenges can motivate continued use of an app if they reinforce the users' understanding of the apps goals (Zichermann & Cunningham, 2011). With mobile gaming found to be higher in the young adults from lower SEIFA groups, integrating such strategies may maximise engagement of this demographic who self report a lower level of motivation to improve vegetable intake. Considering the differences recorded in preferences for rewards, researchers may consider offering users a personalised approach to selecting their ideal reward/gaming elements. This approach has been suggested to be superior over a "one-size-fits all" design (Busch et al., 2015).

Further comparison of responses by SEIFA revealed that having poor cooking skills was more frequently reported as a barrier to vegetable consumption among the lower SEIFA participants, the majority of which resided in their family home and ate twice as many meals outside of home. These results are in agreement with a recent US study conducted with 19–24 year olds indicating that the majority (74.1%) of this demographic living at home have limited to no cooking abilities (Wilson, Matthews, Seabrook, & Dworatzek, 2017). Studies in Australia and the US have trialled cooking classes and web-based demonstrations with positive effects found on cooking confidence and vegetable intake (Flego et al., 2014; Levy & Auld, 2004). This evidence, along with the desire for instructional cooking videos and recipes expressed by the young adults, highlights the relevance of practical skill development strategies in nutrition interventions. The COM-B framework which integrates capacity building strategies (C) with the provision of opportunity (O) to apply learned skills and support to increase motivation (M) was used to inform the intervention content tested in these focus groups and appears to be an appropriate means for instigating behaviour change (Michie et al., 2011).

As demonstrated in other Australian (Pollard, Daly, & Binns, 2009) and international (Rooney et al., 2017) surveys, knowledge of vegetable serving sizes and recommended daily intake was poor among respondents. Participants indicated support for use of a quiz or infographic within the app for building their knowledge. Previous research with young adults found that one time quiz play was not effective in improving nutrition knowledge (Miskovsky, 2012), so future studies intending to use such a feature may consider allowing users continued access to support learning. Furthermore, it is important that infographics are evidence-based and supported by behaviour change theory. A recent content analysis of online nutrition infographics revealed that inclusion of health behaviour theories such as self-regulation/self-control results in greater engagement (likes and comments). The infographics with greater health behaviour theory were more likely to contain a larger amount of text and photographs of real people (Wilkinson, Strickling, Payne, Jensen, & West, 2016).

Previous research has highlighted the importance of personalised feedback and reminders for maintaining user engagement with online programs (Alkhaldi et al., 2016; Crutzen et al., 2010). Our study, in line with other literature (Fukuoka, Kamitani, Bonnet, & Lindgren, 2011), found that users would prefer to alter the timing and frequency of such messages to suit their personal schedule. A recent study conducted with high income university educated young adults (Pollard et al., 2016) found they disliked authoritative and Gen Y toned messages. Contrastingly, in our study using a more generalizable sample of young adults, respondents preferred messages with an authoritative tone balanced by “comical” messages using Gen Y “slang”. It is possible that these variations are due to demographic differences. Our sample had representation from low socioeconomic strata, whereas their population included a majority of tertiary educated young adults in high paying employment. Another possibility could be factors such as perceived self-control and barriers. Furthermore, we found that the young adults disliked messages which suggested vegetables as a substitution for unhealthy foods. Prior work suggests that any mention of unhealthy foods may be counteractive and encourage further consumption (Woolford et al., 2011). As found in another smartphone intervention with young adults (Partridge et al., 2016), short, simple situational cues and tips, commonly referred to in literature as “just in time” messages (Fukuoka et al., 2011) were preferred instead. Research confirms that use of such event-based cues can support behaviour change (Nguyen et al., 2012) and assist with automaticity and habit formation (Stawarz et al., 2015), with a call for apps to go beyond self-monitoring by providing real-time habit support. Overall, it is expected that messages that resonate with certain individuals or groups may be of no value to others. In addressing these differences, researchers should always attempt to capture perspectives of the specific target audience during the design of public health messages.

Importantly, it was noted that the young adults were less motivated by the longer term health implications of improving vegetable intake. Other researchers have used the term “young invincibles” to describe this demographic who are more concerned with immediate and personally relevant outcomes of behaviours (Bibbins-Domingo & Burroughs Peña, 2010; Goodman & Sheeshka, 2016). This group expressed preference for messages centred on benefits such as improvements in skin (females) or body shape (males). Thus, future nutrition interventions should consider pitching the benefits of behaviour change in an age-appropriate manner.

Finally, findings indicated that social media could serve as an acceptable support platform in nutrition interventions with young adults. Participants preferred meal inspiration posts and recipe ideas, especially those with attractive food images. The young adults ranked awareness-raising and emotional support posts low. This contrasts to a recent study which explored the most popular Facebook posts on pages of 20 Australian public health organisations and found that emotionally appealing posts and those providing factual information had greater user engagement (Kite, Foley, Grunseit, & Freeman, 2016). However, only one of these Facebook pages was nutrition related and the age group interacting with the posts cannot be discerned. Furthermore, although research has suggested the development of active social media communities whereby users share new content to assist in improving engagement (Korda & Itani, 2013), the young adults of this study expressed reluctance to interact by posting on social networking sites themselves but were interested in viewing content created by others. These contrasting findings emphasise the importance of acceptability testing of intervention materials with a sample of the intended target audience.

4.1. Strengths and limitations

While researchers have examined the use of online platforms for behaviour change (Crutzen et al., 2010), few have explored preferences regarding nutrition specifically (Goodman & Sheeshka, 2016), with this paper being the first to report on preferences for an intervention targeted at increasing vegetable consumption. The focus groups gathered opinions from a broad range of young adults from Sydney. The demographic extended beyond the student population typically surveyed in studies with young adults. However, the findings may not be generalizable to other age groups or to all young adults, especially those from other countries with different cultures.

4.2. Conclusion and practical implications

Overall, a socially connected smartphone app is an acceptable medium for the delivery of a nutrition intervention to young adults. To specifically support improvements in vegetable intake, this population requires instructional guidance for skill development through situational cues, recipes and cooking demonstrations. The findings presented here may serve as a guide to researchers designing mobile phone based interventions aiming to improve other nutrition habits of young adults. The paper can provide a framework for exploring the inclusion of gaming and social technologies; and/or a summary of elements most likely to be accepted by this age group.

Young adults want nutrition apps that are simple in their design and use visual aids for self-monitoring. Gamification principles such as badges could help in maintaining motivation and engagement, but allowing users to personalise their rewards may be a more successful approach given the mixed response. Social media can serve as a platform for the delivery of support resources, however the credibility of the source of information must be well established and language to be used should be pre-tested with the target population. Researchers should also give careful consideration to what messages motivate behaviour change among their audience, and may need to focus on promotion of the immediate benefits as opposed to longer term implications in younger populations. Enlisting an expert from a nutrition/dietetics background for content development and a behavioural scientist for selection of relevant theory is recommended.

The findings from this study will be used to refine the design of our theory-based self-monitoring app developed specifically for young adults. To our knowledge, this will be the first smartphone intervention to combine social media and gaming to support improvements in vegetable intake in this population. The intervention will be piloted with evaluation of behavioural and psychological outcomes. User engagement will also be assessed to provide insight on the impact of these innovative strategies on behaviour.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.appet.2017.10.016.

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Chapter 8: Cooking videos reduce perception of barriers to home cooking with vegetables in young adults: focus group findings.

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8.1 Publication details

This chapter presents the manuscript titled 'Cooking videos reduce perception of barriers to home cooking with vegetables in young adults: focus group findings.' published in *Journal of the American College of Nutrition*, 2018 (see *Appendix 8*). It has been reformatted but contains exactly the same text.

8.2 Author contribution

I Monica Marina Nour (the candidate) was the primary researcher involved in developing the research question. I guided two Masters of Nutrition and Dietetics students (Ms Zilvia Cheng and Ms Jessica Farrow) through the process of producing the cooking videos and conducting the focus groups. The cooking videos were designed and filmed by the master's students who also assisted with summarising the results for the initial manuscript draft however the final manuscript was written by the candidate.

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8.3 Introduction to chapter

As detailed in n chapter 7, formative research revealed that cooking videos that build skills and provide modelling would be useful in supporting young adults to overcome some of their barriers to improving vegetable intake. This chapter describes the development of a series of short educational cooking videos designed for delivery through the smartphone and the findings from focus group testing which explored the acceptability of these videos.

8.4 Abstract

Objective: Digital platforms offer innovative opportunities for nutrition education to motivate young adults to improve eating behaviors and practices. This study aimed to pilot test short educational cooking videos for dissemination through a smartphone designed to address barriers to home cooking and vegetable consumption among young adults.

Method: Instructional videos (1–3 min) were produced and acceptability and perceived effectiveness for reducing barriers was investigated. Short free-response questions explored enablers of home cooking and feedback on the videos was collected through open discussion. Qualitative findings were coded using NVivo 11.

Results: Three focus groups with 16 young adults (mean age D 21.1 years) were conducted. Videos were well received and 9 of 13 participants who had low motivation to cook at baseline reported an increase in motivation post–video viewing. Perception of time as a barrier was reduced for 10 of 16 participants and thematic analysis revealed that accessibility to ingredients, ability to conceptualize recipes, and costsaving tips were key enablers to cooking with vegetables.

Conclusions: Short cooking videos may be a useful tool in interventions to address barriers to vegetable preparation and consumption among young adults. Future research should identify whether improvements in attitudes and motivation translate to change in intake.

8.5 Introduction

Healthy diets rich in vegetables have been linked to lower risks of chronic disease (1). The diet quality of Australians is poorest among young adults who have low intakes of fruits and vegetables (2) and regularly consume take-away meals. Only 1.6% and 4.1% of Australian males and females aged 18 to 30 years consume the recommended 5 or more vegetable servings per day (3). Similar patterns are observed in the United States and United Kingdom (4,5). With young adults gaining weight more rapidly than in previous generations (6), immediate support is required to improve their diet quality, particularly vegetable intake, which is associated with lower body weights (7).

Motivation and confidence are key determinants of behavior change (8,9). Young adults report several barriers that reduce their motivation for consuming vegetables, including limited time, perceived cost, poor knowledge of requirements, and/or the availability of convenient and cheap take-away options (10–15). Furthermore, young adults report poor cooking skills (16) and low levels of self-efficacy (confidence) for vegetable preparation (17). There is growing evidence linking low cooking confidence and poor cooking skills with poor food choices and greater consumption of convenience foods (18). Conversely, higher levels of cooking skills and consumption of home-cooked meals are positively correlated with mental wellbeing (19) and healthier eating patterns (20), including greater vegetable purchasing (21) and consumption (19,22). Thus, interventions should consider targeting cooking skills (including technical skills, e.g., chopping and steaming, and perceptual aspects, e.g., conceptualizing recipes and shopping for ingredients) as a prerequisite for increasing vegetable consumption and improving overall diet quality.

The Capability Opportunity Motivation and Behavior (COM-B) framework of behavior change specifies that there are multiple prerequisites related to performance of a given behavior. It expands beyond one's physical skills (capability) and includes psychological capability (knowledge), the opportunity an individual has to engage in the behavior (such as triggers within the environment), and motivation, which is influenced by reinforcements and the formation of automatic habitual responses (9). The body of work described in this paper focuses on enhancing cooking skills (capability) as one of the prerequisites to improving vegetable intake.

Formative research with young adults has highlighted that having a model for food preparation would be a significant motivator for cooking (14). This is supported by the social cognitive theory, which describes how skills are acquired through observational learning and modeling. Using behavioral modeling to increase self-efficacy in these learned skills may enhance motivation to make behavioral changes (23) and is one of the 93 behavior change techniques that inform the COM-B model (9,24).

A study testing the impact of a series of short TV cooking shows developed using social cognitive theory found that this style of intervention resulted in positive shifts in knowledge of vegetable requirements, but changes in motivators, barriers, self-efficacy, and intake were not significant (25). Another study compared cooking classes to demonstrations and found that the classes resulted in superior improvements in cooking enjoyment and self-efficacy

(26) and resulted in less frequent consumption of takeout meals. An Australian study investigating the effectiveness of a 10-week cooking class program yielded improvements in cooking skills, confidence, and mean vegetable intake among adults (27). To date, these effective programs have been delivered using either traditional face-to-face contact or online modules, where instructional guidance has been a key feature. A recent study with young adult females found that providing instruction on cooking meals from basic ingredients is a predictor of intention to cook and cooking con- fidence and enjoyment (28). There remains an opportunity to test whether instructional cooking videos delivered on portable devices such as smartphones are effective in changing confi- dence for cooking and, more specifically, vegetable intake.

With greater than 90% of young adults owning a smartphone and interacting with social networking sites (29,30), an opportunity exists to deliver cooking demonstrations via these easily accessible and wide-reaching media. This study describes the development and pilot testing of a series of short educational cooking videos designed for delivery on a smartphone. The videos were designed to be nutritionally balanced, address the common barriers to vegetable intake, and model the desired behavior. The focus groups aimed to test the acceptability of these cooking videos and understand changes in perception of barriers to home cooking and motivation for vegetable preparation and consumption after viewing the videos.

8.6 Materials and methods

The consolidated criteria for reporting qualitative research 32- item checklist provided the framework for study design, data analysis, and reporting of findings (31). The focus groups utilized a deductive approach to determine whether short cooking videos grounded in existing theory of behavior change are a feasible and acceptable strategy for enhancing confidence of young adults in cooking with vegetables. Likert-scale questions were used to capture quantitative data on attitudes and motivation to cook with vegetables. Qualitative feedback was gathered through open discussion to capture the acceptability and viewer perceptions of the short cooking videos.

Participants

Participants were recruited using a convenience sampling method through social media posts and flyers placed around one university in Sydney, Australia. Eligible participants were young adults aged 18 to 34 years. Nutrition students were excluded, as their knowledge, skills, and attitudes would not reflect those of most young adults. Potential participants were offered a $10 AUD shopping voucher as an incentive.

Recipe and video development

Fifteen recipes were developed by dietitians so that meals provided at least one serving of vegetables for breakfast, 2 servings for lunch, and 3 servings for dinner per person. Recipes were selected so that different types of dishes were represented. For example, both hot and cold dishes such as soups, stir-fries, vegetable omelettes, and salads were chosen. As previous research has indicated the popularity of “designer juices” among young adults (32), recipes for vegetable-based smoothies were also included. Consideration was given to ensure that recipes were simple, quickly prepared, and used basic cooking techniques. Seasonal availability of ingredients was considered in the design of recipes, and alternative ingredients provided where necessary. For example, in a salad recipe in which the summer fruit mango was used, pears were suggested as a substitute ingredient. A budget of $5 AUD per recipe serving was set to fall below the average cost of a take-away meal in Australia (33). The mean estimated cost per serving was calculated using pricing available on ordering websites of local supermarkets in 2016.

A total of 30 videos were produced, with each recipe filmed in two modes: (1) text only and (2) text and voice-over. The videos were instructional, providing nutritional, cost, and timesaving information. A still shot at the start of the video summarized the recipe cooking and preparation time, servings, and cost per serving (see Figure 8.1). Recipes were categorized and labeled based on the skill level required (easy, moderate, or advanced). Easy recipes required minimal skill and ingredient manipulation such as a salad, moderate recipes required some ingredient modification such as stir frying and advanced recipes required multiple cooking methods such as moussaka. Only the hands of the demonstrating chef were filmed and a voice-over or text overlay provided further recipe instructions. Video length ranged from 47 seconds to 2 minutes, 58 seconds.

Tips to address the commonly reported barriers to vegetable consumption were incorporated. To address concerns regarding cost of food, the videos displayed the cost per serving, suggested alternative locations to buy ingredients at a cheaper price, made comparisons to the more expensive cost of a similar meal when eating out, and placed emphasis on canned and frozen vegetables as cheaper, equally nutritious alternatives. To address time-efficiency, suggestions included buying precut vegetables and cooking in bulk and freezing.

Focus group design and data collection

Materials and methods for the cooking videos and focus groups were approved by the Institutional Human Research Ethics Committee (approval number 2016/304). Focus groups were conducted according to the methods recommended by Krueger and Casey (34). Three 90-minute sessions were conducted with a mix of males and females in each group. No further sessions were arranged, as no new concepts were generated in the third group. Focus groups were facilitated by the lead researcher, a female PhD candidate. Two dietetic researchers attended sessions as either a moderator (notetaker and timekeeper) or an interviewer (probing discussion). At the beginning of each focus group, the objectives were outlined and signed consent was obtained prior to commencing. Participants were informed that the Australian Dietary Guidelines recommend consuming at least 5 servings of vegetables per day.

Prior to viewing the videos, participants completed a questionnaire. Open-ended focus group questions used in a study by Jones et al. (14), which explored perceived motivators to home food preparation, were adapted into 7 Likertscale questions to assess attitudes to commonly perceived barriers to home cooking (10–15) and motivation to cook with vegetables. Six short free-response questions were used to investigate enablers of home cooking and frequency of eating home-cooked and take-away/convenience meals (see appendix 8.1).

The 30 videos were shown across the 3 focus groups for pilot testing. Videos were shown in both modes—voice-over and text only—and examples were chosen across all meals (breakfast, lunch, and dinner). For the purpose of testing in a group setting, the videos were played on a large screen in a conference room. During the viewing, participants completed a worksheet to indicate which mode they preferred and were instructed to write down reasons they liked or disliked particular videos. After all videos were shown, participants completed a second questionnaire with the Likert-scale questions on attitudes to commonly perceived barriers to home cooking and motivation to cook with vegetables. Then the focus group interviewer led an open group discussion regarding acceptability of the videos, asking participants to share their likes and dislikes. The main ideas were summarized and another opportunity was provided for final feedback.

Data analysis

Discussions were audiotaped and later transcribed. Content analysis of audio transcripts were conducted independently by two researchers using a focused coding process with NVivo 11 2015, version 11.0.0.317 (QSR International Pty Ltd., Melbourne, Victoria, Australia). A predetermined coding template was designed to guide thematic analysis. This was based on key research questions, including likes and dislikes, appropriateness of video length, perceived simplicity of recipes, ease of acquisition of ingredients, and cost-appropriateness. However, open coding was also used to create subthemes if a different idea was discussed or identified by more than 3 focus group participants. A third investigator assisted with the process of identifying common content, clustering answers, and categorizing patterns and themes. Results were summarized descriptively. Likert-scale responses were converted into numeric form and coded into a standardized spreadsheet (Microsoft Office Excel 2011 version 14.5.1, Microsoft Corporation, Redmond, WA, USA) by 2 researchers and checked by a third. Scores were compared to identify any immediate changes in attitudes toward barriers and motivation after viewing the videos.

Figure 8.1: Sample screenshots of the videos used for pilot testing of short cooking videos designed to model home cooking with vegetables. These videos were shown to young adult participants in a focus group setting. The screenshots show the recipe title, a still shot of the final product of the recipe, number of servings, cooking and preparation time, level of difficulty, and cost per serving, which were included in each video.

8.7 Results

Participant demographics

The young adults (10 females and 6 males) were aged between 18 and 29 years (mean D 21.1 years, standard deviation [SD] D 2.7). Twelve were full-time students, three were full-time workers, and one was unemployed. Fourteen participants were living at home with family and two lived out of home. On average, participants consumed 3 take-away meals per week (range D 1–7) and self-prepared 2.5 meals at home.

Frequency of home cooking

On average, participants consumed home-cooked meals on 5.1 (SD D 1.6) days per week, of which an average of 3 (SD D 1.5) were self-prepared.

Attitudes toward home cooking

Young adult males were primarily motivated to cook when hungry and food was not already available. One male expressed, *"I cook when hungry and parents aren't home."* Females more frequently indicated enjoyment as a motivator for cooking*: "I enjoy cooking, especially if I have found a new recipe to try."*

Thematic analysis of enablers to home cooking revealed three major factors that would increase motivation for selfpreparation of healthy meals. These were accessibility, ability to conceptualize recipes, and cost-saving tips.

Accessibility to fresh vegetables and utensils for preparation were identified as enablers to home cooking by 9 participants. A further 3 participants indicated that to enhance their accessibility to fresh vegetables they required knowledge of appropriate storage techniques to reduce spoilage. As one male summarizes, *"Having fresh vegetables at home would help, but the problem is that vegetables have a short life span."*

Six young adults expressed that support in conceptualizing recipes, including how to put together healthy dishes with vegetables without compromising on flavor, would motivate them to cook at home. As summarized by one female, *"I would like to know how to cook them (referring to vegetables) whilst also tasting nice."* The cost of these recipes would also greatly influence whether the young adults were likely to prepare the meal, as noted by a female participant, who suggested that *"... a tutorial on how to make quick, easy, and cheap veggie meals available online"* would increase motivation to cook with vegetables.

Time, cost, and cooking skills were the highest-ranked barriers to home cooking reported by participants before watching the videos. Some of these barriers were reduced after watching the videos (10, 9, and 7 participants indicated a reduction in perception of time, cooking skills, and cost as barriers, respectively). Nine out of the thirteen participants who had low motivation to cook with vegetables (score less than 4 on 5-point Likert scale) reported an increase in motivation post video viewing. While improvements in motivation were lower for males, overall, the young adults found the strategies addressing barriers to home cooking to be persuasive, as summarized by a male participant: *"I really liked the tips given, the time saving, money saving tips. As a student, money and time are my biggest challenges."*

Acceptability of cooking videos

Qualitative feedback on the cooking videos was organized under four themes: videography, mode preference, recipe design and demonstration, and suggestions for improvement.

Regarding videography, participants indicated that the bird's-eye angle of filming was important for providing a clear view of the recipe components and processes of each step. They also noted that the good lighting made the vegetables appealing, as summarized by one participant who said that the lighting *"highlighted the vibrant colors of the vegetables."* The upbeat jazz style music was better received than soft rock. It was described as *"engaging and catchy"* and essential for the textonly videos. The length of the videos was acceptable to the young adults, who suggested that they should not exceed 2 to 3 minutes.

With regard to mode preference, the majority (10 of 16) of the participants preferred text and voice-over compared to the text-only videos, especially for lunch and dinner recipes, which involved more steps compared to breakfast. The voice-over reportedly made the videos more *"engaging and personable."* Participants preferred when the persona projected enthusiasm and confidence in their tone, as the *"motivation in the voice transfers over to the audience."* Participants indicated that voice-over was the best way to deliver additional tips while avoiding increased text on the screen.

Regarding recipe design and demonstration, the recipes were perceived to be easy and replicable, with the exception of those that required several pan changes or advanced cooking skills. As one male stated, *"Some had too many steps. More steps means it's harder."* All participants were confident that the ingredients could be obtained at a large chain supermarket. Those who encountered an unfamiliar ingredient commented that this would not prevent an attempt at the recipe, with one participant suggesting that *"you can assume young people would search the Internet for any ingredient they weren't familiar with."*

On the topic of suggestions for improvement, participants liked the inclusion of nutrition information, such as the health benefits of vegetables, and suggested that future videos include calorie and macronutrient information in the recipe summary as absolute values and/or as percentage of daily intake. Further suggestions included providing tips on using leftover ingredients to minimize waste as well as storage techniques to extend shelf life. Many of the young adults expressed the need for demonstration of basic culinary skills including how to clean cooking appliances such as blenders and how to chop vegetables.

8.8 Discussion

The results of this pilot study demonstrated that short cooking videos are an acceptable platform for addressing barriers to home cooking and can improve motivation to cook with vegetables among young adults. Encouraging this population to engage in food preparation has been linked with greater frequency of cooking in later life (35). With previous literature highlighting the nutritional and health benefits of home-cooked meals (15,22), investing in building the cooking skills and con- fidence of young adults can help to reduce the burden of preventable chronic disease.

Young adults are typically time-poor, juggling busy work and study schedules. They also have limited disposable income, with two-thirds of Australian students earning less than $20,000 per year (36). These videos addressed the perception of cost and time as barriers to home cooking, with money-saving tips, such as shopping at alternative retailers, appreciated by participants. This is in agreement with research highlighting that young adults are willing to shop at local independent grocers and specialty grocery stores, with only 41% of food purchased from traditional large chain supermarkets (37). Of importance, it became apparent that basic food preparation skills were lacking among many, who felt they needed more information about chopping, washing, and storing vegetables correctly. As a result, future food skill interventions should not overlook the importance of demonstrating fundamental culinary skills.

While motivation to cook with vegetables improved minimally among males, other research suggests that males are interested in exploring new ways to promote the health benefits of vegetables to other young men (38). Future research should test whether the use of a male persona as the model for food preparation is more motivating for young men, particularly since men tend to be motivated to engage in healthy behaviors if it is socially acceptable among their peers (39).

The cooking videos in this study were generally well received by all participants. Therefore, on-screen modeling of cooking, with additional nutritional information and time- and moneysaving strategies delivered by voice-over, can be considered as an alternative to face-to-face cooking demonstrations. We did not measure the impact of the videos on cooking and dietary behavior, however, and a previous study using television cooking shows found no significant differences in dietary outcomes at 4-month follow-up despite initial improvements in self-effi- cacy, cooking confidence, and motivation after viewing the videos (25). Thus, the cooking videos pilot tested in this study may not be sufficient for sustainable behavior change and should be integrated with other strategies for developing longer-term habits, including addressing an individual's environmental triggers and providing positive reinforcement to encourage habit formation as outlined in the COM-B framework of behavior change.

There are a number of limitations in this study that prevent the results from being generalized to the population at large. The use of convenience sampling resulted in the inclusion of mainly university students living at home. Although this sample may not be completely representative of the national population of young adults, more than 50% of young adults in Australia are undergoing some form of tertiary education (40). As this was a pilot study, the sample size was small. While this may have limited discussion, the experienced moderator used neutral prompts to encourage and maximize idea generation. In addition, only immediate shifts in attitudes and motivation were measured. The link among cooking confidence, cooking skills, and dietary patterns (18,21,22) warrants further research to determine whether the improvements in attitudes and motivation toward cooking with vegetables instilled by these videos translate to changes in intake over time. Considering the socioeconomic differences in time spent cooking and vegetable purchasing and consumption (41–43), future work should recruit a socially and economically diverse sample, with a particular focus on young men given their particularly low vegetable intake (2). Furthermore, it was evident that the sampled university students were not largely responsible for cooking, with the majority of food prepared by their parents. Thus, future testing of the impact of these videos on vegetable intake should endeavor to recruit university students or other young adults who live outside of home and are responsible for their own meal provision.

8.9 Conclusions and practical implications

Young adults are a challenging population group to engage in nutrition behavior change, and innovative strategies are required to deliver nutrition education. The findings presented here may serve as a guide to researchers designing and pilot testing video-based interventions for improving nutrition habits of young adults. The short cooking videos were well received, and preliminary testing suggested that they were an effective medium for reducing perception of barriers to cooking with vegetables among young adults. Equipping young adults with knowledge and skills and reducing their barriers is one important step in the behavior change process; however, future research is needed to identify whether improvements in attitudes and motivation resulting from video viewing translate to improvements in vegetable intake. These cooking videos will be included as one educational component of a larger 4-week study for improving vegetable intake in a more diverse sample of young adults. This intervention will use the COM-B behavior change framework, with the videos improving capability by building skills and increasing motivation by their visual appeal. The program will be delivered through social media and a self-monitoring app.

8.10 Acknowledgments

Materials and methods for the cooking videos and focus groups were approved by the Institutional Human Research Ethics Committee (approval number 2016/304). The lead researcher (a PhD candidate) was supported by the Australian Postgraduate Award Scholarship.

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8.11 Conclusions to Chapter

In summary, the short cooking videos were well received by the young adults. They effectively addressed barriers to cooking with vegetables such as time, cooking skills and cost. Improving cooking skills is one important component of increasing food literacy. For sustained behaviour change, the cooking videos should be used as an educational resource within a larger multicomponent intervention that addresses other aspects of food literacy such as meal planning.

Appendix 8

Appendix 8.1
Questionnaire used in focus group to measure barriers and enablers to cooking with vegetables

Pre-questionnaire

Pilot Testing of Short Cooking Videos

Demographics

1. Age: _______

2. Gender

- ☐ Male
- ☐ Female

3. Living situation

- ☐ Living with parent(s)/family members
- ☐ Living alone
- ☐ Living with housemates off campus
- ☐ Living on campus

4. Occupation

- ☐ Student Area of study: ______________
- ☐ Worker Industry: ______________
  - ☐ Part-time
  - ☐ Full-time
- ☐ Unemployed

Dietary behaviour

1. How many days per week do you consume home cooked meals?

2. How many of these home cooked meals do you prepare/cook yourself

3. If you do, list reasons why you cook.

4. How many days/week do you eat takeaway or convenience (e.g. frozen meals) foods?

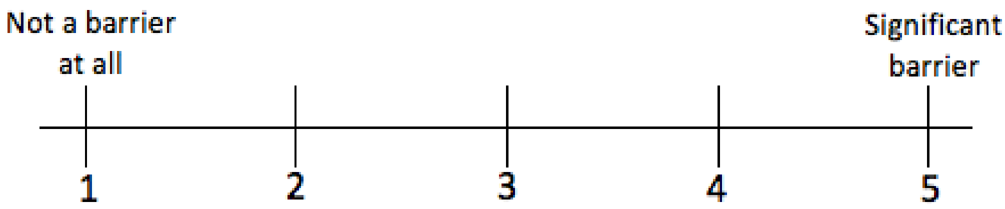
5. Who does the main grocery shopping in your household?

6. What would make it easier for you to cook with vegetables at home?

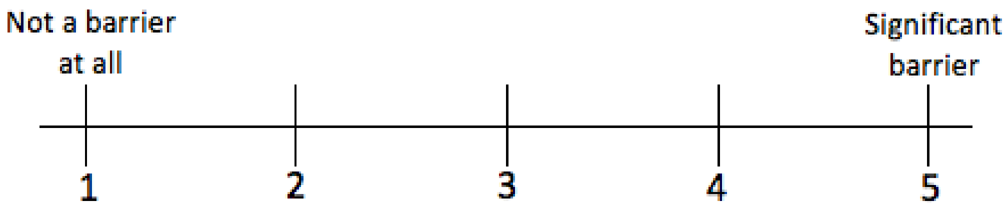
Dietary attitudes:

1. Rate the following barriers to cooking by marking with an 'X' on the scale.

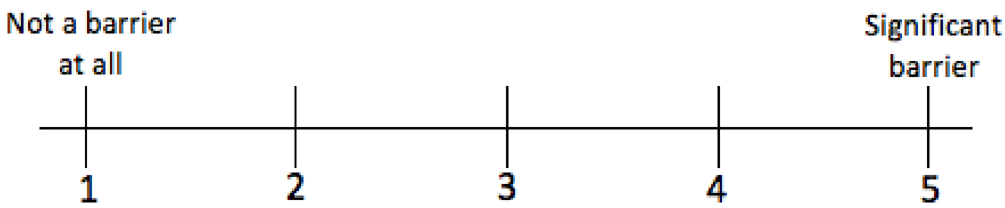
a. Time consuming



b. Lack of nutrition knowledge



c. Cost



d. Lack of cooking/preparation skills

Not a barrier at all — Significant barrier

1 2 3 4 5

e. Availability of more convenient alternatives (e.g. takeaway, ready-made meals)

Not a barrier at all — Significant barrier

1 2 3 4 5

f. Lack of interest/desire/enjoyment for food preparation

Not a barrier at all — Significant barrier

1 2 3 4 5

2. How motivated are you to cook with vegetables?

Not motivated at all — Very motivated

1 2 3 4 5

Appendix 8.2

Publication resulting from Chapter Eight, Journal of the American College of Nutrition, 2018
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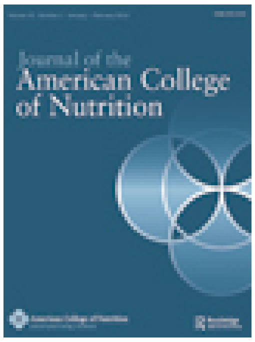
(See next page)



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Short Videos Addressing Barriers to Cooking with Vegetables in Young Adults: Pilot Testing

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Short Videos Addressing Barriers to Cooking with Vegetables in Young Adults: Pilot Testing

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ABSTRACT

Objective: Digital platforms offer innovative opportunities for nutrition education to motivate young adults to improve eating behaviors and practices. This study aimed to pilot test short educational cooking videos for dissemination through a smartphone designed to address barriers to home cooking and vegetable consumption among young adults.

Method: Instructional videos (1–3 min) were produced and acceptability and perceived effectiveness for reducing barriers was investigated. Short free-response questions explored enablers of home cooking and feedback on the videos was collected through open discussion. Qualitative findings were coded using NVivo 11.

Results: Three focus groups with 16 young adults (mean age = 21.1 years) were conducted. Videos were well received and 9 of 13 participants who had low motivation to cook at baseline reported an increase in motivation post–video viewing. Perception of time as a barrier was reduced for 10 of 16 participants and thematic analysis revealed that accessibility to ingredients, ability to conceptualize recipes, and cost-saving tips were key enablers to cooking with vegetables.

Conclusions: Short cooking videos may be a useful tool in interventions to address barriers to vegetable preparation and consumption among young adults. Future research should identify whether improvements in attitudes and motivation translate to change in intake.

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Young adults; vegetables; cooking; smartphones; nutrition education

Introduction

Healthy diets rich in vegetables have been linked to lower risks of chronic disease (1). The diet quality of Australians is poorest among young adults who have low intakes of fruits and vegetables (2) and regularly consume take-away meals. Only 1.6% and 4.1% of Australian males and females aged 18 to 30 years consume the recommended 5 or more vegetable servings per day (3). Similar patterns are observed in the United States and United Kingdom (4,5). With young adults gaining weight more rapidly than in previous generations (6), immediate support is required to improve their diet quality, particularly vegetable intake, which is associated with lower body weights (7).

Motivation and confidence are key determinants of behavior change (8,9). Young adults report several barriers that reduce their motivation for consuming vegetables, including limited time, perceived cost, poor knowledge of requirements, and/or the availability of convenient and cheap take-away options (10–15). Furthermore, young adults report poor cooking skills (16) and low levels of self-efficacy (confidence) for vegetable preparation (17). There is growing evidence linking low cooking confidence and poor cooking skills with poor food choices and greater consumption of convenience foods (18). Conversely, higher levels of cooking skills and consumption of home-cooked meals are positively correlated with mental well-being (19) and healthier eating patterns (20), including greater vegetable purchasing (21) and consumption (19,22). Thus, interventions should consider targeting cooking skills (including technical skills, e.g., chopping and steaming, and perceptual aspects, e.g., conceptualizing recipes and shopping for ingredients) as a prerequisite for increasing vegetable consumption and improving overall diet quality.

The Capability Opportunity Motivation and Behavior (COM-B) framework of behavior change specifies that there are multiple prerequisites related to performance of a given behavior. It expands beyond one's physical skills (capability) and includes psychological capability (knowledge), the opportunity an individual has to engage in the behavior (such as triggers within the environment), and motivation, which is influenced by reinforcements and the formation of automatic habitual responses (9). The body of work described in this paper focuses on enhancing cooking skills (capability) as one of the prerequisites to improving vegetable intake.

Formative research with young adults has highlighted that having a model for food preparation would be a significant motivator for cooking (14). This is supported by the social cognitive theory, which describes how skills are acquired through observational learning and modeling. Using behavioral modeling to increase self-efficacy in these learned skills may enhance motivation to make behavioral changes (23) and is one of the

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93 behavior change techniques that inform the COM-B model (9,24).

A study testing the impact of a series of short TV cooking shows developed using social cognitive theory found that this style of intervention resulted in positive shifts in knowledge of vegetable requirements, but changes in motivators, barriers, self-efficacy, and intake were not significant (25). Another study compared cooking classes to demonstrations and found that the classes resulted in superior improvements in cooking enjoyment and self-efficacy (26) and resulted in less frequent consumption of takeout meals. An Australian study investigating the effectiveness of a 10-week cooking class program yielded improvements in cooking skills, confidence, and mean vegetable intake among adults (27). To date, these effective programs have been delivered using either traditional face-to-face contact or online modules, where instructional guidance has been a key feature. A recent study with young adult females found that providing instruction on cooking meals from basic ingredients is a predictor of intention to cook and cooking confidence and enjoyment (28). There remains an opportunity to test whether instructional cooking videos delivered on portable devices such as smartphones are effective in changing confidence for cooking and, more specifically, vegetable intake.

With greater than 90% of young adults owning a smartphone and interacting with social networking sites (29,30), an opportunity exists to deliver cooking demonstrations via these easily accessible and wide-reaching media. This study describes the development and pilot testing of a series of short educational cooking videos designed for delivery on a smartphone. The videos were designed to be nutritionally balanced, address the common barriers to vegetable intake, and model the desired behavior. The focus groups aimed to test the acceptability of these cooking videos and understand changes in perception of barriers to home cooking and motivation for vegetable preparation and consumption after viewing the videos.

Materials and methods

The consolidated criteria for reporting qualitative research 32-item checklist provided the framework for study design, data analysis, and reporting of findings (31). The focus groups utilized a deductive approach to determine whether short cooking videos grounded in existing theory of behavior change are a feasible and acceptable strategy for enhancing confidence of young adults in cooking with vegetables. Likert-scale questions were used to capture quantitative data on attitudes and motivation to cook with vegetables. Qualitative feedback was gathered through open discussion to capture the acceptability and viewer perceptions of the short cooking videos.

Participants

Participants were recruited using a convenience sampling method through social media posts and flyers placed around one university in Sydney, Australia. Eligible participants were young adults aged 18 to 34 years. Nutrition students were excluded, as their knowledge, skills, and attitudes would not reflect those of most young adults. Potential participants were offered a $10 AUD shopping voucher as an incentive.

Recipe and video development

Fifteen recipes were developed by dietitians so that meals provided at least one serving of vegetables for breakfast, 2 servings for lunch, and 3 servings for dinner per person. Recipes were selected so that different types of dishes were represented. For example, both hot and cold dishes such as soups, stir-fries, vegetable omelettes, and salads were chosen. As previous research has indicated the popularity of "designer juices" among young adults (32), recipes for vegetable-based smoothies were also included. Consideration was given to ensure that recipes were simple, quickly prepared, and used basic cooking techniques. Seasonal availability of ingredients was considered in the design of recipes, and alternative ingredients provided where necessary. For example, in a salad recipe in which the summer fruit mango was used, pears were suggested as a substitute ingredient. A budget of $5 AUD per recipe serving was set to fall below the average cost of a take-away meal in Australia. The mean estimated cost per serving was calculated using pricing available on ordering websites of local supermarkets in 2016.

A total of 30 videos were produced, with each recipe filmed in two modes: (1) text only and (2) text and voice-over. The videos were instructional, providing nutritional, cost, and time-saving information. A still shot at the start of the video summarized the recipe cooking and preparation time, servings, and cost per serving (see Figure 1). Recipes were categorized and labeled based on the skill level required (easy, moderate, or advanced). Only the hands of the demonstrating chef were filmed and a voice-over or text overlay provided further recipe instructions. Video length ranged from 47 seconds to 2 minutes, 58 seconds.

Tips to address the commonly reported barriers to vegetable consumption were incorporated. To address concerns regarding cost of food, the videos displayed the cost per serving, suggested alternative locations to buy ingredients at a cheaper price, made comparisons to the more expensive cost of a similar meal when eating out, and placed emphasis on canned and frozen vegetables as cheaper, equally nutritious alternatives. To address time-efficiency, suggestions included buying precut vegetables and cooking in bulk and freezing.

Focus group design and data collection

Materials and methods for the cooking videos and focus groups were approved by the Institutional Human Research Ethics Committee (approval number 2016/304). Focus groups were conducted according to the methods recommended by Krueger and Casey (33). Three 90-minute sessions were conducted with a mix of males and females in each group. No further sessions were arranged, as no new concepts were generated in the third group. Focus groups were facilitated by the lead researcher, a female PhD candidate. Two dietetic researchers attended sessions as either a moderator (notetaker and timekeeper) or an interviewer (probing discussion). At the beginning of each focus group, the objectives were outlined and signed consent was obtained prior to commencing. Participants were informed that the Australian Dietary Guidelines recommend consuming at least 5 servings of vegetables per day.

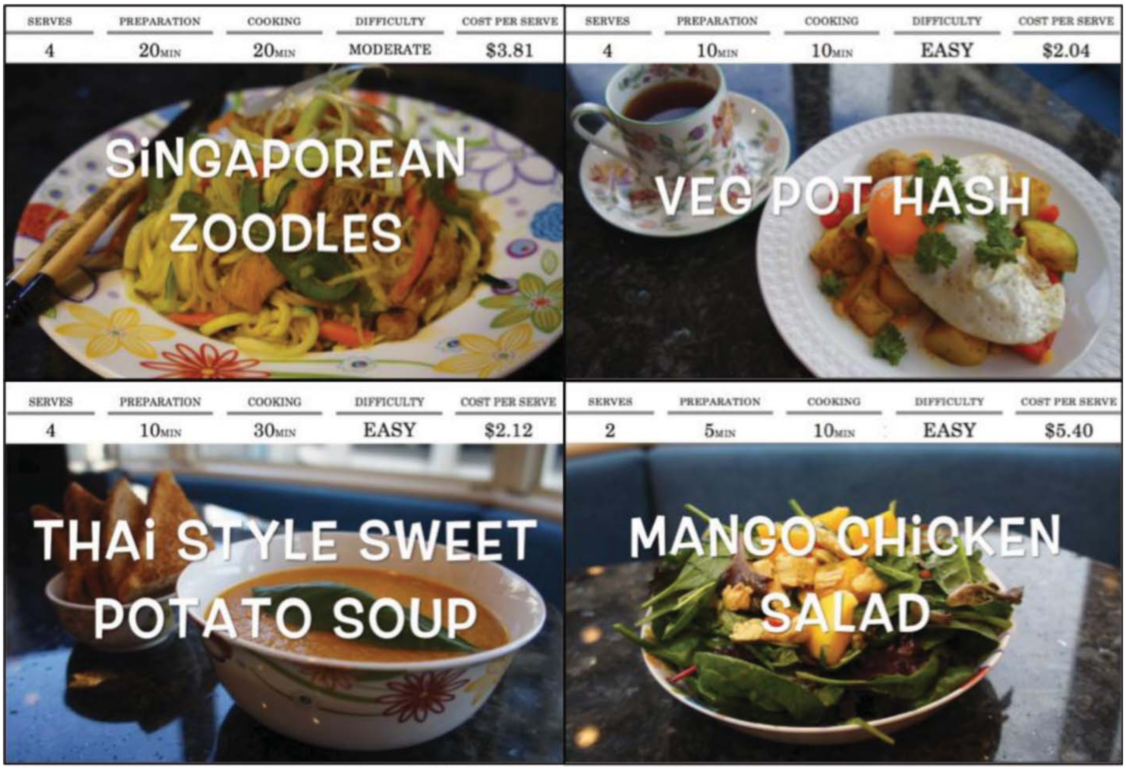

Figure 1. Sample screenshots of the videos used for pilot testing of short cooking videos designed to model home cooking with vegetables. These videos were shown to young adult participants in a focus group setting. The screenshots show the recipe title, a still shot of the final product of the recipe, number of servings, cooking and preparation time, level of difficulty, and cost per serving, which were included in each video.

Prior to viewing the videos, participants completed a questionnaire. Open-ended focus group questions used in a study by Jones et al. (14), which explored perceived motivators to home food preparation, were adapted into 7 Likert-scale questions to assess attitudes to commonly perceived barriers to home cooking (10–15) and motivation to cook with vegetables. Six short free-response questions were used to investigate enablers of home cooking and frequency of eating home-cooked and take-away/convenience meals (see supplementary material 1).

The 30 videos were shown across the 3 focus groups for pilot testing. Videos were shown in both modes—voice-over and text only—and examples were chosen across all meals (breakfast, lunch, and dinner). For the purpose of testing in a group setting, the videos were played on a large screen in a conference room. During the viewing, participants completed a worksheet to indicate which mode they preferred and were instructed to write down reasons they liked or disliked particular videos. After all videos were shown, participants completed a second questionnaire with the Likert-scale questions on attitudes to commonly perceived barriers to home cooking and motivation to cook with vegetables. Then the focus group interviewer led an open group discussion regarding acceptability of the videos, asking participants to share their likes and dislikes. The main ideas were summarized and another opportunity was provided for final feedback.

Data analysis

Discussions were audiotaped and later transcribed. Content analysis of audio transcripts were conducted independently by two researchers using a focused coding process with NVivo 11 2015, version 11.0.0.317 (QSR International Pty Ltd., Melbourne, Victoria, Australia). A predetermined coding template was designed to guide thematic analysis. This was based on key research questions, including likes and dislikes, appropriateness of video length, perceived simplicity of recipes, ease of acquisition of ingredients, and cost-appropriateness. However, open coding was also used to create subthemes if a different idea was discussed or identified by more than 3 focus group participants. A third investigator assisted with the process of identifying common content, clustering answers, and categorizing patterns and themes. Results were summarized descriptively. Likert-scale responses were converted into numeric form and coded into a standardized spreadsheet (Microsoft Office Excel 2011 version 14.5.1, Microsoft Corporation, Redmond, WA, USA) by 2 researchers and checked by a third. Scores were compared to identify any immediate changes in attitudes toward barriers and motivation after viewing the videos.

Results

Participant demographics

The young adults (10 females and 6 males) were aged between 18 and 29 years (mean = 21.1 years, standard deviation [SD] = 2.7). Twelve were full-time students, three were full-time workers, and one was unemployed. Fourteen participants were living at home with family and two lived out of home. On average, participants consumed 3 take-away meals per week (range = 1–7) and self-prepared 2.5 meals at home.

Frequency of home cooking

On average, participants consumed home-cooked meals on 5.1 (SD = 1.6) days per week, of which an average of 3 (SD = 1.5) were self-prepared.

Attitudes toward home cooking

Young adult males were primarily motivated to cook when hungry and food was not already available. One male expressed, "I cook when hungry and parents aren't home." Females more frequently indicated enjoyment as a motivator for cooking: "I enjoy cooking, especially if I have found a new recipe to try."

Thematic analysis of enablers to home cooking revealed three major factors that would increase motivation for self-preparation of healthy meals. These were accessibility, ability to conceptualize recipes, and cost-saving tips.

Accessibility to fresh vegetables and utensils for preparation were identified as enablers to home cooking by 9 participants. A further 3 participants indicated that to enhance their accessibility to fresh vegetables they required knowledge of appropriate storage techniques to reduce spoilage. As one male summarizes, "Having fresh vegetables at home would help, but the problem is that vegetables have a short life span."

Six young adults expressed that support in conceptualizing recipes, including how to put together healthy dishes with vegetables without compromising on flavor, would motivate them to cook at home. As summarized by one female, "I would like to know how to cook them (referring to vegetables) whilst also tasting nice." The cost of these recipes would also greatly influence whether the young adults were likely to prepare the meal, as noted by a female participant, who suggested that "… a tutorial on how to make quick, easy, and cheap veggie meals available online" would increase motivation to cook with vegetables.

Time, cost, and cooking skills were the highest-ranked barriers to home cooking reported by participants before watching the videos. Some of these barriers were reduced after watching the videos (10, 9, and 7 participants indicated a reduction in perception of time, cooking skills, and cost as barriers, respectively). Nine out of the thirteen participants who had low motivation to cook with vegetables (score less than 4 on 5-point Likert scale) reported an increase in motivation post video viewing. While improvements in motivation were lower for males, overall, the young adults found the strategies addressing barriers to home cooking to be persuasive, as summarized by a male participant: "I really liked the tips given, the time saving, money saving tips. As a student, money and time are my biggest challenges."

Acceptability of cooking videos

Qualitative feedback on the cooking videos was organized under four themes: videography, mode preference, recipe design and demonstration, and suggestions for improvement.

Regarding videography, participants indicated that the bird's-eye angle of filming was important for providing a clear view of the recipe components and processes of each step. They also noted that the good lighting made the vegetables appealing, as summarized by one participant who said that the lighting "highlighted the vibrant colors of the vegetables." The upbeat jazz style music was better received than soft rock. It was described as "engaging and catchy" and essential for the text-only videos. The length of the videos was acceptable to the young adults, who suggested that they should not exceed 2 to 3 minutes.

With regard to mode preference, the majority (10 of 16) of the participants preferred text and voice-over compared to the text-only videos, especially for lunch and dinner recipes, which involved more steps compared to breakfast. The voice-over reportedly made the videos more "engaging and personable." Participants preferred when the persona projected enthusiasm and confidence in their tone, as the "motivation in the voice transfers over to the audience." Participants indicated that voice-over was the best way to deliver additional tips while avoiding increased text on the screen.

Regarding recipe design and demonstration, the recipes were perceived to be easy and replicable, with the exception of those that required several pan changes or advanced cooking skills. As one male stated, "Some had too many steps. More steps means it's harder." All participants were confident that the ingredients could be obtained at a large chain supermarket. Those who encountered an unfamiliar ingredient commented that this would not prevent an attempt at the recipe, with one participant suggesting that "you can assume young people would search the Internet for any ingredient they weren't familiar with."

On the topic of suggestions for improvement, participants liked the inclusion of nutrition information, such as the health benefits of vegetables, and suggested that future videos include calorie and macronutrient information in the recipe summary as absolute values and/or as percentage of daily intake. Further suggestions included providing tips on using leftover ingredients to minimize waste as well as storage techniques to extend shelf life. Many of the young adults expressed the need for demonstration of basic culinary skills including how to clean cooking appliances such as blenders and how to chop vegetables.

Discussion

The results of this pilot study demonstrated that short cooking videos are an acceptable platform for addressing barriers to home cooking and can improve motivation to cook with vegetables among young adults. Encouraging this population to engage in food preparation has been linked with greater frequency of cooking in later life (34). With previous literature highlighting the nutritional and health benefits of home-cooked meals (15,22), investing in building the cooking skills and confidence of young adults can help to reduce the burden of preventable chronic disease.

Young adults are typically time-poor, juggling busy work and study schedules. They also have limited disposable income, with two-thirds of Australian students earning less than $20,000 per year (35). These videos addressed the perception of cost and time as barriers to home cooking, with money-saving tips, such as shopping at alternative retailers, appreciated by participants. This is in agreement with research highlighting that young adults are willing to shop at local independent grocers and specialty grocery stores, with only 41% of food purchased from traditional large chain supermarkets (36). Of importance, it became apparent that basic food preparation skills were lacking among many, who felt they needed more information about chopping, washing, and storing vegetables correctly. As a result, future food skill interventions should not overlook the importance of demonstrating fundamental culinary skills.

While motivation to cook with vegetables improved minimally among males, other research suggests that males are interested in exploring new ways to promote the health benefits of vegetables to other young men (37). Future research should test whether the use of a male persona as the model for food preparation is more motivating for young men, particularly since men tend to be motivated to engage in healthy behaviors if it is socially acceptable among their peers (38).

The cooking videos in this study were generally well received by all participants. Therefore, on-screen modeling of cooking, with additional nutritional information and time- and money-saving strategies delivered by voice-over, can be considered as an alternative to face-to-face cooking demonstrations. We did not measure the impact of the videos on cooking and dietary behavior, however, and a previous study using television cooking shows found no significant differences in dietary outcomes at 4-month follow-up despite initial improvements in self-efficacy, cooking confidence, and motivation after viewing the videos (25). Thus, the cooking videos pilot tested in this study may not be sufficient for sustainable behavior change and should be integrated with other strategies for developing longer-term habits, including addressing an individual's environmental triggers and providing positive reinforcement to encourage habit formation as outlined in the COM-B framework of behavior change.

There are a number of limitations in this study that prevent the results from being generalized to the population at large. The use of convenience sampling resulted in the inclusion of mainly university students living at home. Although this sample may not be completely representative of the national population of young adults, more than 50% of young adults in Australia are undergoing some form of tertiary education (39). As this was a pilot study, the sample size was small. While this may have limited discussion, the experienced moderator used neutral prompts to encourage and maximize idea generation. In addition, only immediate shifts in attitudes and motivation were measured. The link among cooking confidence, cooking skills, and dietary patterns (18,21,22) warrants further research to determine whether the improvements in attitudes and motivation toward cooking with vegetables instilled by these videos translate to changes in intake over time. Considering the socioeconomic differences in time spent cooking and vegetable purchasing and consumption (40–42), future work should recruit a socially and economically diverse sample, with a particular focus on young men given their particularly low vegetable intake (2). Furthermore, it was evident that the sampled university students were not largely responsible for cooking, with the majority of food prepared by their parents. Thus, future testing of the impact of these videos on vegetable intake should endeavor to recruit university students or other young adults who live outside of home and are responsible for their own meal provision.

Conclusions and practical implications

Young adults are a challenging population group to engage in nutrition behavior change, and innovative strategies are required to deliver nutrition education. The findings presented here may serve as a guide to researchers designing and pilot testing video-based interventions for improving nutrition habits of young adults. The short cooking videos were well received, and preliminary testing suggested that they were an effective medium for reducing perception of barriers to cooking with vegetables among young adults. Equipping young adults with knowledge and skills and reducing their barriers is one important step in the behavior change process; however, future research is needed to identify whether improvements in attitudes and motivation resulting from video viewing translate to improvements in vegetable intake. These cooking videos will be included as one educational component of a larger 4-week study for improving vegetable intake in a more diverse sample of young adults. This intervention will use the COM-B behavior change framework, with the videos improving capability by building skills and increasing motivation by their visual appeal. The program will be delivered through social media and a self-monitoring app.

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Author contributions

MAF, MN, ZGYC, and JLF conceived the study design. ZGYC and JLF developed the cooking videos; MN, ZGYC, and JLF collected data and conducted data analysis. ZGYC and MN drafted the initial manuscript. All authors read and approved the final manuscript.

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Chapter 9: A factorial study to evaluate intervention components delivered via social media and mobile gaming to improve the vegetable intake of young adults

9.1 Publication details

Some of the material from this chapter has been reproduced in a manuscript titled ‘Young adult’s engagement with a self-monitoring app for vegetable intake and the impact of social media and gamification’ for submission to the *Journal of Medical Internet Research mHealth and uHealth*

9.2 Introduction to Chapter

The formative research conducted in Chapters 7 and 8 were used to refine the program materials for inclusion in this four week intervention to improve the vegetable intake of young adults designed based on The Behaviour Change Wheel (1). This chapter details the results of the feasibility study administered using a factorial study design. The impact of social support (through social media) and incentivisation (through gamification) on outcomes and engagement are discussed.

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9.3 Introduction

Research has demonstrated the link between increased vegetable consumption, reduced all-cause mortality and death from cardiovascular disease and some cancers (2). Poor vegetable consumption is a global concern; with the World Health Organisation (WHO) launching a joint initiative with the Food and Agriculture Organization (FAO) to improve intake (3). Population-wide consumption of vegetables is inadequate (4, 5), but young adults are the lowest consumers among adults in Australia (4) and the United States (5). The Australian Dietary Guidelines recommend five and six serves of vegetables daily for females and males respectively (6). Current intakes sit well below this standard with a mean of 2.8 serves consumed per day among 18-34 year olds (7).Young adults are a vulnerable population group at high risk for weight gain (8, 9). Inadequate consumption of fruits and vegetables is one lifestyle factor which has been shown to play a role in the aetiology of weight gain (10). Recent evidence has demonstrated that vegetables mediate approximately 20% of weight loss in young adults (11).

As this age group are typically less risk aversive and are unconcerned with longer term benefits of healthful behaviours (12-14), novel age-relevant strategies are required to motivate behaviour change (15, 16). A particular focus on vegetables, as opposed to fruit and vegetables in combination is required as research indicates poorer knowledge of vegetable serves (17, 18) and greater reported barriers to vegetable consumption than fruit (19). Knowledge of dietary recommendations is a determinant of healthier eating patterns among young adults (20) so it is imperative that this underlying poor knowledge is addressed. Young adults also have low levels of self-efficacy for planning and practicing healthful dietary behaviours (21), with commonly reported barriers to vegetable intake including; their undesirable taste, low levels of cooking literacy and food preparation skills, the perceived expense of purchasing vegetables, and the time required to prepare them (22-27).

Information and communication technology (eHealth) interventions may be a suitable approach for providing tools that address these barriers and engage young adults in behaviour change (28). In 2016 it was estimated that 92% and 95% of young adults owned a smartphone in the US and Australia respectively (29). Furthermore, 2018 statistics show that young adults are the most frequent users of multiple social media platforms (30), with 91% of 18-29 year olds using their devices for social networking (31). In the last decade, social media has been rapidly adopted by researchers for health promotion, education and behavior change, as it aligns with social cognitive theory (32, 33). The social support, interactive sharing of content, peer influence and empowerment (reinforcement and gratification) that social media offers may motivate users and enhance engagement with interventions (34-36). However, social networking alone may not be sufficient to change behavior, as recent reviews indicate social media networks are frequently part of a multicomponent intervention and independent effects cannot be discerned readily (35-40).

Gamification whereby game strategies are used to motivate behavior change, is another strategy that can be delivered using technology and is becoming popular among public health interventions (41). Gaming has been shown to have positive impacts on physical activity levels, and nutrition knowledge (40). However, research demonstrating its effectiveness in improving nutrition behavior of young adults is limited (40).

The effectiveness of programs using modern information and communication technology to deliver theory-based behaviour change interventions is dependent on user engagement (42). Self-monitoring and regulation are most frequently incorporated as essential strategies for behavior change (43, 44). However, few studies report on user engagement and satisfaction with interventions delivered using modern communication platforms and more evidence concerning gaming and social networking strategies in interventions is required (38, 40). The available evidence indicates that dropout rates are high in social media based studies (38). It has been suggested that use of interactive strategies, gaming or competitions may increase retention (45).

This factorial study aimed to determine the feasibility of delivering a four week vegetable program using apps and social media to deliver various Behaviour Change Techniques. The secondary objective was to assess if the addition of gaming (incentivisation) and/or social support enhance behaviour change when compared to a standard app that provides goal setting, self-monitoring and feedback only. Due to the reported low level of adherence in interventions delivered through modern communication platforms, we also assessed if any of the new modalities increase engagement.

The primary outcome of interest was the change in vegetable intake, with secondary outcomes exploring engagement with program components, self-efficacy and motivation for vegetable consumption, knowledge of daily intake recommendations and standard serve sizes, and habit formation. It was hypothesised that the combination of social media and gamification strategies will be most effective in improving the vegetable intake of young adults, offering more social support than the gamified app or the standard goal setting, monitoring and feedback app.

9.4 Methods

Intervention development

This intervention was designed using The Behaviour Change Wheel as a framework (46). The theoretical background and a detailed description of the intervention functions have been previously documented (see Chapter 6). The process of developing this intervention followed a user-driven approach whereby proposed program materials were tested for acceptability with a sample of the target audience then refined. The outcomes of acceptability testing are reported in Chapters 7 and 8. Table 9.1 presents the refined program components, the specific behaviour change techniques applied, their context within the COM-B framework and their application within the intervention. The proposed smartphone app prototypes described in Chapters 6 and 7 were re-designed based on the feedback collected in user acceptability testing. In appendix 8.1 we present the wire frames which show the re-development of the app, and all the proposed features and functions.

Study design

Collins and colleagues have outlined a methodological approach for development and testing of eHealth interventions called Multiphase Optimization Strategy (MOST) (47). The MOST method uses a three stage approach to intervention design. The first is the screening phase, in which the effectiveness of program components are studied to efficiently identify which are the active ingredients to be included in an intervention. It is suggested that factorial designs are adopted when testing different components for an electronic intervention (48). In the second stage of MOST, the performance of intervention components guides program refinement whereby fine-tuning of the selected components occurs such as determining the optimal level of delivery. Lastly, there is a confirming phase, during which the optimised intervention comprising the key components is evaluated using a randomised controlled study design. This chapter presents the screening phase, whereby feasibility testing of the proposed program components was conducted using a 2 × 2 factorial study design (standard goal setting and self-monitoring app vs. gamified x social support vs. no social support). This design allowed for the comparison of four different conditions to determine the active ingredients for inclusion in an intervention.

As such participants were randomised into one of four groups. Each group was given access to a smartphone app for goal setting, self-monitoring and the provision of feedback. The app also featured a recipe database that was searchable by meal or ingredient. Two groups received additional gaming features within their app for incentivisation to enhance motivation. Two groups (one using the gaming app and one using the standard app) received daily social support and additional material and tips that address barriers to vegetable consumption as an extra program component through a Facebook page. Gamification was also integrated into the Facebook delivery material as competitions (with incentives). These were used to encourage participants to purchase and cook with vegetables. Figure 9.1 shows the four groups, their study conditions and program components. Figure 9.2a-d presents screenshots of the two apps as they appeared to participants.
The reporting of outcomes was guided by the CONSORT E-HEALTH checklist of information to include when reporting on social media, serious games or mhealth (mobile

health) trials (49). All study materials were delivered electronically. The study materials and methods were approved by The University Human Ethics committee, approval number 2017/306

Table 9.1: A summary of the behaviour change techniques selected, their context within the COM-B framework and their application within the platform.

COM-B Framework	Description of behavioural determinant	Behaviour change technique[1]	Application within the program		
Capability			**Standard App**	**Gamified App**	**Facebook**
Psychological Knowledge Intervention function: **Education**	- Knowledge of recommended vegetable intake and serve sizes - Understanding health benefits	- Information about health consequences	Infographic on recommended daily intake and what constitutes a vegetable serve	Infographic (see supplementary figure 1) on recommended daily intake and what constitutes a vegetable serve & Quiz based game on recommended vegetable intake and serve sizes according to Dietary Guidelines	Infographic (see supplementary figure 1) on recommended daily intake and what constitutes a vegetable serve & Facebook posts on the health benefits of vegetables
Self-monitoring and Feedback on behaviour Intervention function: **Enablement and Education**	Tracking vegetable consumption and review discrepancy between current intake and goal to encourage continued improvement	- Self-monitoring of behaviour - Feedback on behaviour	Tracking app enables user to enter serves of vegetables consumed at each meal and review progress against personalized goal	Tracking app enables user to enter serves of vegetables consumed at each meal and review progress against personalized goal	
Physical Skill building Intervention function: **Training**	Cooking skills: practicing the process of cooking with vegetables	- Demonstration of the behaviour - Instruction on how to perform a behaviour	Recipe database searchable by ingredient or meal type	Recipe database searchable by ingredient or meal type	Short cooking videos to model cooking with vegetables, with challenges to encourage young adults to practice cooking skills and upload pictures of their dish

COM-B Framework	Description of behavioural determinant	Behaviour change technique[1]	Application within the program		
Opportunity			**Standard App**	**Gamified App**	**Facebook**
Physical					
Cues to action Intervention function: **Environmental restructuring**	- Creating healthy triggers within the environment to support increased vegetable consumption.	- Prompts/cues			Providing tips to increase exposure to vegetables *"Take your forgotten veg out of that bottom fridge draw and place on the top shelf so you're reminded to cook with them"*
Reducing barriers Intervention function: **Environmental restructuring**	Addressing flavour, time and cost as a barrier to vegetable intake by developing meal planning and budgeting skills	- Prompts/cues			Facebook posts providing cues on how to enhance flavour of vegetables, and plan meals on a budget
Cues to action Intervention function: **Enablement**	- Providing weekly challenges to increase vegetable intake	- Graded tasks		Weekly challenge to increase vegetable intake based on previous weeks progress e.g. Add some vegetables to breakfast	
Habit formation Intervention function: **Training**	Prompt rehearsal and repetition of vegetable consumption	- Habit formation	The app requires participants to track vegetable intake against their goal daily	The app requires participants to track vegetable intake against their goal daily	
Social					
Social support Intervention function: **Enablement**	Instigating positive peer rivalry to encourage vegetable intake	- Social support (practical)			Competitions such as "best cooked vegetable dish", "quirkiest vegetable of the week" between social network peers on Facebook page to create a sense of shared accountability and encourage positive peer pressure

COM-B Framework **Motivation**	Description of behavioural determinant	Behaviour change technique[1]	Application within the program		
			Standard App	**Gamified App**	**Facebook**
Reflective Cognitive strategies Intervention function: **Persuasion**	Restructuring beliefs & perceived barriers by "debunking" myths about vegetables e.g. bad taste	- Framing/reframing			"Myth busting" articles encouraging participants to re-evaluate beliefs e.g. Top 5 ways to enjoy the taste of vegetables
Automatic Goal setting and self-monitoring Intervention function: **Enablement**	Setting SMART[2] goals for increasing vegetable intake	- Goal setting (behaviour) - Review behaviour goal(s)	App prompts user to set goal for vegetables serves/day, personalized based on current intake so it is achievable. Can assess progress against goal and recommended intake in review page.	App prompts user to set goal for vegetables serves/day, personalized based on current intake so it is achievable. Can assess progress against goal and recommended intake in review page.	
Rewards/Incentives Intervention function: **Incentivisation**	Increasing the value of consuming vegetables through rewards	- Incentive		Rewards (badges) provided for tracking intake, consuming a variety of vegetables, achieving challenges and playing knowledge quiz	Competitions such as uploading picture of dish containing vegetables rewarded with voucher
Self-efficacy Intervention function: **Enablement and Modelling**	Providing the opportunity to gain confidence in eating more vegetables by breaking the behaviour up into small achievable tasks	- Goal setting (behaviour) - Demonstration of the behaviour	Weekly goals for increasing vegetable intake slowly	Weekly goals for increasing vegetable intake slowly. Weekly challenges providing easy ways to increase veg in diet e.g. Add some vegetables to breakfast	Cooking videos & challenges for preparing vegetables, meal planning resources and recipes, tips on simple ways to eat more veg e.g. *"What's for dinner tonight? Add in veggies, make a side salad or stir fried veg"*
Social support Intervention function: **Persuasion**	Validating and reinforcing improvements in vegetable intake to encourage repetition of the desired behaviour	- Information about others' approval			Validation of behaviour Participants can post pictures of vegetable dishes to receive positive reinforcement from the researchers

[1] Based on Susan Michie's Behaviour Change Taxonomy Behaviour Change Techniques (1) [2] SMART; Specific Measurable Achievable, Relevant, Time-bound

Participants and recruitment

Young adults aged 18-30 years who owned a Smartphone were eligible to participate. While young adulthood encompasses those aged 18-34 years (50), this intervention focuses on the lower end of this age bracket as adults aged 30 years and over would likely experience different challenges and barriers associated with the transition to marriage and raising a family. The most recent Australian statistics indicated that the median age of marriage and birthing the first child was 31.4 and 28.9 years respectively (51). Pregnant women and those with a history of disordered eating or medical contraindications were excluded from this study. The study was advertised in the community-at-large throughout NSW via Facebook posts, flyers posted in tertiary education campuses and distributed through local club newsletters and information stands. The recruitment flyers used the University logo as per ethical requirements however affiliation with the institution did not appear on other program material.

Participants expressing interest in the study were directed to an online survey providing information about the study and the eligibility screener. If eligible, participants were directed to the baseline questionnaire assessing the primary outcome; usual vegetable intake and secondary outcomes; knowledge of standard serving sizes and recommendations, self-efficacy and motivation for consuming vegetables and habits surrounding vegetable purchasing, preparation and consumption (see Appendix 9.1). Informed consent was collected via this survey. The survey was delivered using the Redcap software. Redcap is a secure online application for building and managing web-based surveys (52).

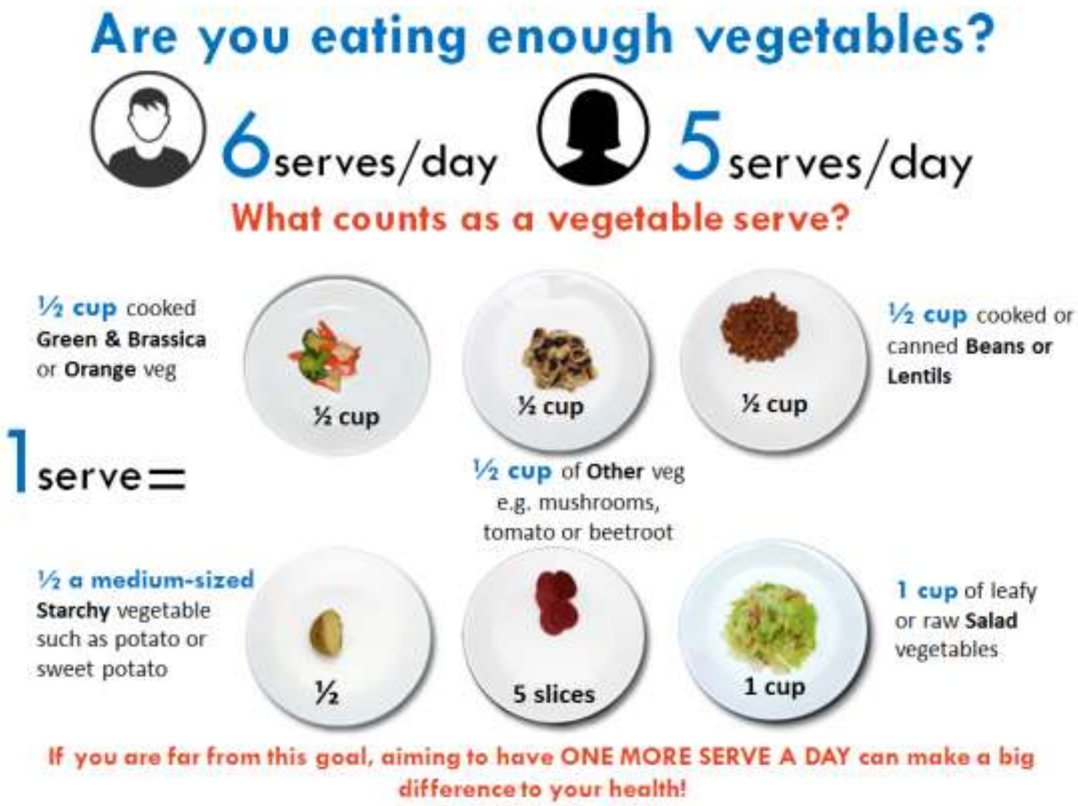
Randomisation and participant instructions

Participants who met study eligibility and provided consent were enrolled into a study group by an independent researcher (JC). Participant enrolment was staggered dependent on recruitment. A web-based number generator allowed randomisation and stratification by gender. The researcher collecting and analysing the data was blinded to allocations throughout the duration of the study, data collection and analysis (MN).

Participants were emailed a link to download the designated app for their allocated intervention group. The application was available at no cost from the Google play or Apple store. All participants were instructed to set intake goals at baseline and use the app daily to track vegetable intake throughout the four week study period. Short pop up instructions explained the functions of the app to users on first log in (see appendix 8.3). A reminder text message was sent to participants who had forgotten to log in the app for three consecutive days. All participants were also emailed an infographic educating on the recommended daily vegetable intake and what constitutes a vegetable serve (Figure 9.3). Those randomized into a Facebook support group were invited via email to join the study Facebook group specific to their allocated intervention condition. They were instructed to view content posted daily. Posts were made daily using a pre-determined schedule to ensure consistency across the two groups. Participants were informed in the participant information sheet that the study comprised of different "technologies" (i.e. app or Facebook) and so could not be blinded completely. However, the exact details of the differences and the intervention of interest were concealed. There was no human involvement other than the email correspondence for trial registration and regulation of Facebook posts. No counselling was given to participants.

After four weeks of using the designated app and/or social media page, the participants received an email invitation to complete the follow-up questionnaire similar to baseline, with a few additional questions asking for their experience/feedback on the program.

Figure 9.3: Educational infographic provided to all participants at baseline via email



Outcomes

The primary outcome of interest was the change in vegetable consumption (serves per day) at four weeks, including canned and frozen varieties but excluding fried potatoes. The secondary outcomes were the impact of the intervention on determinants of vegetable intake including, knowledge of daily intake recommendations and serve sizes, self-efficacy and motivation for consuming vegetables and habit formation. Engagement was measured as usage of materials by all participants and frequency of use.

Data collection

Demographic details, including age, gender, postcode (for categorising socio-economic status), education level, occupation, cultural background and income were collected at baseline through an online questionnaire administered through the web based platform Redcap. Vegetable intake (serves/day) was assessed at baseline and at the conclusion of the trial (4 weeks) using validated short questions (53) (Appendix 9.1). Knowledge, self-efficacy and habits related to vegetable intake were assessed at baseline and four weeks through an online survey. Participant knowledge of standard vegetable serving sizes was measured through multiple choice questions developed by the researchers. Knowledge of the recommended daily vegetable intake was assessed using a multiple choice question; *"what do you think is the recommended number of serves of vegetables that should be eaten in a day?* An additional note explaining that one serve of vegetables is equivalent to 1 cup raw salad vegetables or, ½ cup cooked or tinned vegetables (include legumes like lentils or baked beans), or, 1 medium potato or ½ medium sweet potato was provided. Participants could select from the following options; ‘one or two serves a day’, ‘three or four serves a day’ and ‘five or more serves a day’. This question was adapted from the tool used by Pollard et al (54) and the NSW health survey (55). Responses to these questions were coded as either correct or incorrect, with the proportion correctly identifying a vegetable serving and the daily recommendation compared between baseline and follow-up.

Self-efficacy for consumption of vegetables was measured using a five item five point likert scale questionnaire validated for use in young adults (α= 0.85 for Vegetables)(see appendix 8.4)(56). The maximum possible score was 25 with higher scores indicating stronger self-efficacy. Autonomous and controlled motivation for consumption of vegetables was quantified using 4 point scale questions adapted from the Self-Regulation Questionnaire (57, 58), with a maximum possible score of 16. A higher score indicated greater motivation. Habit formation was measured using the validated 4 item 7 point scale Self-Report Behavioural Automaticity index (SRBAI) (59)(see appendix 8.5). A score of 28 indicated that an individual had achieved automaticity in carrying out the behaviour.

Engagement with the program was measured through usage (the uptake of intervention material e.g. prevalence of at least one engagement with the app) and the frequency and manner of use. Data related to individual app usage was captured via inbuilt software which recorded log-ins, number of vegetable serves logged per day, and the time and date of logging. The manner of use of the app was captured through follow-up semi-structured interviews conducted via telephone with a randomly selected sub-sample of participants (n=10). Participants were asked to report which features were most useful in supporting goal attainment. Uptake of the social media (Facebook) content was measured by tracking whether a post was marked as “seen” by the participant. According to Facebook’s definition, engagement with material posted was measured through user reactions such as ‘‘likes’’ and “comments” (60). This outcome measure reflects the ability of content to capture user attention rather than an estimation of total reach.

Process Evaluation and measurement of engagement

The APEASE criteria were used to guide process evaluation, capturing the Acceptability, Practicability, Effectiveness, Affordability, Safety and Equity of the proposed program (61) (Table 9.2).

A mixed methods approach was applied to collect the appropriate process outcomes. Acceptability of program components was captured using a short post intervention questionnaire (all participants) and a post-program interview (selected participants). The questionnaire included four 5-point likert scale questions as follows; “*Rate how easy it was to use this program” “Rate how much you liked this program”, “On a scale of 1-5, how likely would you recommend this program to others?” and “How useful was the program to you?”* At the conclusion of the study a random selection of participants received an email invitation to participate in a 15 minute semi-structured telephone interview for gathering subjective opinions of user experiences and feedback on the program components. While it was unlikely that unwanted side effects would result from the program, we asked the interviewed participants to report on undesirable outcomes (if any) that resulted from participation in the program. Separate informed consent was obtained from those agreeing to participate in the post program interview. The telephone interview was audio recorded and transcribed for later thematic analysis. Each respondent received a gift voucher valued at AU$10 for participation in the interview.

Practicability and Affordability were documented throughout dissemination of the program by keeping a record of participation rates, as well as cost and time spent for intervention implementation. Measures were taken to streamline the intervention by delivering all material online and over the phone allowing implementation of the program at scale. The potential for translation was measured by asking participants to comment on their willingness to use the intervention components outside of the study environment. Measures of effectiveness are related to the level of improvement in vegetable consumption and/or its determinants such as motivation, self-efficacy, knowledge and habit formation as described earlier. The majority of young adults own a smartphone, making the program accessible. Furthermore, effort was made to ensure the equity of the program by recruiting a representative sample across all SEIFA levels.

Table 9.2: The APEASE criteria (from the guide to applying the behaviour change wheel[1]) with associated outcome measures

APEASE criteria	Outcome measure
Acceptability	Post intervention questionnaire and a post-program interview assessing satisfaction with program components and ease of use.
Practicability	Measure adherence to plan for dissemination using modern communication technologies (email, smartphones)
Effectiveness	Improvement in vegetable consumption and/or its determinants such as motivation, self-efficacy, knowledge and habit formation.
Affordability	Assessment of cost of dissemination per participant
Safety	Participants will self-report any side-effects of the program
Equity	Assessment of socioeconomic distribution among participants

[1]Michie, S., Atkins, L., & West, R. (2014). The behaviour change wheel: a guide to designing interventions. Great Britain: Silverback Publishing.

Data Analysis

Descriptive statistics were used to summarise the baseline characteristics of participants. Analysis of covariance (ANCOVA) was applied to detect changes in vegetable intake after four weeks (primary outcome) between groups, controlling for baseline vegetable intake. The continuous secondary outcomes; self-efficacy, motivation and habit formation, were also analysed using ANCOVA. Change in knowledge (categorical variable) was assessed using chi-squared analysis for changes in proportions of respondents who selected the correct response in the questions on serving sizes and daily recommendations.

Analysis was by “intention to treat” with multiple imputation used for missing values so that all participants randomized at the commencement of the trial were retained for analysis regardless of compliance. Five imputed data sets were created based on age, gender, SEIFA, and the baseline primary and secondary outcomes. The imputed values were pooled using Rubin’s rule (62). Due to large drop out an analysis of completers only was conducted to observe if there were any differences from imputed data. As no differences in the significance of findings were found, only the intention to treat analysis is shown (see appendix for data of completers only). All analyses were completed in the SPSS statistical program (Version 22).

Engagement with the app was explored quantitatively by summarising log data by frequency of tracking intake, and period of app use by group. Facebook engagement was also examined by group with percentage of “seen” posts used as a measure of uptake. The most and least popular posts were determined using the following criteria; most popular: seen by 80% or more of the study sample, least popular: seen by 30% or less of the study sample. Feedback collected through the follow-up semi-structured interviews with participants were coded into the NVivo Software program (QSR International Pty Ltd. Version 10, 2012, Victoria, Melbourne). Thematic analysis using an open coding method and inductive approach was applied to group together common themes.

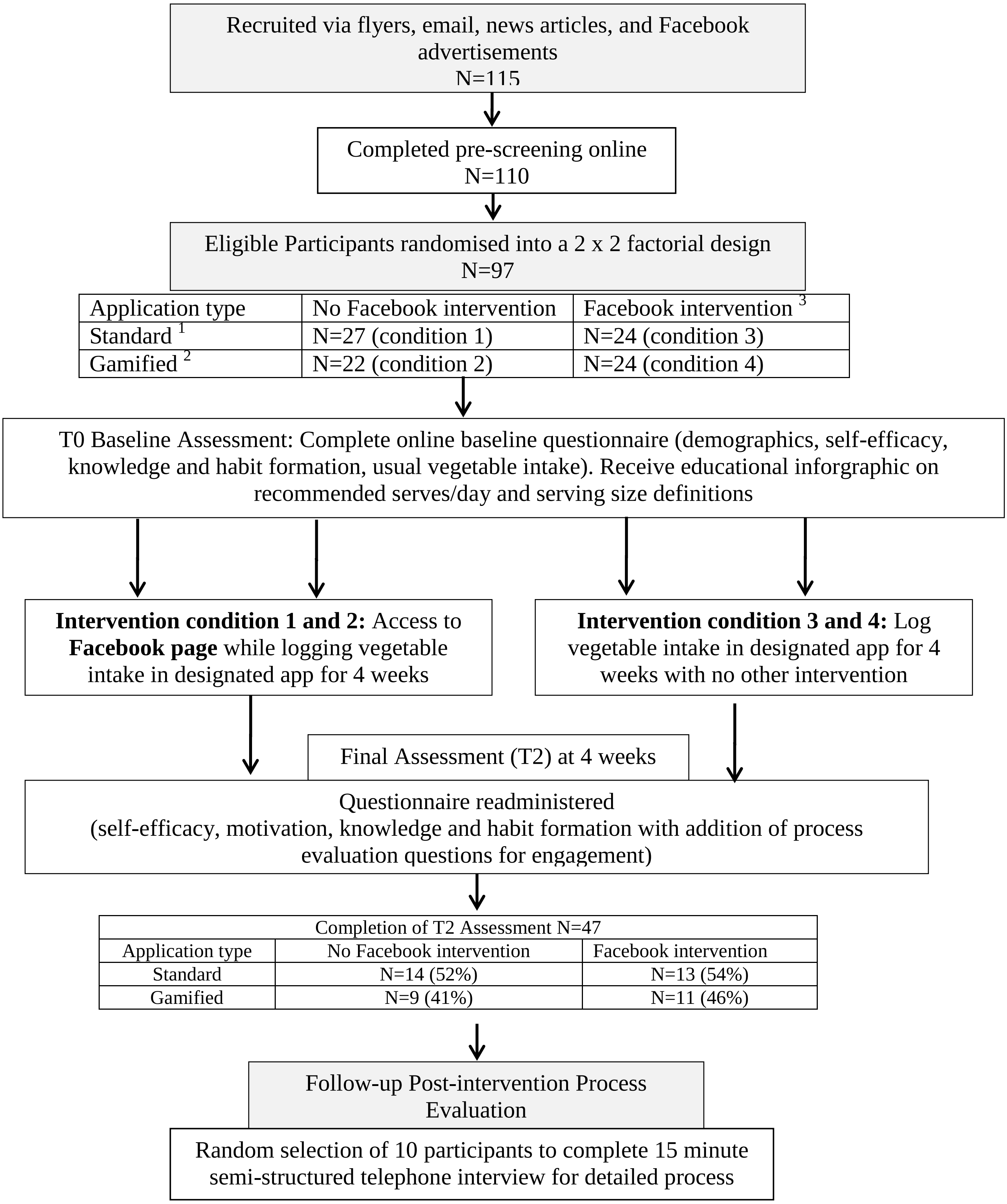


Figure 9.1: Diagrammatic description of the intervention with protocol flow for each treatment group including randomisation, intervention materials, time-line and frequency of measures.

[1]Standard app has goal setting and self-monitoring feature with recipe database
[2]Gamified application has goal setting and self-monitoring feature for improving vegetable intake with weekly challenges around eating more vegetables rewarded with badges. Also includes a knowledge quiz on vegetable types and serving sizes as well as a recipe database
[3]Facebook page provides social support and access to cooking videos, budgeting & meal planning materials, additional educational resources addressing the link between eating more vegetables and health outcomes

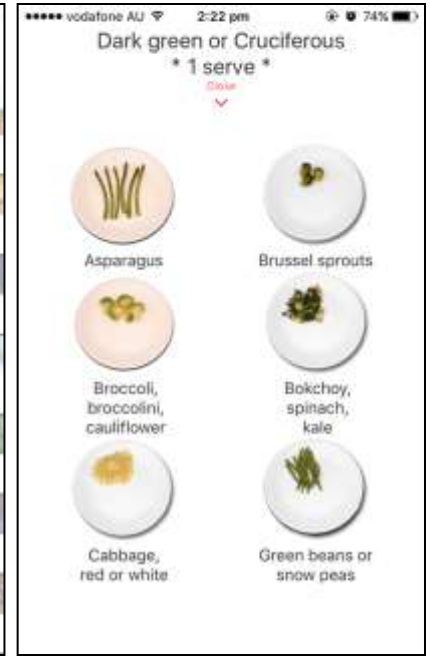
Figure 9.2a-d: Screenshots of the mobile application “Veggie Tracker”.

2a: Introduction screen

2b: Dial used to set goal

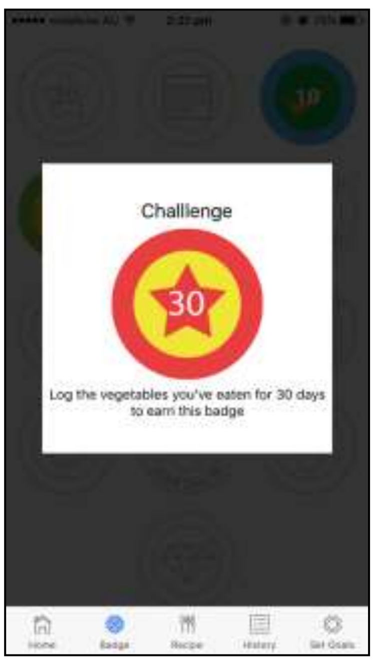
2c: Home screen indicating progress

2d: Logging screen



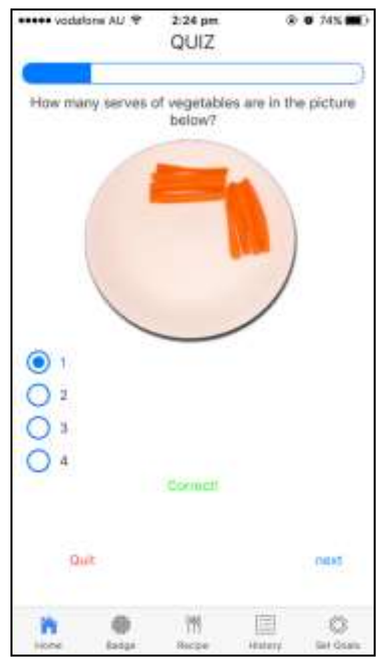
2e: Images of vegetable serve by category

2f: Example recipe from database

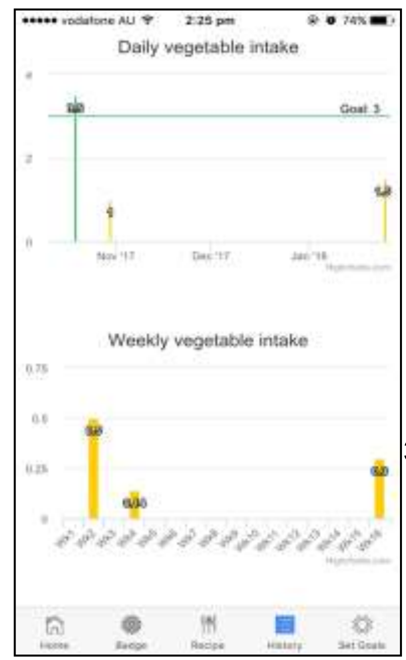


2g: Example challenge

2h: Badge icon screen



2i: Example Quiz question



2j: Detailed progress charts

9.5 Results

Participants

A total of 115 young adults expressed interest in participating in the study. Out of the 110 potential participants who completed the pre-screening questionnaire online, 97 were eligible and randomised into one of the four groups. The breakdown of group allocation is displayed in Figure 9.1.

The characteristics and demographics of participants at baseline are presented in Table 9.3. The mean age was 24.8 years (SD 3.4). The sample comprised 40% males. A total of 52 participants (54%) reported their highest level of education as a university degree or higher. The sample captured young adults across all socio-economic areas, with 28% (n=27) categorised in the lower two SEIFA quartiles. The mean intake of vegetables was 1.95 serves per day, which is lower than the average consumption of Australian young adults reported in Chapter 2 (7). Chi-squared tests were used to examine differences between groups in education level, gender and socio-economic status. ANOVA was used to determine differences in baseline vegetable intake. There were no statistically significant differences found between the groups for these factors; vegetables (p=0.27), education (0.79), gender (0.95) and SEIFA (0.3). Age was significantly different between groups (p=0.04) in that the group using standard app with Facebook was younger than the other three groups.

Attrition

Ten participants withdrew from the intervention; three due to injury or illness; four due to lack of time and three withdrew without giving a reason. At the end of the four week study period, participants were emailed the follow-up survey. Approximately half (47/97, 48%) completed this assessment (Figure 9.1). The attrition rate between groups was not significantly different (p=0.81).

Table 9.3: Baseline characteristics of participants by group condition

Baseline Characteristics	**Standard app[1]**	**Gamified app[2]**	**Standard app with Facebook**	**Gamified app with Facebook**
Age in years, mean (SD)	25.7 (3.2)	24.6 (3.8)	23.3 (3.0)	25.5 (3.1)
Gender, n (%)				
Male	12 (44)	9 (41)	9 (38)	9 (38)
Female	15 (56)	13 (59)	15 (62)	15 (62)
Highest level of education, n (%)				
High school	7 (26)	5 (23)	7 (29)	4 (17)
Diploma or certificate	7 (26)	5 (23)	6 (25)	4 (17)
University degree or higher	13 (48)	12 (54)	11 (46)	16 (66)
SEIFA, n (%)				
Quartile 1 (Lowest)	2 (7)	5 (23)	2 (8)	2 (8)
Quartile 2	3 (11)	2 (9)	5 (21)	6 (25)
Quartile 3	10 (37)	3 (13)	3 (12)	4 (17)
Quartile 4	5 (19)	5 (2)	4 (17)	2 (8)
Quartile 5 (Highest)	7 (26)	7 (32)	10 (42)	10 (42)
Currently studying, n (%)	3 (11)	8 (36)	9 (38)	5 (21)
Vegetable intake (serves/day), mean (SD)	1.6 (1.4)	2.0 (1.5)	2.4 (1.3)	1.8 (1.6)

SEIFA; Socioeconomic index for areas, [1]Standard app for goal setting and self-monitoring with feedback, [2]Gamified app for goal setting and self-monitoring with feedback with the addition of gamification

Change in vegetable intake

Significant differences in vegetable intake overtime (p =0.001) were found. However no change was observed in the group by time differences (P=0.4). The imputed data suggested that self-monitoring alone can result in an increase in vegetable intake by 0.1 serves per day (Table 9.4).

Change in secondary outcomes

Knowledge

At baseline, 20 out of the 97 participants correctly identified the definition of a vegetable serving. The change in knowledge of serving sizes over time was significant (p=0.04) (Table 9.5). Regarding knowledge of recommended daily serves of vegetables at baseline, 51 out of 97 participants selected the correct response. All groups improved over time (p=0.04). The group by time differences for knowledge were not significant (Table 9.5).

Self-efficacy

At baseline the mean (SD) score among all participants was 18.9 (3.9) out of 25. Change in self-efficacy over time was significant (p<0.01) (Table 9.4). The differences observed between groups overtime were not significant (p=0.2), although two groups appeared to improve and two became less confident (Table 9.4).

Motivation

At baseline the mean (SD) score among all participants was 12.3 (1.8) out of a possible 16. A significant time effect was observed (p=0.04) with an increase in motivation for all groups four weeks post intervention but no group by time effect was found (p=0.2) (Table 9.4).

Habit Formation

At baseline the mean (SD) habit score among all participants was 15.7 (6.1) out of a maximum of 28. At follow-up, all groups indicated significant improvements in the automaticity of habits related to vegetable consumption by a mean of 3 points (time effect $p<0.01$). However, the group by time effect was not significant ($p=0.6$) (Table 9.4).

Table 9.4: Changes in vegetable intake, motivation, habit formation and self-efficacy from baseline to follow-up by group (n=97, using imputed data set)

Group	**Vegetable Intake (serves per day)**	**Motivation (score out of 16)**	**Habit formation (score out of 28)**	**Self-efficacy (score out of 25)**
Standard app[1]				
Baseline (mean (SD))	1.6 (1.4)	12.2 (2.0)	14.5 (5.5)	18.6 (3.2)
Follow-up (mean (SD))	1.7 (1.2)	13.0 (1.3)	18.8 (4.8)	19.3 (2.8)
Change	**0.1**	**0.8**	**4.3**	**0.7**
Gamified app[2]				
Baseline (mean (SD))	2.0 (1.5)	12.3 (1.8)	17.5 (6.4)	19.9 (3.7)
Follow-up (mean (SD))	1.6 (1.2)	12.7 (1.5)	18.7 (5.3)	18.5 (2.8)
Change	**-0.4**	**0.4**	**1.1**	**-1.4**
Standard app with Facebook				
Baseline (mean (SD))	2.4 (1.3)	12.8(2.0)	15.9 (6.4)	19.7 (3.9)
Follow-up (mean (SD))	2.2 (1.6)	13.2 (1.4)	17.9 (4.5)	19.0 (3.5)
Change	**-0.1**	**0.5**	**2.0**	**-0.7**
Gamified app with Facebook				
Baseline (mean (SD))	1.8 (1.6)	11.9 (1.5)	14.6 (6.0)	17.3 (4.7)
Follow-up (mean (SD))	1.5 (1.2)	13.0 (1.3)	18.6 (5.0)	18.1 (4.3)
Change	**-0.3**	**1.1**	**4.0**	**0.8**
P value (time)	0.001	0.04	<0.01	<0.01
P value (group x time)	0.4	0.2	0.6	0.2

[1]Standard app for goal setting and self-monitoring with feedback, [2]Gamified app for goal setting and self-monitoring with feedback with the addition of gamification

Table 9.5: Persons (n) with correct responses for questions assessing knowledge of serving size and daily vegetable recommendations and the percentage change from baseline to follow-up by group (n=97 using imputed data sets)

Group	Persons with correct responses for serving size (n)	Persons with correct responses for daily recommendations (n)
Standard app[1] (n=27)		
Baseline (n)	5	13
Follow-up (n)	5	21
Percentage change	**0**	**31**
Gamified app[2] (n=22)		
Baseline (n)	4	14
Follow-up (n)	6	19
Percentage change	**8**	**19**
Standard app with Facebook (n=24)		
Baseline (n)	6	13
Follow-up (n)	7	20
Percentage change	**5**	**33**
Gamified app with Facebook (n=24)		
Baseline (n)	5	11
Follow-up (n)	7	19
Percentage change	**9**	**36**
P value (time)	**0.04**	**0.04**
P value (group x time)	**0.8**	**0.1**

*P for change using Pearson Chi-square test, [1]Standard app for goal setting and self-monitoring with feedback, [2]Gamified app for goal setting and self-monitoring with feedback with the addition of gamification

Engagement

Self-monitoring apps

Analysis of the app log data showed that on average each participant logged their vegetable intake on 11 out of 28 days during the intervention. The differences between groups for frequency of logging and days of engagement with the app were not significantly different (Table 9.6).

Facebook posts

Uptake (views)

Uptake of Facebook posts (% posts viewed by participants) did not differ between the group that used the gaming app and those that used the standard app (Mean [SD] percentage of posts seen by participants; 61.2 [22.1] 58.4 [23.9] respectively) (Table 9.6). The most popular Facebook posts (i.e. viewed by ≥80% of participants) were recipes with time-saving elements (e.g. using frozen vegetables) and those that offered vegetable preparation hacks such as how to quickly chop a capsicum. Meal inspiration posts that suggested new ways to try vegetables such as by adding spinach to smoothies, making vegetable-based dips or adding beans to salads were well received. Meal planning information was also very popular (particularly posts that featured a weekly meal plan and shopping list). Additionally, uptake was high on posts that suggested money saving tips and used infographics to pictorially illustrate 5 serves a day (Figure 9.4).

The least popular Facebook posts (i.e. seen by ≤30% of participants) were cooking videos with unfamiliar ingredients (e.g. squash), meal inspiration posts based on "cliché" ingredients such as avocado and suggestions to shop at farmers markets for cheap vegetables (Figure 9.4). The uptake of cooking videos and posts made regarding the health benefits of vegetables was moderate (approximately 60%). Overall retention within the Facebook groups was good. This was measured from when a participant joined the Facebook group until the end of the intervention period. All but 2 participants were retained.

Engagement (Likes)

Interaction with posts was limited to likes, with no comments made by participants. Only one participant shared their own material within the group as shown in Figure 9.5. These posts (made by a participant) were very well received with 100% uptake from group participants.

Overall Engagement

It appeared that the group receiving both the gamified app and the Facebook intervention most frequently logged their vegetable intake, stayed engaged with the app for longer and viewed and engaged with Facebook material the most (Table 9.6).

Table 9.6: Data on engagement with the app and Facebook material by group according to frequency of logging intake, days engaged with the app, uptake of Facebook material and number of likes

Group	Mean (SD) Frequency of logging intake in app	Mean (SD) number of days engaged with app (log ins)	Uptake of Facebook material (% posts seen)	Engagement with Facebook material (number of likes)
Standard App	11 (7)	23 (9)	N/A	N/A
Gamified App	8 (5)	20 (8)	N/A	N/A
Standard App with Facebook	11 (7)	22 (9)	58.4	32
Gamified App with Facebook	14 (8)	23 (6)	61.2	46
P for difference between groups[1]	**0.3**	**0.8**	**0.8**	**0.3**

[1]P for differences between groups using ANOVA

Process evaluation

Feedback on the program components were collected through the post-program questionnaires as well as interviews conducted with a random selection of 10 participants. The results gathered are summarised quantitatively for survey data and under themes where information is related to qualitative feedback gathered in interviews. Quotes are used to represent the key themes.

Quantitative Analysis

Acceptability

Among participants who completed the follow-up questionnaire, the mean rating given to reflect how much the programed was "liked" was 3.3 out of 5. On average, the program was rated 3.5 out of 5 for how useful it was. The differences between groups were not statistically significant on ratings of "liking" or "usefulness". However ratings regarding "ease of use" were more positive for the two groups who were allocated standard self-monitoring app (than people allocated the gaming app for self-monitoring) (mean [SD] 4.1 [0.85], P=.06).

Affordability, Safety and Practicability

While the program was provided to participants at no cost, there were costs involved in the development and dissemination of program materials. The estimated cost of delivering the intervention (smartphone app with social support through Facebook) is $90 AUD per participant (modelled based on enrolment of 1000 participants). This estimate includes the cost of app development and the time required to manage study enrolment, data collection, text message reminders and administration of Facebook groups. If the program was to be disseminated on a larger scale, issues regarding safety would be unlikely. During this feasibility trial, there were no occurrences of online misconduct in the Facebook groups. Furthermore, interviewed participants did not report any undesirable outcomes from partaking in the study. Finally, there were no technical problems identified during dissemination of the intervention using the selected technologies (smartphone, Facebook and email). One challenge faced was related to the design of the mobile app as a native app that still required an internet connection for data collection. Moving forward, the app should be upgraded to collect and store data while offline. The implications of the current app design on practicability are further discussed in the section below on "offline functionality".

Qualitative Analysis

App Usability

Back-logging

One of the most commonly cited disadvantages of the app design was the inability to log vegetables eaten from previous days. Eight out of ten participants interviewed indicated that on several occasions they remembered to log their vegetable intake too late at night (after midnight) or only remembered the following morning. The current app design resets at midnight each day. Participants expressed that at times this was discouraging as they could not accurately monitor their progress. As stated by a female; "*I couldn't go back log in the app and put in what I had forgotten so that made it hard to keep track of when I achieved my goals.*"

Understanding vegetable categories

It was frequently reported by participants that they were unfamiliar with the "vegetable categories" at the start of the program and this made it more challenging to quickly navigate through the app to add in vegetables eaten. For some this resulted in user fatigue and they stopped logging; however for others they found this as a good opportunity to learn the categories that vegetables belonged to. A male stated; "*To keep track of the different categories at first was challenging, like which vegetable goes in which category.*"

Offline functionality

While less commonly reported, three participants noted that the apps inability to allow use when offline made it hard to log at the moment of the meal occasion. These participants would revert to logging their meal consumed on the go when they returned to internet connectivity which often resulted in missed logging opportunities due to forgetfulness. One male summarised this experience with the statement; *"The app only loaded when I had internet connection, so when I was out for lunch for example I couldn't add in what I had eaten and would later forget about it."*

Self-monitoring saturation

It was frequently reported by participants that the goal setting and self-monitoring features of the app were the most useful for increasing vegetable intake. As summarised by one male *"I found it useful to set a goal of how many veggies to have a day and revise the target over time."* Despite the positive implications of self-monitoring, a majority of those interviewed also indicted that tracking with the app discontinued towards the end of the four week period and this resulted in a slight drop in their consumption. As stated by one female; "*It definitely helped to increase vegetable intake at the time when I was using the app, but since I stopped tracking I haven't been accountable for my intake so I feel I am not as conscious".* It became apparent in the interviews that use of the app for self-monitoring is short-lived and logging would become less frequent beyond the study environment. Some stated that they would keep the app on their devices for access to recipes and meal ideas.

Key skills obtained

Self-assessing adequacy of intake

Several participants expressed that after a couple of weeks of logging they learnt to self-assess daily vegetable intake as well as the variety consumed. They liked that the app gave them a "benchmark" goal to work against. A few mentioned that they now give consideration to what they eat throughout the day and if their consumption of vegetables is low, they would compensate through the dinner meal. This is well summarised by one male who stated; "*I* *didn't realize how many serves you are meant to eat and the variety, and now I think about the whole day, like I've had some this morning but none all day so I should have some at dinner."*

Meal planning and recipe modification

Many participants reported that they learnt simple ways to increase their vegetable intake such as adjusting commonly prepared meals so that vegetables featured as an ingredient or including vegetables in meals where they wouldn't usually consume them such as breakfast. For example one male stated; "*I learnt that it was quite easy to increase your vegetable intake without trying too hard or taking too much time, effort or cost. Like just adding some mushrooms or tomatoes to breakfast*." The young adults who were responsible for meal preparation indicted that the simple in-app recipes provided good ideas on how to cook with vegetables on a budget. As summarised by one female; "*The recipes were so simple whereas recipes I look up online are not using my usual pantry items. I liked that I could use leftovers in the fridge especially since I am watching my budget a bit more. The pricing was good."* Young adults who didn't prepare meals at home indicated that they didn't use the recipe function within the app, as stated by one male; *"I live with my parents so they do most of the cooking and that's why I didn't find the recipes relevant."*

Motivation instilled by Facebook posts

The process evaluation interviews with participants allocated to the Facebook conditions revealed that Facebook notifications served as a reminder to log vegetables when they had forgotten to do so. One male stated; *"Logging helped me keep track of what I was eating and I did find sometimes the Facebook post would be a reminder to log (especially at the end of* *the day when I'm busy)".* Participants indicated that while the tips provided on the Facebook page were motivating, the app was critical for keeping track of progress and maintaining motivation to achieve personal intake goals. As one female stated *"Recipes and tips posted on the Facebook group helped but the app was the most motivating to help me achieve my goals and seeing my progress."*

Personal motivations for participation in the program

The top three reasons expressed by participants as motivators for joining the program were; firstly being eager to assess whether their current intake was sufficient, secondly having the objective of learning ways to add more vegetables to their diet and lastly a desire to be healthier. As summarised by one participant; *"I thought it would be interesting as I have wondered whether I eat enough vegetables. I try to eat healthy as I do a lot of sport and stuff."* (Male)

Figure 9.4: Examples of most (top three images) and least (bottom three images) popular posts with regards to uptake

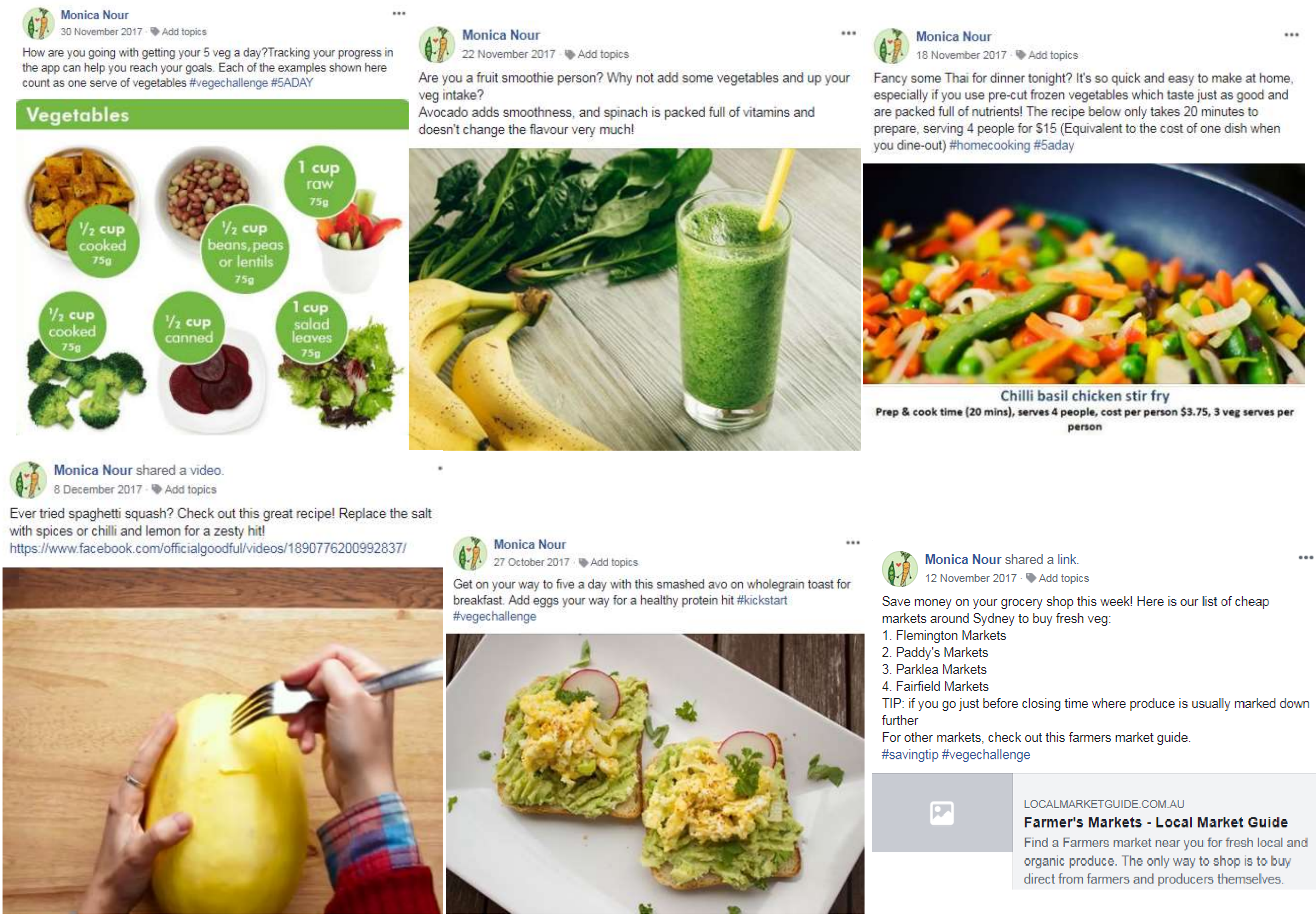


Figure 9.5: Posts made by member of the Facebook group

9.6 Discussion

This study aimed to assess the feasibility of delivering an intervention to improve vegetable intake using apps and social media (Facebook). The secondary objective was to determine if social support (Facebook) and incentivisation (gaming) have additive benefits for improving knowledge, self-efficacy, motivation, habit formation and engagement.

To the best of our knowledge, this was the first study to explore the impact of social support using social media in combination with gaming elements in a nutrition intervention for young adults. Our research revealed that it is feasible and practical to deliver behaviour change interventions to young adults using these novel communication mediums. Prior research has suggested that the feasibility of apps and social media as platforms for behaviour change is limited by attrition in app use over time and poor engagement with social media material (63, 64). Our study found that the overall mean engagement with the self-monitoring apps (measured as number of log in days) was comparable to popular commercial nutrition apps (65). Additionally, engagement with the Facebook material was double that of other studies which report uptake of around 25-30% (66).

We also observed that the addition of gaming and social support supported the greatest overall engagement. Features such as game-based incentives (e.g. badges) introduce novelty and prevent boredom (67) and have been shown to enhance engagement with digital interventions (68). Researchers who integrate these features into research-based apps should prioritise “ease of use” in the design stage as evidence suggests that if ease of use of an app is rated low and complexity high, it is possible that participants will disengage (67). Our process evaluation revealed that the simple design of the standard self-monitoring app was preferred by participants.

Furthermore, evidence (40) suggests that dropout rates are usually high in social media based studies (63). However, in our study, once a participant joined the Facebook group, retention was high**.** This may be a result of the efforts expended to pre-test the Facebook material prior to use in the intervention, ensuring what was presented was relevant, acceptable and sustained the interest of the participants. User engagement in the process of development of intervention materials has been recognised by other researchers as a way to improve retention in social media based studies (63).

With regards to vegetable intake all groups showed differences in vegetable intake over time. Paradoxically, three of four showed a small decline. Although the group using the standard goal setting and self-monitoring app had a small increase in vegetable intake, the app was not sufficient to support improvements in knowledge of serving sizes. Only participants who received the additional components (social support or gaming) showed improvements. It is possible that the gamified app which integrated a quiz and Facebook posts presenting pictorial examples of vegetable servings supported knowledge acquisition. Improving knowledge of serving sizes is important as previous research has suggested that correct identification of serving sizes is correlated with vegetable intake and meeting daily requirements (17, 69).

The process of goal setting and self-monitoring facilitates self-awareness (27, 70) and has been established as a successful strategy for enhancing self-efficacy and improving health behaviours (43). Feedback from the process evaluation interviews revealed that goal setting and tracking intake were the most used and helpful features of the app. It has also been established in the literature that self-monitoring is important for habit formation (71). All participants improved in their habits scores over the four weeks. Additionally, the process evaluation interviews revealed some valuable developments in habitual behaviours related to vegetable intake such as the incorporation of vegetables across all meals, especially at breakfast, and the modification of personal recipes to include vegetables.

Contrary to our hypothesis, the additional behavioural components offered by gaming and social support did not appear to have an additive effect on the outcomes of interest. Previous research exploring the impact of additive components has shown that extra features do not necessarily enhance the observed effect. For example an online smoking intervention which trialled the addition of personalised testimonials or email reminders found no differences between groups (72). Another study compared the impact of an enhanced website with features such as personalised weight goals, to a basic website for user driven self-monitoring of weight, and found no additional benefits to weight loss outcomes (73).

While additive components such as reminders, incentives or social support may not enhance behavioural outcomes, evidence suggests that accountability is important. In a RCT with young adults, it was reported that being accountable to a dietitian who reviewed participant progress during personalised phone coaching sessions was a key determinant of goal attainment (74). Furthermore, a recent study using a gamified self-monitoring app successfully improved the vegetable intake of overweight adults when compared to the waitlist control (75). Notably, the treatment group was part of a larger trial where they also received counselling sessions which may have introduced a degree of accountability. Future research may consider the inclusion of an electronic means of providing accountability, such as short text messaging services (SMS) asking participants to report progress with goals. This has been successfully trialled in weight loss interventions (76, 77).

Strengths and limitations

A significant strength of this feasibility trial was the development of program components using theory-based behaviour change techniques, guided by the COM-B framework. Additionally, all program materials were pre-tested for acceptability in focus groups with the target audience. This qualitative user-centred approach of addressing the needs of a population is important for the development of tailored interventions for health behaviour change (78, 79). The population for this study included young adults beyond the tertiary education setting. This is a unique strength of the current research, given that a majority of studies conducted with young adults focus on those within Universities or Colleges.

One of the main limitations of this research was that it was a feasibility study and not adequately powered for statistical analysis. To measure a change in vegetable intake by one serve which is considered a clinically significant outcome (80, 81), a sample size of 1000 participants would be required in a 4 group factorial study. This sample size would allow for an attrition of 20%. Given that the intervention period was only four weeks, it is also possible that program was not long enough to amount to significant changes or differences between groups. Furthermore, the level of control the participants had over their diet related to their involvement in meal planning, shopping and cooking was not captured in this study and is an important variable to measure in future research. Finally, although this study used a validated measure of vegetable intake, the tool estimated portions using household measures, whereas in the intervention participants were trained to record intake using the plate method. The impact of this on the accuracy of intakes reported in the follow-up questionnaire is uncertain. It is also possible that participants overestimated vegetable intake at baseline due to social desirability bias.

Conclusions

This trial has provided insight into the process of disseminating a social media and smartphone based intervention to young adults. We found it was feasible to deliver this program and engagement and retention in the Facebook study groups was much better than previously reported. There was no reliance on in person interaction for dissemination of the program and the chosen platforms (social media, email and a smartphone app) indicated the practicability of modern communication technology for the delivery of behaviour change interventions to young adults.

We could not confidently ascertain whether gamified incentives and social support can enhance behaviour change outcomes for young adults with a small sample size and the process of goal setting and self-monitoring may be enough to result in the desired small improvements in vegetable intake. Recruitment of additional participants will allow us to determine which program components should be integrated into a future program that promotes change but is cost effective, ensuring government funding is appropriately invested.

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9.8 Conclusion to Chapter

The findings presented in this chapter confirmed that the use of modern communication technology for the dissemination of nutrition interventions is feasible and practical. This is the first theory-based intervention to apply gaming strategies and use social media for delivery of a program to improve the vegetable intake of young adults. While the aim of this factorial study was to determine which program components were most effective in supporting behaviour change, the small sample size meant that definite conclusions could not be drawn. As such further research is required before the proposed intervention could be translated and disseminated to the population at large. In the chapter that follows the main learnings from this body of work, and key considerations for future research will be discussed.

Appendix 9

Appendix 9.1
Baseline questionnaire administered through Redcap, including participant information sheet, screener, consent, demographic questions and tools for measuring primary and secondary outcomes

Baseline Questionnaire

This study is testing a 4-week smartphone program designed to help you eat more vegetables. Vegetables are important for weight control and can improve skin appearance, mood and reduce your risk of disease. Please read the attached study information sheet then answer the below screening questions to see if you are eligible to join the program.

[Attachment: "Study Information.pdf"]

E-mail address

____

Are you aged 18-30 years?

○ Yes
○ No

Have you studied or are you currently studying nutrition or nutrition related subjects?

○ Yes
○ No

Do you own a smartphone and have a personal Facebook account?

○ Yes
○ No

What type of phone do you own/use?

○ iPhone (Apple)
○ Android (includes Motorola, HTC, Samsung, Sony Ericsson and other non-Apple phones)

Have you ever been diagnosed with, or treated for, any of the following conditions...
Anorexia Nervosa or Anorexia Athletica
Binge Eating Disorder
Bulimia Nervosa
Mental Illness (not including mild depression or anxiety)
Illicit drug abuse
Diabetes (Type 1 or Type 2)

○ Yes
○ No

Are you pregnant

○ Yes
○ No

Based on the screener you are eligible to participate in this study. Please read the statement below and then provide your consent so you can progress to the questionnaire. After this, you will receive an email with a link to the program app.

PARTICIPANT CONSENT FORM

By proceeding with this survey you agree and give consent to take part in this study

In giving your consent you state that:

• You understand the purpose of the study, what you will be asked to do, and any risks/benefits involved.
• You have read the study information sheet and have been able to discuss your involvement in the study with the researchers if you wished to do so.
• The researchers have answered any questions you had about the study and you are happy with the answers.
• You understand that being in this study is completely voluntary and you do not have to take part. Your decision whether to be in the study will not affect your relationship with the researchers or anyone else at the University of Sydney, now or in the future.
• You understand that you can withdraw from the study at any time. However, if you withdraw, you will not be eligible to enter the draw for the chance to win 1 of 4 $25 Coles/Myer gift cards.
• You also understand that it will not be possible to withdraw answers from the questionnaires and phone interviews once they have been submitted.
• You understand that personal information about you that is collected over the course of this project will be stored securely and will only be used for purposes that you have agreed to. You understand that information about you will only be told to others with my permission, except as required by law.
• You understand that personal information about you that is collected over the course of this project may be provided to third parties for use in research, for which ethical approval will be sought, and that all identifying information will be removed, so that the third party will not know whose information it is.
• You understand that the results of this study may be published, and that publications will not contain my name or any identifiable information about you.

Please indicate whether you consent to the following to continue with the survey

	Yes	No
Do you consent to participating in this 4 week program	○	○
Do you consent to being contacted for a follow up 10 minute phone interview to share your thoughts on the program?	○	○
Would you like to receive feedback about the overall results of this study	○	○

Unfortunately, you are not eligible to participate in this study. Please find advice on healthy eating in the attached document "The Australian Guide to Healthy Eating". Please press submit to exit the survey.

[Attachment: "n55g_adult_brochure.pdf"]

First Name

____

Contact number

____

Age

____

Gender	◯ Male ◯ Female
Postcode	______________________________
Are you of Aboriginal and/or Torres Strait Islander background?	◯ No ◯ Yes, Aboriginal ◯ Yes, Torres strait Islander ◯ Yes, Aboriginal and Torres strait Islander ◯ Prefer not to say
Where was your father born?	◯ Australia ◯ Asia ◯ Africa ◯ Europe ◯ Other
Please specify where your father was born	______________________________
Where was your mother born?	◯ Australia ◯ Asia ◯ Africa ◯ Europe ◯ Other
Please specify where your mother was born	______________________________

Occupation

◯ Student
◯ Full-time work
◯ Part-time or casual work
◯ Unemployed

In what field do you work/study?

◯ Education
◯ Office support
◯ Healthcare
◯ Management
◯ Finance
◯ Food service industry
◯ Information Technology
◯ Building, Design or Construction
◯ Other

Please specify the "other" industry you work/study in:

____

What is the highest level of education that you have completed?	◯ Year 10 (4th Form) or below ◯ Year 12 (6th Form) ◯

What is the total of all wages/salaries, government benefits/allowances and other income that you usually receive? NOTE! Do not deduct: tax, superannuation contributions, health insurance, or any other automatic deductions.	◯ Nil or negative income ◯ $1 - $499 per week ($1- $25,999 per year) ◯ $500- $999 per week ($26,000 - $51,999 per year) ◯ $1,000 - $1,499 per week ($52,000 - $77,999 per year) ◯ $1,500 - $1,999 per week ($78,000 - $103,999 per year) ◯ $2,000 or more per week ($104,000 or more per ye
Who purchases the main groceries in your household?	◯ Myself ◯ My Partner ◯ My Parents ◯ My housemate/s

Indicate how much you AGREE with the following statements (1=DISAGREE, 7=AGREE)

	1. Disagree	2.	3.	4.	5.	6.	7. Agree
Eating vegetables is something I do automatically	◯	◯	◯	◯	◯	◯	◯
Eating vegetables is something I do without having to consciously remember	◯	◯	◯	◯	◯	◯	◯

	1. Disagree	2.	3.	4.	5.	6.	7. Agree
Eating vegetables is something I do without thinking	◯	◯	◯	◯	◯	◯	◯
Eating vegetables is something I start doing before I realise I'm doing it	◯	◯	◯	◯	◯	◯	◯

What do you think is considered a serve of vegetables (select the correct answer)

◯ 2 cups of cooked vegetables
◯ 1 cup of cooked vegetables
◯ ½ cup of cooked vegetables
◯ ¼ cup of cooked vegetables
◯ 1/3 cup of cooked vegetables

To answer the next question, refer to the images below. Each plate is an example of one vegetable serve.

What do you think is the recommended number of serves of vegetables that should be eaten IN A DAY?

- ◯ 1 or 2 serves A DAY
- ◯ 3 or 4 serves A DAY
- ◯ 5 or more serves A DAY

Please select how true the following statements are as they relate to you.
1=Very UNTRUE, 4=Very TRUE
I would try to eat more vegetables because...

	1.Very UNTRUE	2.A little untrue	3.A little true	4.Very TRUE
Eating vegetables helps me feel better	◯	◯	◯	◯
Eating vegetables is an important thing for me to do	◯	◯	◯	◯
I would feel bad about myself if I didn't	◯	◯	◯	◯
Others want me to eat more vegetables	◯	◯	◯	◯

Please rate how CONFIDENT you are to do the following: 1=Not Confident At All, 5=Very Confident					
	1. Not Confident At All	2.	3.	4.	5. Very Confident
I can keep vegetables at hand/readily available	○	○	○	○	○
I can eat the recommended number of serves of vegetables when I eat on my own	○	○	○	○	○

	1. Not Confident At All	2.	3.	4.	5. Very Confident
I can shop for a variety of vegetables	○	○	○	○	○
I can make time to eat vegetables	○	○	○	○	○
When I eat at home, I can eat more vegetables	○	○	○	○	○

The last few questions ask about how often you eat different types of vegetables/legumes.

- Include all the vegetables & legumes eaten, even those that contributed to mixed dishes such as stir fry or salad, soups and other recipes.
- Include fresh, cooked, dried, canned, juiced and frozen vegetables/legumes
- For each food, select how often you have eaten the given amount, over the LAST ONE MONTH ONLY.

IMPORTANT: Please take notes of the amount listed under each vegetable/legume. If you eat a different amount than what is listed, this will affect your response.

The two examples below demonstrate this, please read them before completing the following questions

Over the LAST ONE MONTH ONLY, on average, how often did you eat the following vegetables/legumes in the given amounts?

EXAMPLE 1: If over the last month, the only type of legumes you ate were baked beans AND you ate **½ a cup** of baked beans every **2 weeks**, you would select the **"1-3 times per month"** option like this:

LEGUMES --> E.g. soy beans, four bean mix, baked beans, lentils, chickpeas *AMOUNT = ½ cup (once cooked or canned)

* must provide value

- ○ None
- ● 1-3 times per month
- ○ 1 time per week
- ○ 2 times per week
- ○ 3 times per week
- ○ 4 times per week
- ○ 5 times per week
- ○ 6 times per week
- ○ 1 time per day

EXAMPLE 2: If over the last month, the only type of legumes you ate were baked beans BUT you ate **1 cup** of baked beans every **1 week,** this is the same as eating ½ a cup 2 times per week. So would select the **"2 times per week"** option like this:

LEGUMES --> E.g. soy beans, four bean mix, baked beans, lentils, chickpeas *AMOUNT = ½ cup (once cooked or canned)

* must provide value

- ○ None
- ○ 1-3 times per month
- ○ 1 time per week
- ◉ 2 times per week
- ○ 3 times per week
- ○ 4 times per week
- ○ 5 times per week
- ○ 6 times per week
- ○ 1 time per day

Over the LAST ONE MONTH ONLY, on average, how often did you eat the following vegetables/legumes in the given amounts?

SALAD VEGETABLES *AMOUNT = 1 cup
(E.g. raw lettuce/leafy vegetables, tomatoes, capsicum, cucumber, sprouts, celery etc. DO NOT INCLUDE juice)

- ○ None
- ○ 1-3 times per month
- ○ 1 time per week
- ○ 2 times per week
- ○ 3 times per week
- ○ 4 times per week
- ○ 5 times per week
- ○ 6 times per week
- ○ 1 time per day
- ○ 2 times per day
- ○ 3 times per day
- ○ 4 times per day
- ○ 5 or more times per day

COOKED VEGETABLES --> E.g. zucchini, eggplant, corn, peas, green beans, asian greens, pumpkin, sweet potato, broccoli, cauliflower, brussel sprouts, cabbage. *AMOUNT = ½ cup or ½ medium sweet potato or 1 small corn cob (DO NOT INCLUDE white potato or legumes or juice.)

- ○ None
- ○ 1-3 times per month
- ○ 1 time per week
- ○ 2 times per week
- ○ 3 times per week
- ○ 4 times per week
- ○ 5 times per week
- ○ 6 times per week
- ○ 1 time per day
- ○ 2 times per day
- ○ 3 times per day
- ○ 4 times per day
- ○ 5 or more times per day

LEGUMES --> E.g. soy beans, four bean mix, baked beans, lentils, chickpeas *AMOUNT = ½ cup (once cooked or canned)

- None
- 1-3 times per month
- 1 time per week
- 2 times per week
- 3 times per week
- 4 times per week
- 5 times per week
- 6 times per week
- 1 time per day
- 2 times per day
- 3 times per day
- 4 times per day
- 5 or more times per day

100% VEGETABLE JUICE --> DO NOT INCLUDE vegetable juice that is not 100% vegetable juice *AMOUNT = ½ cup of 125 mL

- None
- 1-3 times per month
- 1 time per week
- 2 times per week
- 3 times per week
- 4 times per week
- 5 times per week
- 6 times per week
- 1 time per day
- 2 times per day
- 3 times per day
- 4 times per day
- 5 or more times per day

WHITE POTATO --> Include boiled, steamed, baked, roasted, mashed. *AMOUNT = ½ cup or 1 medium white potato (DO NOT INCLUDE fried potatoes such as hot chips, hash browns or chips/crisps.)

- None
- 1-3 times per month
- 1 time per week
- 2 times per week
- 3 times per week
- 4 times per week
- 5 times per week
- 6 times per week
- 1 time per day
- 2 times per day
- 3 times per day
- 4 times per day
- 5 or more times per day

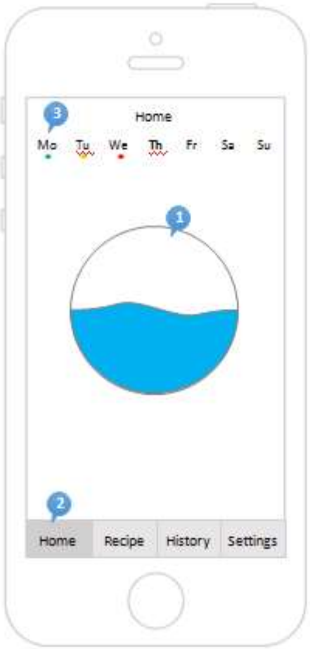
Appendix 9.2
Changes in vegetable intake, motivation, habit formation and self-efficacy from baseline to follow-up by group (n=47, using data set for completers only)

Group	**Vegetable Intake (serves per day)**	**Motivation (score out of 16)**	**Habit formation (score out of 28)**	**Self-efficacy (score out of 25)**
Standard app[1]				
Baseline (mean (SD))	2.0 (1.6)	12.0 (1.9)	15.9 (5.9)	19.4 (3.3)
Follow-up (mean (SD))	2.3 (1.9)	14.0 (1.5)	19.1 (5.7)	19.6 (4.3)
Change	**0.3**	**2.0**	**3.2**	**0.2**
Gamified app[2]				
Baseline (mean (SD))	1.9 (1.7)	11.9 (2.0)	19.3 (5.0)	19.4 (4.8)
Follow-up (mean (SD))	1.6 (0.9)	13.1 (1.4)	19.6 (6.6)	18.6 (6.6)
Change	**-0.3**	**1.2**	**0.3**	**-0.8**
Standard app with Facebook				
Baseline (mean (SD))	2.2 (0.9)	12.5(2.1)	13.8 (5.9)	18.7 (4.5)
Follow-up (mean (SD))	1.9 (1.1)	12.7 (1.4)	17.6 (7.6)	19.3 (3.8)
Change	**-0.3**	**0.2**	**3.8**	**0.6**
Gamified app with Facebook				
Baseline (mean (SD))	2.3 (2.0)	12.5 (1.1)	15.9 (6.8)	17.4 (5.1)
Follow-up (mean (SD))	2.8 (1.9)	12.8 (1.7)	18.5 (5.6)	19.4 (3.0)
Change	**0.5**	**0.3**	**2.6**	**3.0**
P value (time)	0.02	0.03	0.01	<0.001
P value (group x time)	0.3	0.5	0.8	0.6

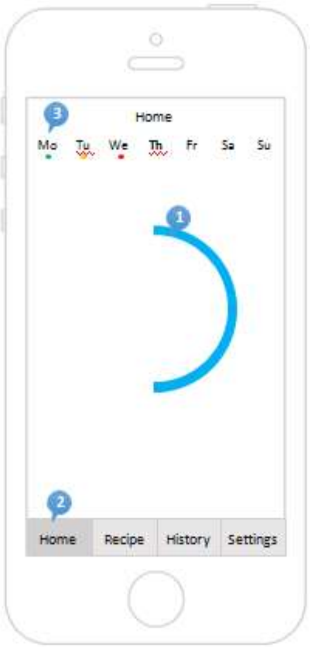
[1]Standard app for goal setting and self-monitoring with feedback, [2]Gamified app for goal setting and self-monitoring with feedback with the addition of gamification

Appendix 9.3

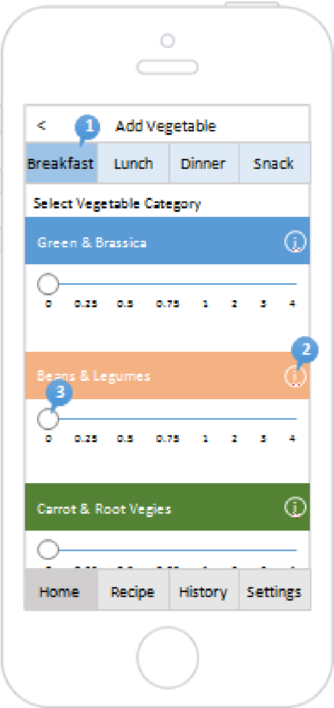
Wire frames drawn by Jisu Jung from the School of Information Technology (The University of Sydney) during the process of collaboration with Dietitian Monica Nour for the development of the Vegetable tracking app



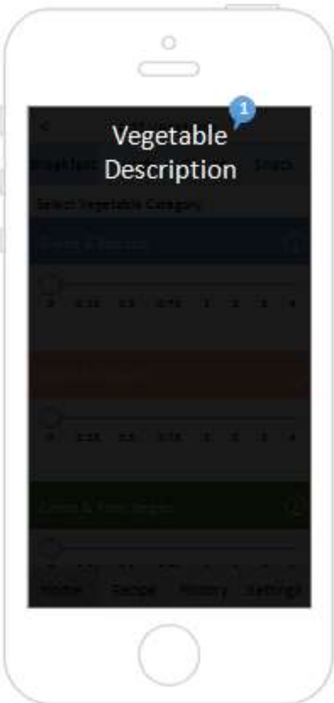
No	Name	Description
1	Vegetable Intake Progress	Showing vegetable intake progress for today
2	Tab Bar	Menu for functions 1. Home: Logger screen 2. Recipe: Recipe search screen 3. History: Daily and weekly trend 4. Setting: Goal and personal settings
3	Daily progress	Visualizing daily vegetable servings in this week



No	Name	Description
1	Vegetable Intake Progress	Showing vegetable intake progress for today
2	Tab Bar	Menu for functions 1. Home: Logger screen 2. Recipe: Recipe search screen 3. History: Daily and weekly trend 4. Setting: Goal and personal settings
3	Daily progress	Visualizing daily vegetable servings in this week

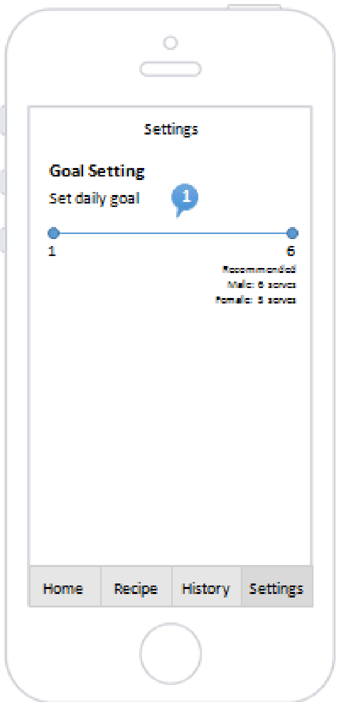


No	Name	Description
1	Meal type	Tab bar for each meal
2	Vegetable information	Description about vegetable category
3	Slider control	Record serving size



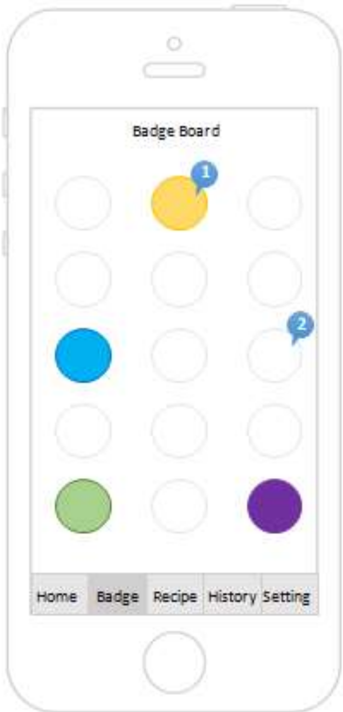
No	Name	Description
1	Vegetable Description	Show Vegetable serving sizes

No	Name	Description
1	Search bar	Search for recipe
2	Recipe Image	A searched recipe's image
3	Recipe Title	Recipe title



No	Name	Description
1	Daily Goal	Spin control from 1 to 6 serves for goal setting

No	Name	Description
1	Vegetable Intake Progress	Showing vegetable intake progress for today
2	Tab Bar	Menu for functions 1. Home: Logger screen 2. Badge: Badge collection screen 3. Recipe: Recipe search screen 4. History: Daily and weekly trend 5. Setting: Goal and personal settings
3	Daily progress	Visualizing daily vegetable servings in this week
4	Total goal progress	Showing the rewards for self reward (It is designed weekly basis but achievement totally depends on personal progress) When user reached the goal. It should be reset
5	Challenge	Challenge to achieve for certain goal for today
6	Vegetable Star	Indicator how variety of vegetable has been eaten for today



No	Name	Description
1	Activated badge	Earned badge
2	Inactivated badge	Not earned badge

Appendix 9.4

Facebook posts created for the social media component of the four week vegetable program.

Monica Nour

22 March at 10:25

Do you know if you're getting your 5ADAY? Each of the examples shown here count as one serve of vegetables #vegechallenge #5ADAY Acknowledgements to Cancer Council NSW for their image

Like Comment

Monica Nour shared a link.

21 April

These simple tips and tricks will help you on your way to eating a little more veg every day!

How To Eat More Vegetables (Even If You Hate Them)

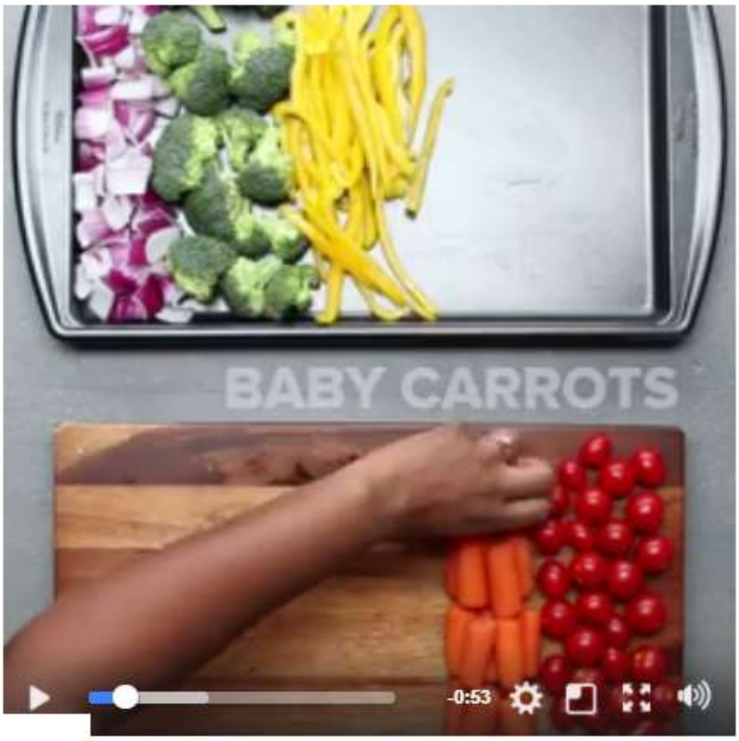
And we don't mean eat salad every day.

HUFFINGTONPOST.COM.AU

Monica Nour shared Tasty's video.

21 April

Get your Rainbow in with this easy baked veggie and chicken recipe! https://www.facebook.com/buzzfeedtasty/videos/1793921897527118/



Monica Nour shared a link.

21 April

Not familiar with how to cook with Vegetables? These Veggie preparation hacks will blow your mind!

These Veggie Preparation Hacks Will Blow Your Mind

Never chop your fingers off while cutting a squash AGAIN!

BUZZFEED.COM

Monica Nour
7 February

Buying vegetables that are in season can save you so much money! $$
Here's a summary of vegetables by season for our Sydneysiders. Other regions can be found through the Seasonal Food Guide Australia
http://seasonalfoodguide.com/

Artichokes (Globe)	Spring			
Asian Vegetables	Spring	Summer	Autumn	Winter
Beans		Summer	Autumn	
Beans (Broad)	Spring			
Beetroot		Summer		
Broccoli	Spring		Autumn	Winter
Cabbage	Spring	Summer	Autumn	Winter
Capsicum		Summer	Autumn	
Cauliflower	Spring		Autumn	Winter
Celery	Spring	Summer		
Chillies		Summer	Autumn	
Chinese Cabbage	Spring		Autumn	Winter
Cucumbers	Spring	Summer		
Eggplant		Summer		
Lebanese Cucumbers				Winter
Leek	Spring			Winter
Lettuce	Spring	Summer	Autumn	Winter
Mushrooms	Spring	Summer	Autumn	
Okra		Summer	Autumn	
Parsley	Spring	Summer	Autumn	Winter
Pecans			Autumn	
Potatoes	Spring			Winter
Pumpkins		Summer	Autumn	
Radish	Spring	Summer	Autumn	Winter
Rhubarb	Spring	Summer	Autumn	Winter
Silverbeet	Spring			Winter
Spinach	Spring			Winter

Monica Nour
8 February

Think eating healthy is expensive? Take a look at how much money you can save when you swap some of those common take-away convenience foods for their healthy equivalents #moneywise #healthkick #smallchangescount

Takeaway meals/ snacks	Cost	Home-prepared meals/snacks	Cost	Savings
Bacon and egg roll Skinny latte	$5.95 $3.90	2 slices Wholegrain toast with avocado and 1 egg Cup of instant coffee	$1.75 $0.10	$8.00
Medium juice drink with Celery, Pineapple, Mango, Banana, Apple	$6.50	Celery sticks, 1 whole banana and 1 apple	$1.99	$4.51
Ham & salad six-inch	$5.15	Ham & salad on grainy bread roll	$2.65	$2.50
Burger, fries & coke	$7.95	Chicken breast & salad on 2 grainy bread rolls	$2.60	$4.35
Chinese fried rice	$7.90	Homemade fried rice	$3.50	$4.40
Chocolate bar Savoury pastry	$2.30 $3.80	Carrot sticks and 1 handful of strawberries Toasted cheese and tomato sandwich	$2.00 $1.10	$3.00
			Total savings	$26.76

** Prices for take-away meals taken from the average take-out restaurants. Prices of home cooked meals calculated as cost per serving based on supermarket products divided by quantity used in this case, a single serve.

Monica Nour
21 April

Want to feel more energised? Essential nutrients in vegetables boost energy to help us perform at our peak.
#vegechallenge

Monica Nour uploaded a file.
26 April

Stuck for ideas on what to cook this week? We've got a sample menu an shopping list that might help. This plan uses recipes straight from the ap and assumes you are cooking for two. If you live on your own divide reci in half or simply freeze meals for the following week.

PDF

Menu and shopping list.pdf
PDF

Download | Preview | Upload Revision

Monica Nour shared a link.
21 April

Did you know that frozen vegetables are actually just as nutritious as fresh vegetables? You'll also save lots of time because they are washed, chopped and ready to be thrown into your next meal!

Do frozen vegetables contain more nutrients than fresh?

They might be convenient but are vegies straight from the freezer any healthier than fresh?

GOODFOOD.COM.AU

Monica Nour
8 February

Love gourmet burgers? Why not make them at home? You could save between $5-10 per burger. Try these lean burger patties (cost per pattie $1.30). Add all your favourite veg like lettuce, tomato, avocado and serve on a wholemeal or grainy bun all for $3.50 #cheapeats #burgerlove

Monica Nour
8 February

Want to get your 5 a day? It's all about timing! When do you usually eat vegetables? At dinner? Maybe a little at lunch?
Try to think of every meal and snack time as an opportunity for another serve of veg. At breakfast time why not have baked beans on toast? And for a snack cut up some carrot, cucumber and/or capsicum sticks, and enjoy them with a vegetable dip. Look out for our healthy guac dip recipe later this week #5aday #everymealcounts

Monica Nour
7 February

Did you know that beans count toward your veggie serves? They also contain protein and fibre to keep you fuller for longer. Why not add some kidney beans or chickpeas to your lunch this week? #VegeChallenge #5aday

Monica Nour
8 February

Ever tried Guacamole? This dip is super easy to make and goes down well with some crackers and veggie sticks #healthyeats #snackfood

Guacamole

Prep & cook time (5 mins), serves 4 people

Ingredients

1. 2 ripe avocadoes
2. Juice of 1 small lime
3. 1 small red onion diced
4. 1 medium tomato diced
5. 2 garlic cloves crushed
6. Salt and pepper to season

Method

1. Place the avocado flesh and lime juice in a medium bowl and use a fork to mash until almost smooth.

Monica Nour
8 February

Stocking your freezer and pantry with canned and frozen vegetables will make it easy to add veg to your meals. They contain all the nutrition of fresh varieties and can save you lots of money when vegetables aren't in season. Look for Australian grown produce where possible and pick canned veggies with no added salt #5aday #VegeChallenge

Monica Nour shared a link.
21 April at 17:16

Save money on your grocery shop this week! Here is our list of cheap markets around Sydney to buy fresh veg:
1. Flemington Markets
2. Paddy's Markets
3. Parklea Markets
4. Fairfield Markets... See more

Home - Local Market Guide
Local Market Guide details the growing number of markets in Sydney together with...
LOCALMARKETGUIDE.COM.AU

Like Comment Share

Monica Nour
22 March

Placing vegetables on the top shelf of your fridge where they are in sight can be a useful reminder to use them in your meals #vegechallenge

Monica Nour shared Goodful's video.
8 February at 16:20

These breakfast cups are so quick and easy to make. A great way to add some veg to breakfast on the go. You could even have them as an afternoon snack. Make in batches and freeze up to 2 months! #breakieonthego Acknowledgements to Goodful for their video. https://www.facebook.com/officialgoodful/videos/1460451714025290/

Monica Nour
Just now

Mmmm, This Roasted Brussel Sprout Salad Is Calling Your Name!
https://www.buzzfeed.com/.../this-roasted-brussels-sprouts-sa...

Like Comment

Monica Nour
23 March

Trending right now: cosmetically challenged pieces of vegetables that should be tasted, not wasted. Share a snap of a weird but wonderful veg you've purchased for a chance to win a voucher! Thanks to woolies for this great image, see in store for the odd bunch! #vegechallenge #oddbunch #Woolworths

Monica Nour
8 February

Eating a variety of vegetables each day exposes us to a wide range of nutrients for better health and glowing skin! Have you had your rainbow today? #5aday #eatarainbow

Monica Nour shared a link.
Just now

Stop throwing away your half used salad bag because it's gone soggy with this simple trick!

How to stop bagged lettuce rotting - Lifestyle - NZ Herald News

Sometimes when you're making a salad, it's easier to buy a bag of freshly washed...

NZHERALD.CO.NZ

Like Comment Share

Monica Nour shared a link.
21 April

Ever considered growing your own vegetables? This app teaches you how and when to plant a veggie garden!

Gardening Australia - Vegie Guide App

ABC Vegie Guide is an essential tool for all vegetable gardeners – from the novice to the experienced - to help you find out what vegie should be planted when, no matter the climate zone you're in. ABC Vegie Guide will give you all the information you need to produce

ABC.NET.AU

Like Comment Share

✔ Seen by everyone

Monica Nour For Android users TRY OUT The Yates My Garden App: http://www.yates.com.au/my-garden#oweiJoUsfcbEPb4o.97

My Garden - Yates

Green thumbs at the ready! The Yates My Garden App is now available for iPad, iPhone and Android devices for...

YATES.COM.AU

Monica Nour
21 April

Are you a fruit smoothie person? Why not add some vegetables and up your veg intake?
Avocado adds smoothness, and spinach is packed full of vitamins and doesn't change the flavour very much!

Monica Nour
21 April

Love hot chips?

Potatoes are packed full of nutrients but when fried they lose their goodness & are best eaten in small amounts.

Try baking, barbecuing, or microwaving for a healthier alternative.

Monica Nour
21 April at 14:44

Veggie Frittata, ready in 10 minutes! What's your favourite vegful dish? Upload a dish with lots of vegetables you've made for a chance to win a voucher! #vegechallenge #getcooking

Monica Nour
8 February at 10:48

ating more veg doesn't always mean you have to munch away at a salad. dd it to your fave dishes like this spaghetti bolognese with carrot, apsicum, and mushroom #sneakyveg #everybitcounts

Healthy Spaghetti Bolognese

rep & cook time (25 mins), serves 6 people, cost per person $2.50, 2 veg serves per pers

gredients

1. 500 g lean beef mince
2. 1 medium carrot (diced)
3. 1 red capsicum (diced)
4. 1 large onion (diced)
5. 8 button mushrooms (chopped)
6. 1 jar tomato pasta sauce
7. 3 cloves of garlic (crushed)

Method

1. Brown onion and garlic
2. Add in mince and cook until brown
3. Add in diced carrot, capsicum and mushrooms and mix until they soften
4. Add in tomato paste and ¼ cup of water, season Bolognese with pepper
5. Cook pasta as per packet instructions

Monica Nour
8 February at 11:44

Fancy some Thai for dinner? It's so quick and easy to make at home, especially if you use pre-cut frozen vegetables which taste just as good and are packed full of nutrients! The recipe below only takes 20 minutes to prepare, serving 4 people for $15 (Equivalent to the cost of one dish when you dine-out) #homecooking #5aday

Chilli basil chicken stir fry

Prep & cook time (20 mins), serves 4 people, cost per person $3.75, 3 veg serves per person

Ingredients

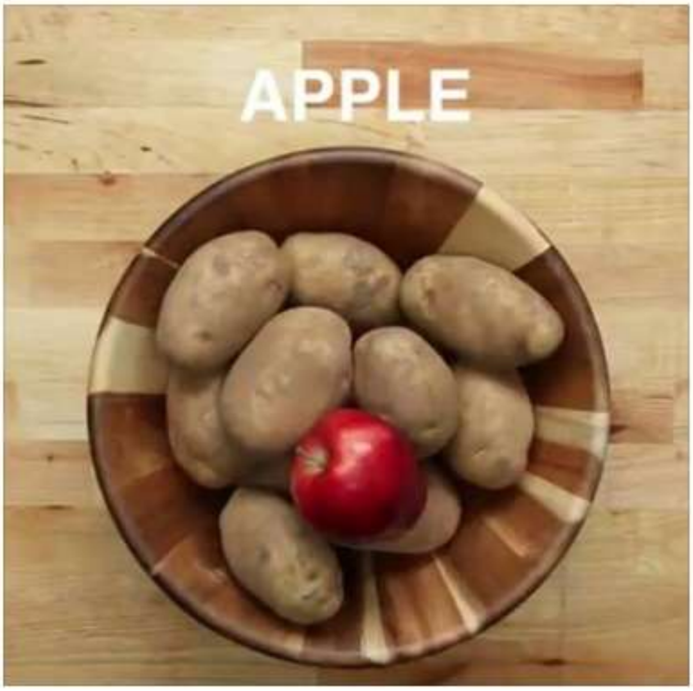
1. 400 g chicken breast thinly sliced
2. 1 brown onion cut into wedges
3. 1 red capsicums sliced
4. 500 g mixed frozen vegetables thawed
5. 2 garlic cloves, crushed
6. 2 large red chillies, deseeded, finely chopped

Method

1. Heat a wok or large frying pan over high heat
2. Spray with oil and stir-fry chicken until brown. Remove and set aside.
3. Add the onion, capsicum and mixed veg stir-fry for 2 minutes.
4. Add garlic and chilli and stir-fry for 2 minutes.

Monica Nour
Just now

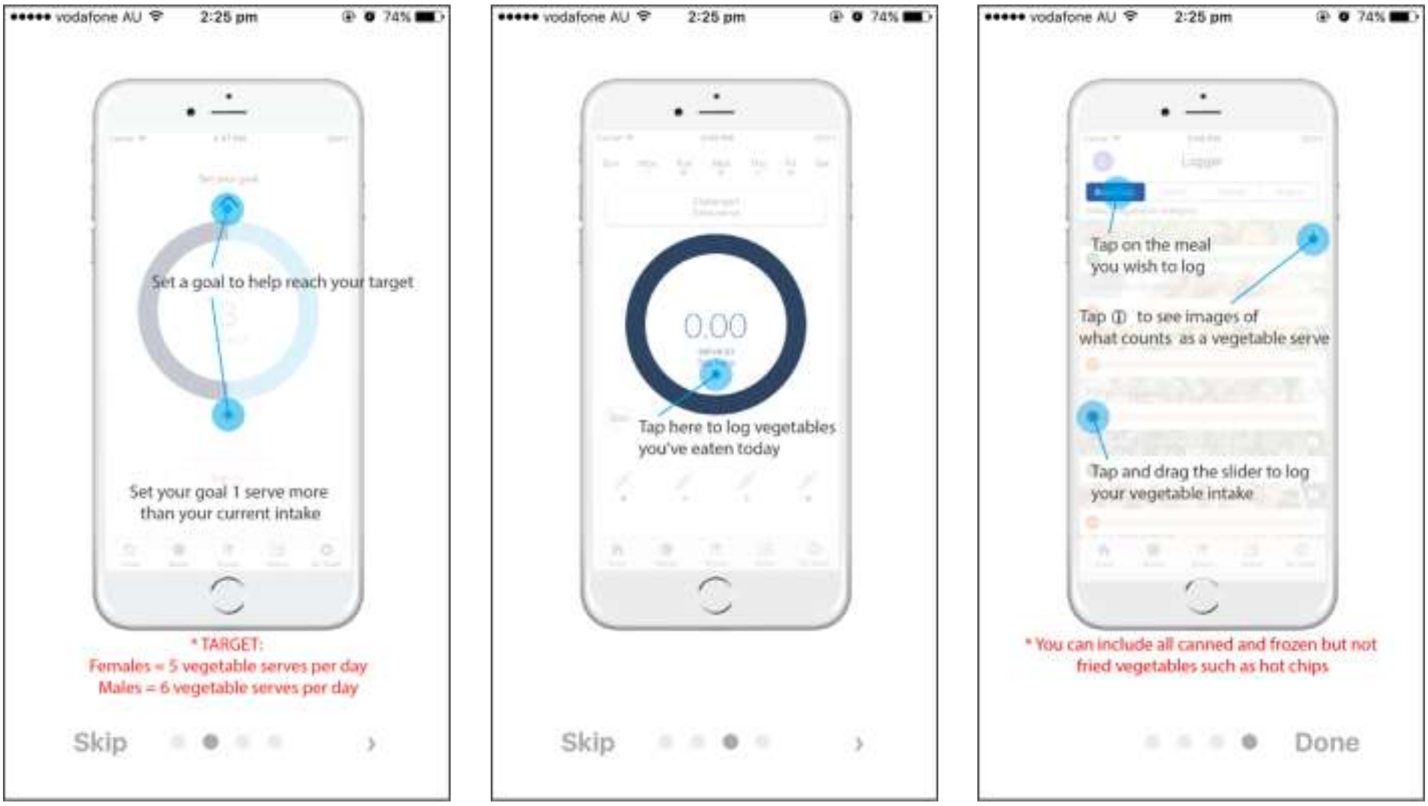
Do your potatoes start sprouting before you've had a chance to cook them? Store them with an apple to stop the sprouting and keep them fresh for longer!



Like Comment

Appendix 9.5

Instructions shown to users on how to use the mobile application



Appendix 9.6

Five item liket scale questionnaire measuring self-efficacy for consumption of vegetables in young adults

1. I can keep vegetables at hand/readily available

Not Confident at All			Very Confident	
1	2	3	4	5

2. I can eat the recommended number of serves of vegetables when I eat on my own

Not Confident at All			Very Confident	
1	2	3	4	5

3. I can shop for a variety of vegetables

Not Confident at All			Very Confident	
1	2	3	4	5

4. I can make time to eat vegetables

Not Confident at All			Very Confident	
1	2	3	4	5

5. When I eat at home, I can eat more vegetables

Not Confident at All			Very Confident	
1	2	3	4	5

Appendix 9.7

Four Item Habit formation questionnaire based on the 7 point scale Self-Report Behavioural Automaticity index (SRBAI)

Eating vegetables is something I do automatically

DISAGREE **AGREE**

1 2 3 4 5 6 7

Eating vegetables is something I do without having to consciously remember

DISAGREE **AGREE**

1 2 3 4 5 6 7

Eating vegetables is something I do without thinking

DISAGREE **AGREE**

1 2 3 4 5 6 7

Eating vegetables is something I start doing before I realize I'm doing it

DISAGREE **AGREE**

1 2 3 4 5 6 7

Chapter 10: Key research findings and directions for future research

10.1 Introduction to chapter

The publications presented in Chapters Two, Three, Four, Five, Seven and Eight have summarised the research findings that informed the theory-based intervention for improving vegetable intake in young adults described in unpublished Chapters Six and Nine. This last chapter ties together the key learnings from this body of work (Section 10.2) and discusses directions for future research (Section 10.3). The chapter closes with a thesis conclusion (Section 10.4).

10.2 Key research findings

The under consumption of vegetables among all Australians, but especially young adults, is a key public health issue that needs to be addressed. The body of research presented in this thesis was conducted to inform the development and feasibility testing of a theory-based intervention to support young adults to improve their vegetable intake. Young adults are the highest users of smartphones and social media among Australian adults (1, 2) and communicate and gain knowledge using these platforms. Hence, the selected digital media were chosen as age-appropriate platforms for dissemination of the intervention.

The first step in developing an effective intervention was to understand the characteristics of the problem, in particular, who is eating what vegetables, how much and when they are consumed. My secondary analysis of the Australian National Nutrition Survey data confirmed that consumption levels were well below the national recommendations, revealing that 18-24 year old males had the lowest level of intake. Furthermore, the varieties of vegetables consumed were limited and intake was almost exclusively confined to lunch and dinner. These findings were used to pinpoint the specific opportunities for improvement that would be integrated into the intervention (See Chapter 2 for published manuscript). It was established that our program should promote the consumption of a wider variety of vegetables, as well as prompt intake across all meal occasions, particularly breakfast and snacks because those who ate the most achieved it via this consumption pattern.

The second key step undertaken prior to developing the intervention was a review of the existing literature on programs delivered to the young adult population to improve vegetable intake. A systematic review of RCTs was carried out with the aim of investigating the efficacy and external validity of e/mHealth interventions. At the time of this review a scarcity of interventions were found that used e/mHealth strategies to target improvements in vegetable intake alone. The majority were multi-component healthy lifestyle interventions or targeted fruit and vegetables as a combined food group in the intervention. As such, the effect of these interventions on vegetable consumption independent of fruit could not be determined. From the available evidence, it was shown that strategies such as texting, phone coaching and online education platforms may be effective for improving vegetable consumption among young adults, however the effect was only small (effect size 0.15). Furthermore, the use of social media as an intervention platform was limited to blogs and discussion boards, with no studies employing contemporary mediums such as Facebook or Instagram.

A second review was conducted in narrative style to explore the efficacy of interventions that use novel strategies such as social media and gamification to improve the nutrition habits of young adults. This review found evidence that interventions that employed social media and gamification have positively influenced nutrition knowledge and participant attitudes. However, there was limited evidence indicating that these mediums could successfully improve vegetable intake or other dietary behaviours. To address this gap in the evidence, a theory-based mobile gaming and social media program was developed with the aim of increasing the vegetable intake of young adults.

The third stage of program development involved acceptability testing of the proposed components using focus groups. This was an important step in the process of refining intervention materials and ensuring the selected program components were relevant to young adults. This formative research revealed that the selected platform for improving vegetable intake (a goal setting and self-monitoring app) was favoured by the target audience. As expected (based on the COM-B model which shows that behaviour is influenced by a range of determinants), discussions with the young adults confirmed that additional support such as guidance for the development of meal planning and cooking skills may be necessary. Social media was seen as an acceptable platform for delivery of this additional support. This thesis presented further evidence to support the value of pretesting intervention material before using it in a RCT. Engagement with program material in the feasibility trial was better than previously reported. Thus, it is suggested that when developing new tools to improve health behaviours, researchers invest in a similar iterative approach whereby the target audience are involved in discussion to provide feedback on the acceptability of proposed program components.

The process of developing this theory-based program was comprehensive and spanned almost two and a half years from the initial explorative needs assessment to the literature reviews, program design, user testing and final refinements. This detailed process, although lengthy, should be considered by those endeavoring to develop evidence-based interventions. In this way, resources (researcher time and money) for behaviour change research can be applied more appropriately. While a 'top-down' approach whereby classical behavioural theories such as control or social cognitive theory is typically applied to guide an interventions design, the 'bottom-up' approach demonstrated in this thesis produced an intervention which is not only theory-based but adopts a holistic approach to behaviour change by addressing multiple determinants of the behaviour (Capability, Opportunity and Motivation).

The final stage of this thesis applied a factorial study design (3) to test the effectiveness of different program components. The aim was to assess if the behavioural components delivered by social media (through Facebook) and via gaming elements enhanced the outcomes achieved using a standard goal setting and self-monitoring app alone. The number of participants recruited to the feasibility trial is acknowledged as too small to confirm effectiveness, but it was apparent that the process of goal setting and self-monitoring with the provision of feedback was in itself enough to produce positive changes from baseline across all outcomes related to vegetable intake (except knowledge of servings sizes, where gaming and additional content through social media posts improved knowledge acquisition). Overall, we also observed that the process of self-monitoring supported habit formation and the development of skills in assessing adequacy of intake across the day and modifying food selection/recipes to include vegetables across all meal occasions. While the observed differences between groups for primary and secondary outcomes were not significant, this does not negate the role of electronic platforms and novel strategies for behaviour change. This trial suggested that gamification and social support via social media may enhance engagement among young adults. It provided evidence of the feasibility of delivering behaviour change interventions, to the individual, using modern communication technology. The accessibility of these platforms among young adults ensured the program is equitable and would allow it to be disseminated to the population at wide.

10.3 Future directions

At the commencement of this thesis, there was little evidence to support the use of social media and gaming elements as platforms for the delivery of theory-based interventions for improving the nutrition behaviours of young adults. Furthermore, the number of interventions employing social media in nutrition promotion to young adults remains limited. No new interventions have appeared in PubMed since my review was completed. The work conducted during my candidature led to the development of an evidence-based intervention guided by a comprehensive model of behaviour change. It is one of the first programs to target vegetable intake as a specific behaviour separate to fruit among young adults. While the research presented in this thesis supports the acceptability and feasibility of the program, further research using a larger sample of young adults that is adequately powered (i.e. n=1000) is necessary to confidently conclude which program components should be incorporated in a nationwide program. Ultimately, the purpose of thoroughly testing any health promotion program is to ensure its efficacy prior to dissemination at a larger scale. This ensures that government funding is used appropriately.

While the preliminary data summarised in Chapter Nine suggested that the process of goal setting and self-monitoring vegetable intake using a mobile app was effective in producing short-term improvements in vegetable intake and related outcomes, the longer term outcomes are yet to be studied. It is possible that further or delayed improvements in the behaviour may be observed downstream as sometimes skills/knowledge obtained during an intervention period may not be applied immediately. Thus, it is recommended that in the next phase of testing, follow-up measures at three and six months post-intervention are included. This will also allow measurement of behaviour change maintenance which has not been reported in the current body of work and was not well captured in the other studies identified and reviewed in this thesis.

To support young adults in the maintenance of their healthy behaviours in the long term, future work in this area should provide training to participants in creating action plans for the execution of their goals. For example, a goal to consume 4 serves of vegetables a day is translated to an action plan whereby the individual selects specific behaviours such as swapping their processed breakfast cereal for baked beans on wholegrain toast twice per week, adding salad to their a lunch sandwich on work days and/or packing cherry tomatoes as an afternoon snack. This ensures that the goal is Specific, Measurable, Achievable, Relevant and Time-bound (SMART).

Prior to evaluating the effectiveness of this intervention in a larger trial of longer duration further consideration should be given to investigating how best to engage young adults in interactive peer-to-peer social support. As discussed in Chapter nine, retention of participants was well maintained within the Facebook groups, however the type of engagement observed was passive, with the majority “viewing” and “liking” posts but not commenting and sharing. Further qualitative research needs to be completed to understand how best to facilitate active engagement and peer support within social media groups for healthy lifestyle behaviours.

Moving forward, research in this area could also study the impact of tailoring the delivery of gaming features based on personality traits. Experts in computer human interaction have shown that Points, Levels, and Leaderboards are more motivating for extraverted people, suggesting these incentives would not be appealing for the population at large and may lead to dis-engagement(4). It may be possible to segment the study population based on their personality characteristics and deliver motivational incentives accordingly. Future work in this area should also consider providing personalised messages tailored to the participant's progress with their intake goals so the individual remains engaged in the process of self-monitoring. While tailoring at this level would require advanced computer programming that was beyond the scope of this thesis, it is an important consideration for maintaining participant engagement in future interventions.

The potential for wider reach and greater engagement when these technologies are used to deliver health behaviour change interventions could decrease the costs of public health programs. This thesis estimated the cost of delivering the proposed intervention and other studies have reported the cost-effectiveness of eHealth care (5). However, there is still limited data confirming that the selected modes of delivery (apps and social media) are cost-effective for behaviour change interventions (6). Thus, all future research which harnesses these technologies should measure and report cost-effectiveness for a sounder estimate of economic value.

The delivery of efficacious interventions that provide an individual with the knowledge, self-efficacy and motivation to improve vegetable consumption is only part of the solution. Public Health Practitioners and researchers working in this area should also consider the importance of campaigning for reforms within the broader environmental setting to support sustainable change. This may include restructuring of the food environment so that healthier foods such as vegetables are more salient to the consumer. Supermarkets have been well researched as one such food environment where changes can be made to influence purchasing of healthier foods such as vegetables. Product placement, percentage space allocated to healthier foods, and use of shelf-labels and brochures/posters has been shown to improve purchasing of vegetables and other healthy foods (7). However, the majority of this work has been conducted in the USA (7). Thus, there is an opportunity for large chain supermarkets in Australia to implement these strategies to support the goal of influencing individual behaviours.

Reformulation of food policy may also improve the affordability of and access to vegetables. Previous surveys with Australian adults have indicated that the cost of vegetables is a major barrier among 14% of those who are not meeting the recommended five serves a day. Cost was a particularly significant barrier among families within the lower income bracket (8). Thus, changes to policy to support the introduction of subsidies that reduce the cost of fresh produce items for lower socioeconomic communities may be helpful. This is one example of an environmental intervention that may improve the affordability of and thus access to vegetables, and may support efforts made for behaviour change on the individual level. In fact a recent Australian trial modeled this process using a 20% price-reduction on vegetables. They found that the group exposed to the price reduction purchased more vegetables than control (9). Work can also be done to create policies conducive to a food environment that encourages vegetable intake; this may include the provision of recommendations to the food manufacturing and catering industries for the inclusion of a specified quantity of vegetables in processed/ready foods and restaurant/take-away meals. The current Health Star Rating

System in place would positively reward manufacturers and food suppliers with a higher star rating of their product by increasing the vegetable content (10).

10.4 Conclusion to thesis

The combination of individual behaviour change programs within a supportive food environment gives the best chance of improving vegetable intake. This thesis has confirmed the feasibility and acceptability of social media and smartphone apps as platforms for the delivery of theory-based behaviour change interventions. These novel communication technologies make the individual approaches accessible to the population at large in a way that could not be achieved by previous generic mass media campaigns.

10.5 References

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10.6 Conclusions to chapter

Developing theory-based interventions to improve the fruit and vegetable intake of young adults is an important goal for health professionals given the alarmingly low levels of consumption among this population group, and the available evidence demonstrating the myriad of health benefits vegetables provide. As such, the research presented in this thesis is of great importance. This body of work has provided public health researchers with a guide that may assist with the process of program planning and development of theory-based interventions using novel and modern technological platforms for dissemination. The thesis used a comprehensive and user-centered approach to program planning and development and demonstrated the processes of acceptability and feasibility testing.