School of Public Health

Healthy and Sustainable Dietary Behaviours in Western Australian Adults

Amelia Jeanne Harray

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Doctor of Philosophy
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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. This research study utilised two existing datasets; (1) the Nutrition Monitoring Survey Series (2009 and 2012) and; (2) the Connecting Health and Technology Study. The 2009 and 2012 Nutrition Monitoring Surveys were granted ethics approval from the Western Australia Department of Human Research Ethics Committee. The Curtin University Human Resources Ethics Committee (RD-22-11) granted ethics approval to translate the findings from research into practice as part of the project titled Food Law, Policy and Communications to Improve Public Health.

The Connecting Health and Technology Study was registered on the Australian and New Zealand Clinical Trials Registry (ACTRN12612000250831) and received human research ethics approval from the Curtin University Human Resources Ethics Committee (HR181/2011) and the Western Australian Department of Health Research Ethics Committee (#2011/90).

Amelia Jeanne Harray

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Abstract

Aim

The consumption of highly processed energy-dense nutrient-poor (EDNP) foods and beverages contributes to the increased risk of chronic diseases, including overweight and obesity. The diets of Australian adults are typically high in packaged EDNP foods, sugar-sweetened beverages and animal-based foods, while low in fruits, vegetables and legumes. These dietary practices can have negative implications on health and the environment. The concepts of a diet for good health and a diet supportive of the environment are often considered in isolation from one another. Aligning key policies on healthy diets with sustainable diets has great potential to reduce chronic disease risk and lessen burden on the environment. However, little is known about people's attitudes, influences and behaviours relating to healthy and sustainable diet in Australia. In addition, there is no set guideline around sustainable food choices in the Australian Dietary Guidelines and no purpose designed dietary assessment method to assess multiple elements of a sustainable diet. Against this background the objectives of this research were:

1. Determine the factors associated with measures of adults' support for a sustainable food supply using Western Australian population-based survey data.
2. Evaluate perceptions toward current energy-dense nutrient-poor food and beverage intake, compared to actual intake data collected using a 4-day image-based mobile food record.
3. Determine the association between eating frequency and the intake of foods related to a healthy and sustainable diet, as defined by the consumption of fruits, vegetables and energy-dense nutrient-poor foods and beverages.
4. Develop a Healthy and Sustainable Diet Index to measure key components of a healthy and sustainable diet using images, including:
    - Animal-based foods (ruminant meat, pigs, poultry, fish, dairy foods and eggs)
    - Fruits and vegetables (including seasonality)
    - Ultra-processed energy-dense nutrient-poor foods and beverages
    - Individually packaged foods and beverages
    - Food (plate) waste
5. Apply and evaluate the Healthy and Sustainable Diet Index using 4-day image-based mobile food records.

Methods

This research utilised two existing datasets and took part in three stages. Stage one utilised the 2009 and 2012 Nutrition Monitoring Survey Series data. These were used to assess the attitudes of 2832 Western Australian (WA) adults (aged 18 to 64 years) toward a sustainable food supply and how their attitudes were associated with intake their of eight foods related to a sustainable diet.

The following two stages of this research utilised data collected during the Connecting Health and Technology (CHAT) study, a six-month randomised controlled trial of which the candidate was a Research Assistant and collected and analysed all the dietary data. The CHAT study assessed dietary intake by collecting two 4-day image-based mobile food records (mFRs) from 247 adults (aged 18 to 30 years); using a purpose-built App. Anthropometric measurements were collected by the research team and written questionnaires captured demographic information, measured attitudes regarding the health aspects of diet, and assessed self-perception of their current intake.

Stage two of this research used the CHAT study data to assess whether perceptions of diet and eating frequency were associated with actual intake of foods related to healthy and sustainable dietary behaviours. The mFR had not previously been used to assess eating frequency or sustainable diets. Stage three involved the development, application and evaluation of a theoretically derived prediction model - the Healthy and Sustainable Diet Index *(*HSDI). This involved assigning weighting to individual components of the index according to evidence on their impact on health and/or environmental sustainability. The HSDI was applied to a duplicate and longitudinal sample of 4-day mFRs and evaluated using SPSS Version 22. The HSDI is composed of behaviours impacting health and environmental sustainability which can be enumerated from images of ‘before’ and ‘after eating’ occasions, and further informed by contextual information. Images were analysed and food serve sizes were estimated according to the Australian Guide to Healthy Eating standard food servings. All dietary data were added to a purpose built Microsoft Access database and exported to SPSS. Such dietary behaviours include intake of fruits and vegetables (including seasonality); non-animal protein sources (such as nuts, seeds, legumes and tofu); animal-based foods, and ultra-processed EDNP foods and beverages; use of individually packaged items as a food source and; plate (food) waste.

Results

Stage one found WA adults had a high and increasing level of concern about an environmentally friendly food supply and place a high level of importance on government regulating the issue. Four in five adults reported being 'quite' or 'very' concerned about the effect of the environment on future food supplies. Respondents who reported paying less attention to the health aspects of their diet were less likely than those who were health conscious to be 'quite' or 'very' concerned about the effect of the environment on future food supplies (OR 0.53, 95%CI [0.35, 0.80] and 0.38 [0.17, 0.81], respectively). Over 85% of people believed it was 'quite' or 'very' important that government had regulatory control over an environmentally friendly food supply, with women being more likely than men to rate regulatory control as 'quite' or 'very' important (OR=1.63, 95%CI [1.09, 2.44], $p< 0.05$). Multiple regression modelling found that no other factors predicted concern or importance of government regulation. There were limited associations between attitudes towards environmentally friendly food and the intake of key foods related to a sustainable diet.

Stage two analysed perceptions of current intake versus actual food intake, assessed using images, found young adults consumed an average of 3.7±2.0 serves of EDNP foods and beverages per day, inconsistent with a healthy or sustainable diet. Participants who believed they were already consuming a diet low in 'junk food' consumed less than those who reported currently trying to eat less junk food ($p< 0{\cdot}001$), thinking about cutting down ($p< 0{\cdot}001$) or not thinking about cutting down ($p< 0{\cdot}001$). The stage two analyses on eating frequency and foods related to a healthy and sustainable diet found significant positive associations between the number of daily eating occasions and the intake of fruits (r=0.309, $p< 0.0001$), vegetables (r=0.320, $p< 0.0001$), EDNP foods (r=0.242, $p< 0.0001$), and alcohol (r=0.335, $p< 0.0001$). There was no association with sugar-sweetened beverage intake. Pearson's correlation showed an inverse association between body mass index and eating frequency (r=-0.190, $p< 0.005$).

Results from stage three of this research (the application and evaluation of the HSDI) found people who ate non-animal protein foods (such as legumes, tofu, nuts and seeds) were significantly more likely to eat fruit ($p< 0.001$), vegetables ($p< 0.05$) and dairy foods ($p< 0.05$). The strongest association found was between the intake of individually packaged EDNP foods and ultra-processed EDNP foods ($p< 0.001$) and beverages ($p< 0.001$). People who reported taking vitamin supplements were significantly more likely to have a higher HSDI score than those who reported not taking supplements ($p< 0.005$).

After adjusting for all variables in the multivariate regression model, the strongest predictor of one's likelihood of being in the lowest tertile for total HSDI score was their dietary health consciousness. Those who reported only taking 'a bit of notice' (OR=5.276, 95%CI [1.765, 15.619], $p < 0.005$) or 'not thinking much' or 'at all' about the health aspects of their diet (OR=8.308, 95%CI [2.572, 26.836], $p < 0.0001$) were more likely to be in the lowest tertile for HSDI.

Conclusions

Findings from this research provide evidence on the attitudes and behaviours of WA adults relating to sustainable food supplies. This research developed a novel and innovative dietary assessment method to apply and evaluate a prediction model to assess multiple components of a healthy and sustainable diet. This research contributes to the field of research by providing evidence on attitudes and behaviours relating to healthy and sustainable diets, a prediction model to measure adherence to a healthy and sustainable diet, and a method to increase consumer awareness of their dietary behaviours.

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Abbreviations

$AUD	Australian dollar
24HR	24- hour recall
95%CI	95% confidence interval
ABS	Australian Bureau of Statistics
ADGs	Australian Dietary Guidelines
AHS	Australian Health Survey
AGTHE	Australian Guide to Healthy Eating
AMPM	Automated Multiple Pass Method
ANOVA	Analysis of variance
App	Application on a mobile device
ASA24	Automated Self-Administered 24-hour Recall
BMI	Body mass index
CHAT	Connecting Health and Technology Study
CVD	Cardiovascular disease
DASH	Dietary Approaches to Stop Hypertension
DQI	Diet quality index
EDNP	Energy-dense nutrient-poor
EF	Eating frequency
EO	Eating occasion
FAO	Food and Agricultural Organization
FFQ	Food frequency questionnaire
g	Gram
H&S	Healthy and sustainable
HEI	Healthy Eating Index
HSDI	Healthy and Sustainable Diet Index
IPAQ	International Physical Activity Questionnaire
JF	Junk food
kg	Kilogram
kJ	Kilojoule
LCA	Life cycle analysis (or assessment)
MI	Motivational interviewing
mFR	Mobile food record
mL	Millilitre

NHMRC	National Health and Medical Research Council
NHANES	National Health and Nutrition Examination Survey
NMSS	Nutrition Monitoring Survey Series
OR	Odds ratio
RCT	Randomised controlled trial
SD	Standard deviation
SDT	Self-determination theory
SEIFA	Socio-Economic Indexes for Areas
SSB	Sugar-sweetened beverage
TADA	Technology Assisted Dietary Assessment
UK	United Kingdom
US	United States
WHO	World Health Organization

Definitions

The following terms are defined for the purpose of this research and are used throughout this thesis:

Animal-based foods	Includes all food products derived from animals, including meat, poultry, fish, seafood, dairy foods and eggs.
Eating frequency	The number of daily eating occasions.
Eating occasions	Separate occasions by which a food, beverage or food and beverage is consumed, excluding when water is the only item ingested.
Junk foods	Junk foods are high in saturated fat, added sugar, salt and/or alcohol and are energy dense. Also referred to as 'discretionary foods' in the Australian Dietary Guidelines (ADGs) and the Australian Guide to Healthy Eating (AGTHE), these foods and beverages contain minimal, if any, nutritional value and are high in kilojoules (NHMRC, 2013).
Environmental sustainability	"Meeting the resource and service needs of current and future generations without compromising the health of the ecosystems that provide them" (Morelli, 2011, p. 24).
Food waste	Food losses which occur at any stage of the food supply chain, including production, postharvest, processing, retail, preparation and consumption (Department of Agriculture Fisheries and Forestry, 2013).
Food miles	The distance between where a food is grown (or produced) and where it is consumed.
Greenhouse gas emissions	Emissions that absorb infrared (heat) radiation in the atmosphere (Raphaely & Marinova, 2016) and contribute to the greenhouse effect. Examples include methane, carbon dioxide and nitrous oxide (Fogelberg, 2013).
Healthy diet	A diet which aligns with the ADGs such that it includes a variety of nutritious plant-based foods every day, moderate amounts of lean red meat and dairy foods, and limits EDNP foods and sugar-sweetened beverages to only occasionally and in small amounts (NHMRC, 2013). The types and volumes of foods aligned with a healthy diet are consistent with the recommendations of the AGTHE.
Healthy and sustainable diet	A diet which aligns with both the ADGs (NHMRC, 2013) and has low environmental impacts while contributing to food security and to "healthy life for present and future generations." (Burlingame & Dernini, 2012, p. 7).

Mobile food record	A dietary assessment App that captures ‘before’ and ‘after’ eating images of all foods and beverages consumed, which are automatically sent to a backend cloud-based server for analysis.
Plant-based foods	Foods derived from plants including whole grains and cereals, legumes, beans, peas, fruits and vegetables.
Red meat	Includes meat from sheep, cattle, kangaroo and goat (NHMRC, 2013).
Ruminant animals	Animals that chew the cud regurgitated from its rumen, which includes animals includes predominantly cattle, sheep and goats in Australia (Oxford University Press, 2016).
Sustainable diets	“Diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.” (Burlingame & Dernini, 2012, p. 7).
Ultra-processed foods	Ready-to-eat, durable and appealing foods that require minimal to no preparation (Monteiro, Levy, Claro, Ribeiro de Castro, & Cannon, 2010). These foods are often packaged after being baked, fried, cured, smoked, canned, sugared or salted, and often contain additives and preservatives.

Publications and presentations arising from this thesis

Published manuscripts in peer-reviewed journals

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Chapter 1 Introduction

1.1 Statement of the problem

Poor nutrition can contribute to chronic disease risk and is a major public health issue in Australia (NHMRC, 2013). Diet-related diseases pose a significant cost at an individual, economic, environmental and societal level. Improving dietary behaviours plays a key role in reducing health risks, yet Australian's have diets inconsistent with current recommendations for good health. Young adults consume the highest amounts of energy-dense nutrient-poor foods (EDNP) and sugar-sweetened beverages (SSBs) (Australian Bureau of Statistics, 2012), behaviours related to excess weight gain (NHMRC, 2013). Over half of young adults aged 18 to 24 years and 59% of 25 to 34 year olds in Western Australia (WA) are classified as overweight or obese (Australian Bureau of Statistics, 2014). In Australia, 25 to 34 year olds have the greatest yearly increment in waist circumference and weight compared to any other age group, and are gaining weight at a faster rate than previous generations (Tanamas, Shaw, Backholer, Magliano, & Peeters, 2014). To slow the trajectory of weight gain and reduce disease risk earlier in life, this age group is an important target population for nutrition education to improve dietary habits.

The impact of global warming is a major public health issue, which may be improved by modifying dietary behaviours. The issues of environmental sustainability and nutrition are often considered in isolation from one another (Institute of Medicine, 2014).The 2016 World Health Organization's Sustainable Development Goals made clear links between dietary behaviours and climate change, and although 193 countries agreed on these goals, they are not legally binding (World Health Organization, 2016). Policies supporting and encouraging more sustainable dietary behaviours would benefit both health and the environment (Bradbear & Friel, 2013; Lowe, 2014; Macdiarmid et al., 2012). Approximately 30% of greenhouse gas emissions globally can be attributed to the food supply, with consequent negative impacts on the environment (Aleksandrowicz, Green, Joy, Smith, & Haines, 2016; Dangour, Mace, & Shankar, 2017). Agriculture alone is responsible or 16% of Australia's total greenhouse gas emissions, and this is mostly from the enteric fermentation of ruminant animals (Department of Primary Industries and Regional Development, 2017). Changes to the climate can significantly affect agricultural practices and in turn can threaten future food supplies, however, experts working in the fields of agricultural science and nutrition infrequently collaborate (Institute of Medicine, 2014). Food choices are a modifiable behaviour that can detrimentally impact biodiversity and ecosystems (Aleksandrowicz et al., 2016), therefore supporting and encouraging more sustainable diets through programs and policies should be a priority (Johnston, Fanzo, & Cogill, 2014). The Australian Dietary Guidelines contain an Appendix titled 'Food, Nutrition and Environmental Sustainabiliy', however, do not contain a set dietary guideline encouraging Australians to adopt sustainable dietary behaviours. Policy changes are unlikely to occur without a solid evidence base, and current methods to assess how dietary patterns adhere to a healthy and sustainable (H&S) diet have significant limitations.

This research will address four main gaps in the literature; first being the issue of healthy diets and sustainable diets largely being considered separately (although a sustainable diet is typically a healthy way of eating and vice versa). Secondly, there is limited evidence on how adults' perceive environmentally friendly foods and the future food supply and whether these attitudes are related to food intake. Thirdly, there is limited evidence on how the dietary behaviours of WA adults align with those supportive of both health and the environment, a topical area of nutrition. Lastly, there is no dietary assessment method to collect data on multiple elements of a healthy and sustainable (H&S) diet without placing unrealistic expectations on respondents and researchers.

1.2 Significance of this research

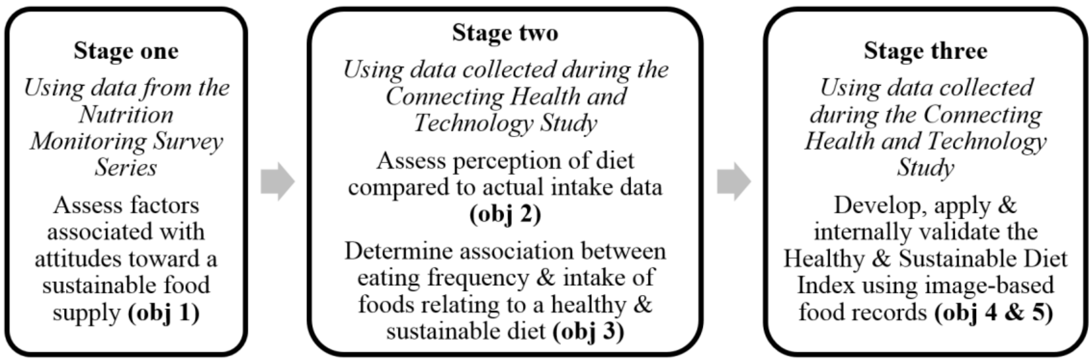
This thesis will examine attitudes and behaviours relating to a H&S diet, an important area of research as dietary behaviours can increase chronic disease risk and negatively impact the environment, beyond what is necessary to meet nutrient requirements. Assessing attitudes on a population level often involves the inclusion of questions in surveys, but current methods to assess dietary behaviours are limited in their ability to measure multiple elements of a H&S diet. Technology-based dietary assessment has potential to integrate within people's lives, be less burdensome than some traditional dietary assessment methods and provide researchers with objective data on H&S dietary behaviours. This research will examine an array of sustainable dietary behaviours using 'before' and 'after eating' images captured with the mobile food record (mFR), and then develop, apply and evaluate a model, the Healthy and Sustainable Diet Index (HSDI). This research will provide evidence on the H&S dietary behaviours of young adults and a novel method for contribution to future nutrition research.

1.3 Aims and objectives

The aims of this research are to assess attitudes toward a sustainable food supply, and develop, apply and evaluate a novel dietary assessment method to assess healthy and sustainable dietary behaviours in Western Australian adults. This will be conducted in three stages (Figure 1.1) to address the specific research objectives, which are:

1. Determine the factors associated with measures of adults' support for a sustainable food supply using Western Australian population-based survey data.
2. Evaluate perceptions toward current energy-dense nutrient-poor food and beverage intake, compared to actual intake data collected using a 4-day image-based mobile food record.
3. Determine the association between eating frequency and the intake of foods related to a healthy and sustainable diet, as defined by the consumption of fruits, vegetables and energy-dense nutrient-poor foods and beverages.
4. Develop a Healthy and Sustainable Diet Index to measure key components of a healthy and sustainable diet using images, including:
    - Animal-based foods (ruminant meat, pigs, poultry, fish, dairy foods and eggs)
    - Fruits and vegetables (including seasonality)
    - Ultra-processed energy-dense nutrient-poor foods and beverages
    - Individually packaged foods and beverages
    - Food (plate) waste
5. Apply and evaluate the Healthy and Sustainable Diet Index using 4-day image-based mobile food records.

Figure 1.1 Stages of this research



1.4 Scope and considerations of this research

Considerations of secondary data analyses

This research involves secondary analyses of two existing datasets; the 2009 and 2012 Western Australian Nutrition Monitoring Survey Series (NMSS) and; the Connecting Health and Technology (CHAT) study. The data used to assess attitudes towards an environmentally friendly food supply were collected prior to the commencement of the present study, and therefore are limited to the questions asked during the NMSS. Similarly, the eating images captured using the mobile food record (mFR) during the CHAT study were prior to the commencement of this research. Using existing data provides strength to this study as participants were unaware of the sustainable dietary behaviours being assessed and hence, reduced the risk of social desirability bias (discussed in Section 2.6.4.1). However, it also means the version of the mFR App used in the CHAT study was not specifically designed to measure sustainable dietary behaviours.

Dietary behaviours captured using the mobile food record

For stages two and three of this research, only dietary behaviours in images captured using the mFR were measured during this research. The assessment of additional dietary behaviours that are consistent with a sustainable diet, such as buying locally grown food, overall household food waste and the use of non-individual food packaging (such as a shared two litre bottle of milk), are beyond the scope of this research.

Evaluation of the Healthy and Sustainable Diet Index

The data used to apply and evaluate the Healthy and Sustainable Diet Index were collected during the CHAT study, which limits the evaluation of this method to young adults aged between 18 and 30 years in a Western Australian context. Although further evaluation of the method has potential to be undertaken in other locations, larger population groups, and wider age ranges.

Calculating the environmental impact of different food products

The most common method for measuring the environmental impact of specific foods is life cycle analysis (or assessment) (LCA). The LCA method is a holistic approach which considers the inputs (e.g. water, raw materials and energy) and outputs (e.g. GHG emissions) of a food product throughout its lifetime (from production and processing to use and disposal) (Roy et al., 2009). Collecting LCA data is financially and resource intensive and hence, there is limited evidence on the LCA values of many Australian foods. Due to different climates and farming practices, LCA values calculated in other countries are not necessarily transferrable to an Australian context (Roy et al., 2009). The present study does not directly compare the LCA values of different foods but summarises the evidence in the area as to which foods and food groups generally have a lesser or greater environmental impact.

Organic food

There is no conclusive evidence on the health benefits associated with eating organic foods compared to non-organic foods (Dangour et al., 2009; Mie et al., 2016). In Australia, there is currently no recommendation to choose organically grown foods over conventionally grown foods. In addition, there is limited peer-reviewed evidence on the environmental impact of organic foods as the production is minimal compared to conventional methods (de Vries & De Boer, 2010). The quality of soil and influence of fertilisers, pesticides and other chemicals were beyond the scope of this research as the dietary intake data collected using the mobile food record (mFR) did not provide this level of detail. The mFR tool was not set up to measure the use of chemicals on food. For example, the mFR App is able to assess whether an apple was consumed, its colour and the volume consumed, however, the origin of the apple and the use of pesticides, fertilisers and other chemicals in the orchard cannot be measured using this tool.

1.5 Thesis structure

This is a hybrid thesis comprised of: an introductory chapter; literature review; separate chapters outlining the methodology, results and discussion (comprised of both published manuscripts and unpublished drafted manuscripts); an overall discussion chapter and; lastly, conclusions and recommendations arising from this research. This thesis contains four peer-reviewed publications to help address the objectives, of which the candidate was the primary (three manuscripts) or secondary author (one manuscript). These manuscripts have not been included in any other PhD thesis. All published work has been replicated with permission from respective publishers and authorship declarations signed by each co-author appear in Appendix B. Chapters 3, 4, 6 and 7 contain the published papers with an introduction preceding each paper detailing the candidate’s significant contribution to the manuscript. The results addressing each of the research objectives are presented in separate chapters, as outlined in Table 1.1. One single reference list appears at the end of this thesis and is inclusive of all citations.

Table 1.1 Research objectives addressed in thesis chapters

Results chapter	**Objectives addressed**
Chapter 3 – Attitudes toward a sustainable food supply	Objective 1
Chapter 4 – Outcomes of the Connecting Health and Technology (CHAT) study**Error! Reference source not found.**	Objectives 2 – 5
Chapter 5 – Perception of dietary intake versus actual intake of foods related to a healthy and sustainable diet	Objective 2
Chapter 6 – Eating frequency and intake of foods related to a healthy and sustainable diet	Objective 3
Chapter 7 – Protocol used to assess healthy and sustainable diets using the mobile food record	Objective 4
Chapter 8 – Development, application and evaluation of the Healthy and Sustainable Diet Index	Objective 5

Chapter 2 Literature review

2.1 Structure of the literature review

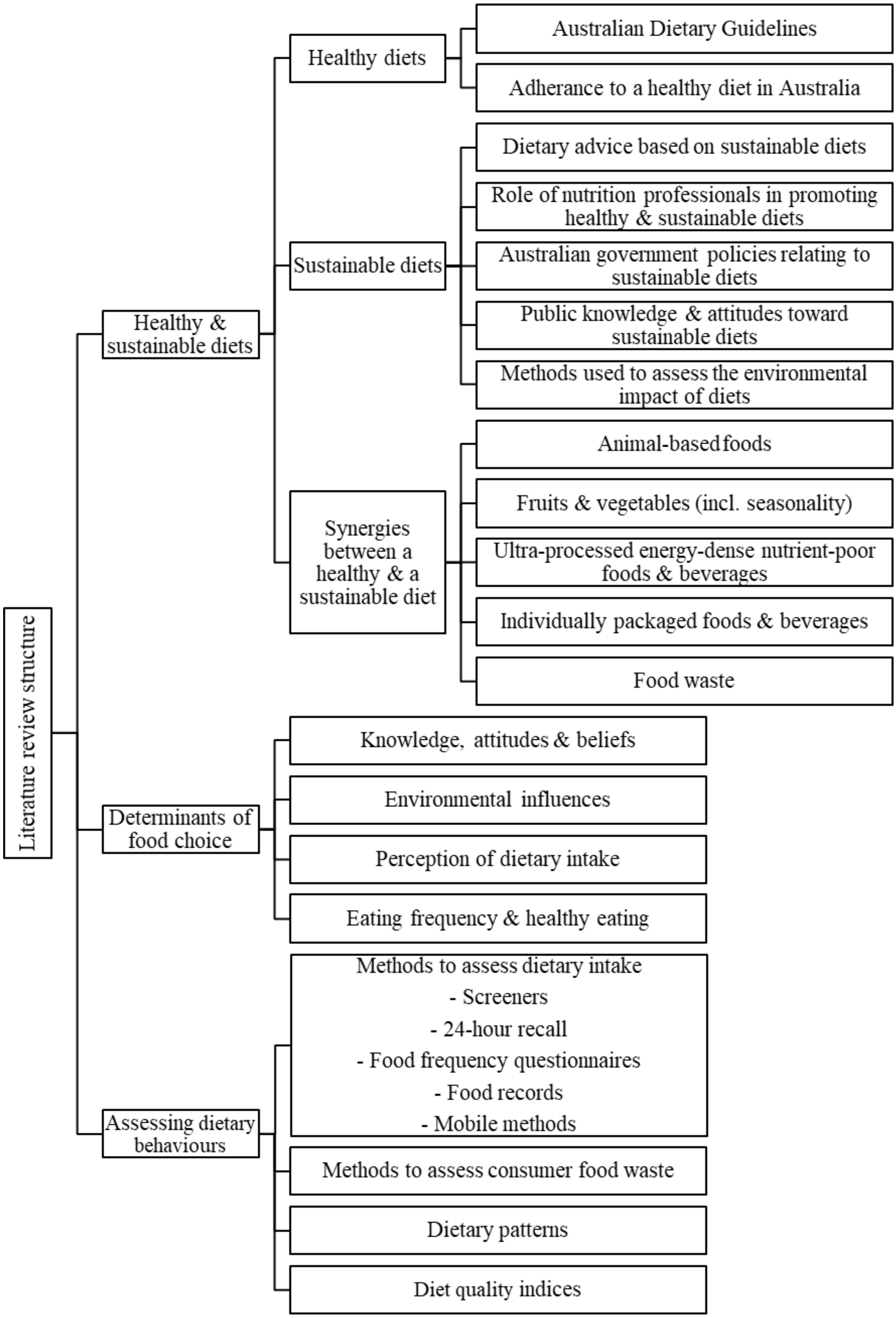
There are three broad sections of this review to highlight; the gaps in the literature; the complexity of the topic and; the importance of merging the fields of nutrition and sustainability (outlined in Figure 2.1). The first section outlines current recommendations and evidence around what constitutes a healthy diet, a sustainable diet, and the synergies between the two that can be assessed using images (Sections 2.3 to 2.5). The second section outlines determinants of food choice and the complexities surrounding why people eat the way they do (Section 2.6). Lastly, the third section examines the literature on existing dietary assessment methods and their ability to assess H&S dietary behaviours (Sections 2.7 to 2.11). This review highlights gaps in the literature and the potential to merge the area of H&S diets with evolving technology in dietary assessment. Details on the search strategy used to conduct this literature review are outlined in Section 2.2.

2.2 Conducting the literature review

Literature was searched from August 2013 to March 2018. The following databases were accessed through the Curtin University Library website: PubMed, ProQuest, Science Direct and MedLine. Key search terms included, but were not limited to; sustainable diet; healthy diet; sustainable food; diet quality index(ices); environmentally friendly food; dietary assessment methods; eating frequency; eating occasions; snacking; perception of diet/food intake; technology dietary assessment; environmental impact diet; life cycle analysis; plant-based diet; animal-based diet; Australian diet; processed food; young adults diet; food waste. Cross-referencing existing papers was also undertaken by the candidate.

National and international grey literature were also included in the search. This involved researching government published documents and recommendations, and engaging with networks who are undertaking work in this area of research, such as the Food and Climate Research Network, based at the University of Oxford (Food and Climate Research Network, 2018). These activities allowed the candidate to gain insight into progressions in this rapidly evolving area of nutrition.

Figure 2.1 Structure of the literature review



2.3 A healthy diet

There is a well-established relationship between dietary intake and poor health, including non-communicable diseases (such as cardiovascular disease, Type 2 Diabetes, some cancers and osteoporosis) (World Health Organization, 2003). Poor diet and inadequate physical activity can lead to overweight and obesity, an independent risk factor for 13 types of cancer (Centres for Disease Control and Prevention, 2017), Type 2 Diabetes and cardiovascular diseases. These preventable lifestyle-related diseases are Australia's leading causes of death and place significant burden on the health system and economy (Australian Institute of Health and Welfare, 2015).

When considering a healthy diet on a population level the most recent evidence should be considered due to ongoing advances in the field of nutrition science. This section explores evidence on healthy diets to provide background and justification for why both healthy *and* sustainable diets are important considerations. In Australia, a healthy diet is one that conforms to the Australian Dietary Guidelines (NHMRC, 2013).

2.3.1 Australian Dietary Guidelines

The most recent iteration of the Australian Dietary Guidelines (ADGs) were funded by the Australian Federal Government and developed by the National Health and Medical Research Council (NHMRC, 2013). The ADGs provide culturally appropriate guidance on dietary patterns, and the types and amounts of foods to promote health and prevent disease. These guidelines are developed to align with the most recent evidence and educate the public on healthy food choices in an aim to meet national Nutrient Reference Values (NHMRC, 2006). The ADGs are designed for dissemination and use by the public, health professionals, educators, researchers, and policy makers.

Australia has had national dietary guidelines since 1982. They are revised approximately every 10 years with the most current edition released in 2013, after a five-year research and consultation process. The translation of these recommendations into policies and programs to influence food choice practices is a core issue. The average Australian diet does not meet the dietary recommendations (Australian Bureau of Statistics, 2015), with numerous factors influencing adherence to the guidelines, including the availability, affordability, convenience, and marketing of EDNP foods and beverages. There are other fundamental issues with the ADGs, such as the lack of ongoing funding for production and dissemination of resources and messages. However, due to the public availability and comprehensive development process of the ADGs, they are fundamental to translating the evidence around sustainable diets into easy-to-understand food-based recommendations for the public. The five Dietary Guidelines in the 2013 iteration are tabulated below (Table 2.1).

Table 2.1 The Australian Dietary Guidelines (NHMRC, 2013)

Guideline 1	To achieve and maintain a healthy weight, be physically active and choose amounts of nutritious food and drinks to meet your energy needs.	Children and adolescents should eat sufficient nutritious foods to grow and develop normally. They should be physically active every day and their growth should be checked regularly Older people should eat nutritious foods and keep physically active to help maintain muscle strength and a healthy weight
Guideline 2	Enjoy a wide variety of nutritious foods from these five food groups every day:	• Plenty of vegetables of different types and colours, and legumes/beans • Fruit • Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties, such as breads, cereals, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley • Lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans • Milk, yoghurt, cheese and/or their alternatives, mostly reduced fat • And drink plenty of water
Guideline 3	Limit intake of foods containing saturated fat, added salt, added sugars, and alcohol.	a. Limit intake of foods high in saturated fat such as many biscuits, cakes, pastries, pies, processed meats, commercial burgers, pizza, fried foods, potato chips, crisps, and other savoury snacks • Replace high fat foods that contain predominately saturated fats such as butter, cream, cooking margarine, coconut, and palm oil with foods, which contain predominately polyunsaturated and monounsaturated fats such as oils, spreads, nut butters/pastes, and avocado • Low fat diets are not suitable for children under the age of 2 years b. Limit intake of foods and drinks containing added salt • Read labels to choose lower sodium options among similar foods • Do not add salt to foods in cooking or at the table c. Limit intake of foods and drinks containing added sugars such as confectionary, sugar-sweetened soft drinks, and cordials, fruit drinks, vitamin waters, energy and sports drinks d. If you choose to drink alcohol, limit intake. For women who are pregnant, planning a pregnancy or breastfeeding, not drinking alcohol is the safest option
Guideline 4	Encourage, support, and promote breastfeeding.	
Guideline 5	Care for your food; prepare and store it safely.	

2.3.1.1 Australian Guide to Healthy Eating

Food selection guides provide a conceptual framework for selecting food types and volumes (Binns & Lee, 2001; Britten, Marcoe, Yamini, & Davis, 2006; United States Department of Health and Human Services and United States Department of Agriculture, 2015). Usually the recommendations provided in food selection guides specify what constitutes a food group, and give standard serving sizes with visual representations (Marcoe, Juan, Yamini, Carlson, & Britten, 2006). Australia's food selection guide, the Australian Guide to Healthy Eating (AGTHE) does this by providing the recommended number of food group servings throughout the life course to meet daily energy and nutrient requirements. Serving recommendations vary depending on age, sex, physical activity and health states (for example, pregnant or breastfeeding). These recommendations were based on modelling, which considered foods that were affordable, accessible, culturally acceptable and available in the Australian food supply. Meeting nutrient requirements for health was the primary driver (Dietitians Association of Australia, 2011).

The AGTHE includes five core food groups, plus spreads and oils high in monounsaturated and polyunsaturated fats (such as olive or canola oil), and EDNP foods and beverages, referred to as 'discretionary' choices. The five groups in the AGTHE include; 1) vegetables, legumes and beans; 2) fruit; 3) grain and cereal foods; 4) lean meat, poultry, fish and alternatives and; 5) milk, yoghurt, cheese and alternatives. Serving size amounts and recommended number of serves for each age group and sex can be seen in Appendix D and Appendix E, respectively.

It can be challenging for people to translate recommendations around food 'serves' into actual amounts (Pollard, Daly, & Binns, 2009). Public health nutrition messages have aimed to educate the public on what constitutes a serve of fruit and vegetables, and research has been done to investigate people's understanding of serve sizes (Pollard, Daly, et al., 2009). In WA, public health campaigns, such as the *Go for 2 & 5*™ campaign and the current *LiveLighter*® campaign, have provided education through resources, print, television and electronic media on what constitutes a 'serve' of vegetables (LiveLighter, 2015; Pollard et al., 2008). Yet, challenges for consumers lie in translating food serve recommendations into practice. This may be, in part, due to changes in serve sizes in the 2013 revision of the ADGs. These include changes in the serve of 'grains and cereals' from two slices of bread to one slice (or 40 g). Changes have also been made to a standard serve of red meat, due to the breadth of evidence supporting the relationship between red meat consumption above 120 g per day and colorectal cancer (NHMRC, 2013). The revised ADGs reduced the recommended serve size of red meat from a range of 65 to 100 g in the 2003 iteration, to a set 65 g serve. A maximum intake of 455 g per week, or 65 g per day is also recommended (NHMRC, 2013). Changes such as these highlight the evolving evidence around the synergies between a H&S diet and the need for research into how dietary behaviours affect both.

2.3.1.2 Appendix G of the Australian Dietary Guidelines on food, nutrition and environmental sustainability

There is no set dietary guideline educating people on how their food choices can be adapted to reduce impact on the environment in Australia. The ADGs have however contained supplementary information on sustainability and the food system since 2003 (Selvey & Carey, 2013). The current iteration of the ADGs contains an Appendix (G) on Food, Nutrition and Environmental Sustainability, which contains three key messages to reduce the environmental impact of dietary behaviours. These include; 1) not overconsuming kilojoules; 2) reducing food and packaging waste and; 3) eating seasonal produce. There were no significant changes made in the 10 year period between the 2003 and 2013 ADGs, even though evidence on the impact of other individual behaviours and global warming strengthened and public desire to make more sustainable dietary choices had increased (Johnson, 2015; NHMRC, 2012). Whether this absence of change was due to; a lack of Australian evidence; the influence of industry stakeholders or; the issue of healthy diets and sustainable diets being considered separately, there is no denying the evidence on the relationship between food choice and environmental sustainability (especially red meat, fish and bottled water) available at the time of the ADGs revision (Selvey & Carey, 2013).

2.3.2 Adherence to a healthy diet in Australia

Australian research has found lower diet quality during early adulthood (Thorpe, Kestin, Riddell, Keast, & McNaughton, 2014) with young people consuming the highest amount of EDNP foods and SSBs and inadequate amounts of fruits and vegetables. These poor food choices are not isolated to young people, with less than 7% of all Australians meeting vegetable serve recommendations (Australian Bureau of Statistics, 2014). This highlights the need to ensure dietary interventions and messages are targeted at relevant population groups and behaviours. A table summarising current compliance with the

AGTHE food group recommendations from the most recent Australian Health Survey (Australian Bureau of Statistics, 2014) results can be seen in Table 2.2.

Table 2.2 Australian adults' adherence to the Australian Guide to Health Eating food group recommendations
(Australian Bureau of Statistics, 2014; (NHMRC, 2013)

		Serve size recommendations		
Food group	**Serve size**	**Men**	**Women**	**Current intake of Australian adults on any given day:***
Vegetables, beans and legumes	1 serve = 75 g e.g. 1 cup salad vegetables, ½ cup cooked vegetables	*19-50 years*: 6 serves *51-70 years*: 5.5 serves	*19-50 years*: 5 serves *51-70 years*: 5 serves	• 6.8% of people meet recommended vegetable serves • 75% of people consume vegetable products and dishes • By weight, potatoes constitute about 25% of vegetables consumed
Fruit	1 serve = 150 g (350 kJ) e.g. 1 med piece, 2 small pieces, 1 cup tinned fruit (in juice), 125 mL 100% juice, 30 g dried fruit.	*19-50 years*: 2 serves *51-70 years*: 2 serves	*19-50 years*: 2 serves *51-70 years*: 2 serves	• 60% of people consume fruit products and dishes • 54% meet the recommendations for fruit • 45% of 14-18 year olds consume any fruit • 39% of 19-30 year olds consume any fruit
Grains and cereal foods	1 serve = 500 kJ e.g. 1 slice bread, ½-cup rice, pasta or noodles, 2/3 cup breakfast cereal flakes, ½-cup porridge.	*19-50 years*: 6 serves *51-70 years*: 6 serves	*19-50 years*: 6 serves *51-70 years*: 6 serves	• 97% consume cereal-based products and dishes • 66% eat regular bread and bread rolls • 36% of people eat breakfast cereals
Lean meat, poultry, fish and alternatives	1 serve = 500 - 600 kJ e.g. 65 g lean meats, 80g poultry, 100g fish, 2 large eggs, 1 cup legumes/beans, 170g tofu, 30g nuts/seeds	*19-50 years*: 3 serves *51-70 years*: 2.5 serves	*19-50 years*: 2.5 serves *51-70 years*: 2.5 serves	• 72% men and 66% women consume from this food group • 69% of people consume meat, poultry or game (14% of total energy intake) • 31% of people consume chicken (most commonly consumed food in this group) • 20% of people eat beef 5% eat lamb, 7% eat sausages, • 22% of people eat processed meat (12% consumed ham), 5% eat bacon
Milk, yoghurt, cheese and alternatives	1 serve = 500 - 600 kJ E.g. 1-cup milk, 200g yoghurt, 40g cheese.	*19-50 years:* 2.5 serves *51-70 years:* 2.5 serves	*19-50 years:* 2.5 serves *51-70 years:* 4 serves	• 85% consume milk products and dishes • 68% consume dairy milk • 32% consume cheese

Food group	Serve size	Serve size recommendations Men	Women	Current intake of Australian adults on any given day:*
Discretionary (EDNP) foods	1 serve = about 600kJ e.g. 75g ice-cream, 50g processed meat, 40g cake/ muffin, 25g chocolate, 200mL wine, 400mL beer, 375mL soft drink	Limit to occasionally and in small amounts. Allowances can be made if someone is tall and/or active if they have met other food group recommendations		• 35% of total energy intakes were from EDNP 'discretionary' foods • 41% of total energy for 14-18 year olds • Alcohol, cakes, muffins, confectionary, and cereal bars, pastries, biscuits and sugar-sweetened beverages contribute the most amount of energy from this food group.

* Data collected using 24HR method during 2011/12 Australian Health Survey.

2.4 A sustainable diet

In 2010, the Food and Agricultural Organization (FAO) of the United Nations held an International Scientific Symposium on ‘Biodiversity and Sustainable Diets: United against Hunger’ in Rome. Attendees at this symposium reached a consensus on a definition of sustainable diets:

> “diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.” (Burlingame & Dernini, 2012, pg. 7).

This FAO definition highlights the complexities around sustainable diets and the dependence on external factors, such as geographical location, food access and availability, and agricultural practices. Despite such a definition, there is no single classification of what constitutes a sustainable diet as the environment and food production practices are changing and the evidence is continuing to evolve (Johnston et al., 2014). Foods included in a sustainable diet vary between countries and continents dues to differences in biodiversity, climates, food security, accessibility, cultural differences, nutrient requirements and food production practices (Johnston et al., 2014). Hence, the environmental impact of a food in one country is not directly transferrable to another, for example to an Australian context (NHMRC, 2013).

2.4.1 Dietary advice based on sustainable diets

The awareness of sustainable diets being both healthy and environmentally protective is increasing in Australia (Bradbear & Friel, 2011; Bradbear & Friel, 2013; Friel, Barosh, & Lawrence, 2013) and internationally (Burlingame & Dernini, 2012; Watts et al., 2015). Several countries, including Brazil, Germany, Sweden, the Netherlands and Qatar, have adopted dietary guidelines that include recommendations to achieve lower environmental impacts from food choices (German Council for Sustainable Development, 2013; Health Council of the Netherlands, 2011; Jones et al., 2016; Livsmedelsverket National Food Agency Sweden, 2015; Ministry of Health of Brazil, 2014; Nordic Council of Ministers, 2012; Seed, 2015). The current EATLancet Commission on Food, Planet and Health aims to build the evidence for H&S dietary recommendations (Rockström, Stordalen, & Horton, 2016). Although the United States (US) does not have a dietary guideline based on sustainability, the recent review of their guidelines included features that would result in a more sustaiunable diet, such as the modelling of mediterranean and healthy vegetarian eating patterns (United States Department of Health and Human Services and United States Department of Agriculture, 2015). In Australia, the ADGs have included special considerations of the sustainability of food systems over the last three decades, incorporated as separate evidence chapters (NHMRC, 2003; NHMRC, 2013).

2.4.2 Role of nutrition professionals in promoting healthy and sustainable diets

Dietitians and nutritionists practice in a variety of settings, from hospitals and clinics to community health and policy. As food experts, they need to consider both health and the food supply (Gussow & Clancy, 1986) when conveying messages around food, educating others, or informing interventions and policies. The 2017 British Dietetic Association Sustainable Diet Policy Statement outlined the role dietitians can play in assisting people to choose foods with low environmental impact (British Dietetic Association, 2017). Similarly, the American Academy of Nutrition and Dietetics has held a position on ecological sustainability since 2007, which guides dietitians to encourage people to adopt more environmentally sustainable dietary behaviours (American Dietetic Association, 2007). The Public Health Association of Australia has several policies relating to sustainability, global warming and the impact on the food system (Public Health Association of Australia, 2018) but the Dietitians Association of Australia, the national governing body, has no position encouraging Australian dietitians to promote sustainable diets. This lack of formal, culturally and contextually relevant, guidance can make it challenging for nutrition professionals wanting to adopt evidence-based messages around sustainable diets in their practice.

2.4.3 Australian government policies relating to sustainable diets

The impact of global warming shows itself in events such as floods, droughts and extreme weather conditions, which have a direct influence on food security (Schmidhuber & Tubiello, 2007). Such events drive up the price and affect the availability of fresh fruits and vegetables (Friel, 2010) resulting in additional barriers to consuming these foods (Section 2.6 outlines determinants of food choice). Agriculture is responsible for 16% of Australia's total GHG emissions, with two thirds of this coming from the enteric fermentation of ruminant animals (beef and sheep), therefore it has a major influence on the environment (Department of Primary Industries and Regional Development, 2017). Hence, there is a need for policies and interventions to target a reduction in the environmental impact of consumer food choices, namely the reduction of animal-based foods. Such dietary changes would in turn reduce the demand for meat on food producers. Although work is currently being undertaken by Australian government departments to better understand and monitor the issue of food and environmental sustainability, mainly in relation to tackling food waste (Commonwealth of Australia, 2017), the two issues of diet and sustainability are often considered in isolation in Australia.

Government food policy and regulation aims to protect public health and safety by shaping the food supply, from production through to marketing, promotion, standards and controls (Joint FAO/WHO Codex Alimentarius Commission, 2016; Thow, Jan, Leeder, & Swinburn, 2010). The Australian Policy Cycle highlights the importance of stakeholder consultations, including considerations of consumer attitudes, concerns and support for policy options in policy and regular decision making (Bridgman & Davis, 2004). Consumer concerns are considered during the policy initiation and development process, as is the potential impact of policy or regulatory controls on food choices, dietary patterns and health. Effective policy actions are informed in part by an understanding of consumer concerns regarding the issue, motivations for change and support for policy options. There is a policy interest in consumer information to support the coupling of H&S dietary advice, and inform potential actions to protect the food supply. In Australia, there is a lack of population-based evidence on people's perceptions about environmentally friendly foods and how, or if, these attitudes translate to food choice. Little is known of public concern about a sustainable food supply or whether there is support for tighter government control.

Australia does not have formal guidelines around a sustainable diet and it has been suggested that Australian government agencies are avoiding tighter regulation of food industry practices to create more sustainable food choices, and instead focussing on overweight and obesity (Johnson, 2015). During the revision of the latest ADGs, a draft appendix outlining practical tips on sustainable dietary patterns were released for public consultation (NHMRC, 2012). However, these inclusion were contested by food industry representatives and did not eventuate (Johnson, 2015). Instead an appendix containing key messages for minimising the environmental impact of dietary choices as well as promoting health was included (NHMRC, 2013). The key messages outlined in this appendix are vague and are not set guidelines (Johnson, 2015). Nevertheless, this highlights the need for further research into sustainable diets in Australia.

2.4.4 Public knowledge and attitudes toward sustainable diets

In the scientific community it is widely accepted that the consumption of excess kilojoules, most of which are from highly processed and packaged EDNP foods, creates an avoidable environmental burden and contributes to overweight and obesity (Bradbear & Friel, 2011; Larsen, Ryan, & Abraham, 2008; NHMRC, 2013; Riley & Buttriss, 2011). However, little is known about how 'environmentally friendly' people believe these foods are and whether knowledge and attitudes toward such foods are reflected in food choice.

Although animal-based foods contain high nutrient values, there is evidence demonstrating the greater environmental impact of meat and dairy foods compared to plant-based alternatives (Bradbear & Friel, 2011; Macdiarmid et al., 2012; Reynolds, Buckley, Weinstein, & Boland, 2014; Springmann, Godfray, Rayner, & Scarborough, 2016) (see Section 2.5.1 for details on the health and environmental impacts of animal-based foods). The public's understanding of the potential impact of such dietary practices on the environment has shown to differ from the evidence. A cross-sectional study of 842 British adults found that although awareness of the impact of meat on environmental sustainability was high, human health and animal welfare were greater motivators to reduce meat intake than environmental sustainability (Clonan, Wilson, Swift, Leibovici, & Holdsworth, 2015). As with most food choices, this research highlights that knowledge and attitudes are not the only motivations for consuming a more environmentally sustainable diet. Health aspects of food, taste preferences, convenience, availability and cost should all be considered when providing information to encourage people to eat more sustainable diets (Vermeir & Verbeke, 2008).

A cross-sectional survey of 223 Australian adults examined their beliefs and behaviours relating to food and the environment (Lea & Worsley, 2008). Respondents believed food packaging had a greater impact on the environment than the consumption of meat (Lea & Worsley, 2008). Current evidence on the environmental impacts of dietary behaviours shows agricultural and farming practices place greater pressure on biodiversity than resources used in developing and disposing of food packaging (Bradbear & Friel, 2011; Raphaely & Marinova, 2016). This highlights the need for further research to explore consumer attitudes.

2.4.5 Methods used to assess the environmental impact of diets

Different methods are used to quantify the environmental impact of specific foods from production through to storage, transportation, use and disposal (Jones et al., 2016). Methods which involve the measurement of inputs and outputs involved in a product's lifetime is called the Life Cycle Analysis (or Assessment) (LCA) approach (Section 2.4.5.1). Methods used to assess consumer food waste are explored in Section 2.9.

Another method used to assess the environment impact of diets includes hypothetically designed sustainable diets. In most cases, this requires researchers to determine the types and volumes of foods required to meet nutrient requirements while minimising greenhouse gas (GHG) emissions, which often involves the replacement of foods with similar distinguishing nutrients for more sustainable alternatives. For example, replacing beef with beans or legumes. Table 2.3 includes a summary of studies examining H&S diets, including hypothetically designed diet modelling studies, which are explored in Section 2.4.5.2.

2.4.5.1 Life cycle analysis (including input-output analysis)

When quantifying the environmental impacts of particular foods, the energy and resources used from production through to use and disposal needs to be considered (Foodsource, 2017). Deriving such a value is useful in guiding practice and policy but is often a financially and resource intensive process due to complex food supply chains. LCA is a framework for measuring the materials, energy and emissions of a food product and has been standardised internationally (International Organization for Standardization, 2007). A benefit of using the LCA method to quantify the environmental impact of a food is that it is sensitive to shifting the burden from one part of the food system to another (as it includes all elements) (Pelletier, Ibarburu, & Xin, 2014). The LCA method can either be a full process LCA, an Input-Output Analysis or a hybrid between the two. Input-Output Analysis is a top-down approach which includes both economic and environmental impact data (Reutter, Lant, Reynolds, & Lane, 2017). However, it measures the whole sector or industry footprint and not specific food products. A benefit of Input-Output Analysis is that it requires fewer resources opposed to the full process LCA method which requires information about specific food production and farming techniques (Reutter et al., 2017).

The LCA value of many foods is available internationally, however, there is limited LCA data for foods in Australia (Raphaely & Marinova, 2016). This is mainly due to limited funding (Raphaely & Marinova, 2016). Therefore, when determining what foods are aligned with a sustainable diet the international literature should be drawn upon. One consideration is that LCA values from foods measured in a foreign context are not directly transferrable to an Australian context due to the differences in climates, farming practices and waste disposal.

Pairotti and colleagues (2015) conducted a study using a hybrid method of both LCA and Input-Output Analysis to measure influences of four dietary patterns; a Mediterranean diet; a healthy diet; a typical Italian diet (as defined by current dietary intake data) and; a vegetarian diet. This study found, when taking into account energy consumption and GHG emissions, a vegetarian diet had the lowest carbon footprint; 14.55% lower than the typical Italian diet (national average), and 6.74% lower than the Mediterranean diet. The authors acknowledged a 'Mediterranean diet' is not a set diet inclusive of specific foods but instead a style of eating made up of a variety of plant-based foods (Pairotti et al., 2015), a potential limitation of the study. As with all dietary recommendations, including those around sustainability, considerations should be given to the geographical location, food availability and affordability. For example, consuming high amounts of fish in coastal Italy may be more environmentally sustainable than sourcing fish in central Australia due to transport outputs. The above study confirms that plant-based diets have a lower environmental impact than a typical Italian diet.

2.4.5.2 Hypothetically designed sustainable diets

In Australia, hypothetically designed sustainable diets have been compared to national dietary intake data (Friel et al., 2013; Hendrie, Ridoutt, Wiedmann, & Noakes, 2014). Similar studies comparing dietary scenarios to current dietary habits have also taken place in New Zealand (Wilson et al., 2013) and internationally (Macdiarmid et al., 2012; Scarborough, Allender, Clarke, Wickramasinghe, & Rayner, 2012; Scarborough et al., 2014). These studies have found eating a diet aligned with dietary guidelines, predominantly more plant-based foods and less EDNP foods, reduces impact on the environment (Friel et al., 2013; Hendrie et al., 2014; Macdiarmid et al., 2012; Scarborough et al., 2012; Scarborough et al., 2014; Wilson et al., 2013). However, components of a sustainable diet such as assessing edible plate waste and individually packaged foods have not been assessed using these methods.

An Australian study developed a hypothetical H&S diet based on peer-reviewed evidence and grey literature in the area and compared it to a typical Australian diet (Friel et al., 2013). A limitation of this approach is that the researchers are restricted to the dietary data available. Consumption of EDNP foods were found to be unsupportive of environmental sustainability, due to resources used in processing and packaging, as well as high in energy (Friel et al., 2013). A limitation of this study was the lack of Australian evidence on the environmental impact of individual foods from production to consumption, for example LCA values. Similar scenarios, relating to limited country specific LCA data, have been acknowledged by other researchers in the area (Green et al., 2018). In addition, studies looking at sustainable diets using data collected in the Australian Health Survey are limited to the amount and type of information collected in this survey. This survey was not designed to collect data on sustainable dietary behaviours, therefore, people's use of food packaging, seasonal fruit and vegetable consumption and food waste were not collected in this survey.

Examining evidence-based hypothetically sustainable diets, as opposed to looking at the environmental impacts of individual foods, is more likely to reflect the impact of dietary patterns on the environment. In addition, they provide evidence to inform policy makers of the benefits of such diets without waiting for LCA evidence to become available.

Table 2.3 Summary of studies on healthy and sustainable diets

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Bälter et al. (2017)	n= 5,364 *Adults aged 18-45 years* Sweden	Cross-sectional	Assess whether a diet with low GHG emissions could meet nutrient recommendations, compared to the Nordic Nutrition Recommendations	Used FFQ to assess diet Completed as part of the Swedish LifeGene study. LCA values of foods were linked to the FFQ data. Researchers calculated carbon dioxide emissions and nutrients associated with fruit, vegetables and animal-based food intake.	Carbon dioxide emissions from diet were 4.7 kg per person per day. After adjusting for energy intake, there were minimal differences in nutrient intakes between diets of groups of varying carbon dioxide emissions levels. Adherence to the Nordic Nutrition Recommendations was high for diets with the lowest carbon dioxide emissions, except for saturated fat where the intake was higher than recommended for all groups. Only the group with the lowest carbon dioxide emissions met dietary fibre recommendations.
Clonan, Holdsworth, Swift, Leibovici, and Wilson (2012)	n= 842 497 women, 345 men *Adults aged 18-91 years* United Kingdom (UK)	Cross-sectional	Investigate if health and/or sustainability are motivating factors when buying and consuming fish.	Used a semi-quantitative FFQ self-completion postal questionnaire. The FFQ was developed from the UK's Eatwell plate (5 food groups).	Health benefits were the primary motivator for fish intake (57%). Of participants, 27% tried to purchase from sustainable sources and 31% met dietary recommendations for fish intake.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Clonan et al. (2015)	n= 842 497 women, 345 men *Adults aged 18-91 years* UK	Cross-sectional	Investigate meat consumption behaviours and the perceived impacts for human health, animal welfare and the environment.	Used a semi-quantitative FFQ. Standard serve sizes were specified and an image representing the portion size and participants were then asked to report how often they are a portion of red meat and processed meat, from 'never' to 'twice a day or more'. Postal self-completion survey collected data on attitudes toward red and processed meat, sustainable meat purchasing behaviour, meat intake, and sociodemographic characteristics.	Women were more likely to hold positive attitudes toward animal welfare. 18% of participants agreed climate change could be lowered by reducing intake of meat, dairy and eggs. Health and animal welfare were stronger motivators for reducing less meat intake than environmental sustainability
de Carvalho, Cesar, Fisberg, and Marchioni (2013)	n= 1,677 *Adults aged 19+ years* Brazil	Cross-sectional	Assess red and processed meat intake and evaluate impact of meat intake on diet quality and the environment.	Two 24HR Used the Multiple Source Method	High meat intake was inversely associated with poor diet quality in men. 81% men and 58% women ate more meat than the World Cancer Research Fund recommendation of 71.4 g per day. GHG emissions from meat intake in Brazil is significant.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Dixon and Isaacs (2013)	Interviews and food diaries from 8 households. 3 focus groups with 24 households Australia	Qualitative	Generate hypotheses and uncover consumer views towards sustainable and healthy diets.	Rapid ethnographic appraisal in 3 suburbs (highest, middle and lowest socio-economic status areas). Two households in each area collected a 7-day food diary and used a camera to take images for >4+ days. Images were used to estimate main food groups served as well as range of styles of eating occasions.	People want to support local food producers but they gravitate toward cheap and tasty food from 'anywhere'. People associate nutritious foods with fresh food, but will buy processed foods, which can be less expensive, appeal to children and are prone to less waste. *Used an image-assisted dietary assessment method. Subjects from low SES area of Sydney. Cost and family nourishment comes before nutrition and the environment.*
Friel et al. (2013)	NA	Modelling	Create a H&S diet and describe a method to assess the affordability and availability of a H&S food basket in Australia	Hypothetical H&S diet developed.	A H&S diet has three main principles 1. Avoid the intake of energy above an energy requirements 2. Low in highly processed and packaged EDNP foods and SSBs 3. More plant-based foods, lower in animal foods
Green et al. (2018)	n= 7067 *Adults* India	Cross-sectional	Measure the water footprint and GHG emissions from dietary patterns in India.	Food Frequency Questionnaires collected during the Indian Migration Study between 2005 and 2007	Compared to high income countries, dietary patterns in India have a relatively lower environmental impact. This will likely increase due to urbanisation increasing the affordability and accessibility to animal-based foods and highly processed foods.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Hamilton, Denniss, and Baker (2005)	n= 1,644 *Adults aged 18+ years* Australia	Cross-sectional	Assess attitudes and behaviours relating to wasteful household practices.	Postal survey asking representative sample of adults to retrospectively estimate the amount of money spent on food that was not eaten. These were categorised into fresh, frozen and take-away foods.	Young people waste more than older people. Households with higher incomes waste more than those on lower incomes. Three in five Australians feel some guilt when they buy items that do not get used. Food accounts for most wasteful consumption. Overall Australians threw away $2.9 billion of fresh food, $630 million of uneaten take-away food, $876 million of leftovers, $596 million of unfinished beverages and $241 million of frozen food, a total of $5.3 billion on all forms of food in 2004.5

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Hendrie et al. (2014)	*Adults aged 19+ years* Australia	Diet modelling study using quantitative cross-sectional data	Use dietary modelling to examine the GHG emissions of dietary patterns and the impact on the overall nutrient profiles: 1. average diet; 2. average diet (low in EDNP foods); 3. ADGs recommended diet	Quantitative cross-sectional data from 1995 National Nutrition Survey compared against an input-output model to estimate GHG emissions for different food sectors.	The GHG emissions of the average Australian diet was 14.5 kg carbon dioxide equivalents per person per day. The recommended dietary patterns in the ADGs are nutrient rich and have ~25% lower GHG emissions than the average diet. Food groups that made the greatest contribution to diet-related GHG emissions were red meat (8.0 kg carbon dioxide equivalents per person per day) and EDNP foods (3.9 kg). Non-core foods accounted for 27% of the diet-related emissions. *Eating in line with the ADGs (including less EDNP foods) is better for the environment and health. Intake of EDNP foods increased from 1995 to 2011/12 AHS so this is a likely underestimation of GHG emissions from an average Australian diet.*
Horgan, Perrin, Whybrow, and Macdiarmid (2016)	n= 1,491 *Adults aged 19-94 years* UK	Diet modelling study using quantitative data	Investigate dietary changes needed to achieve a healthy diet and a healthy diet with lower GHG emissions (referred to as a sustainable diet) by taking into account individual's diet and then minimising the changes they need to make.	Diet modelling study using quantitative data collected during the UK National Diet and Nutrition Survey	The healthy diets and sustainable diets produced a 15 and 27 % reduction in GHG emissions. Dietary guidelines need to include recommendations for environmental sustainability.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Macdiarmid et al. (2012)	NA	Diet modelling	Assess whether a reduction in GHG emissions can be achieved while meeting dietary requirements for health	A database linked nutrient composition and GHG emission data for 82 food groups. A sample menu was created to ensure that the quantities and types of food generated from the model could be combined into a realistic 7-d diet. Reductions in GHG of the diets were set against 1990 emission values	A diet that included meat products in smaller amounts than in current diets reduced GHG emission s by 36%. The retail cost of the diet was comparable to the average UK expenditure on food. A sustainable diet that meets dietary requirements for health with lower GHG emissions can be achieved without eliminating meat or dairy products or increasing the cost to the consumer.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Lacour et al. (2018)	n= 34,442 *Adults* France	Cross-sectional	To investigate the relationship between a pro-vegetarian score and diet-related environmental impacts	• Used data NutriNet-Santé cohort study • FFQ • A pro-vegetarian score was used to identify preferences for plant-based products as opposed to animal-based products. • 3 environmental indicators were used to assess diet-related environmental impacts: GHG emissions, cumulative energy demand, and land occupation. Environmental impacts were assessed using production LCA at the farm level.	Participants with diets rich in plant-based foods were more likely to be older urban dwellers, to hold a higher degree in education, and to be characterised by an overall healthier lifestyle and diet. A higher pro-vegetarian score was associated with lower environmental impacts.
Pairotti et al. (2015)	NA	Theoretical dietary analysis.	Measure the environmental impacts of the Mediterranean diet compared to a healthy diet, national dietary intake of Italians and a vegetarian diet.	Household GHG emissions and energy consumption. Use a hybrid method is mainly based on the life cycle of products from specific product categories, in which some stages of the cycle are accounted through standard LCA and others via input output analysis.	Mediterranean diet shows an intermediate environmental performance between the healthy and the vegetarian diets. *Cannot translate to Australia as LCA and input-output analysis not available.*

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Pelletier, Laska, Neumark-Sztainer, and Story (2013)	n= 1,201 *Adults aged 17-51 years* *College and university students* US	Cross-sectional	Examine the characteristics and dietary behaviours (e.g. fruits, vegetables, fast food) of young adults who reported placing low, moderate or high importance on alternative food production practices.	Used online survey to assess diet, physical activity, weight-control behaviours, and personal, social, and environmental factors that influence these behaviours. Height, weight, and body composition measured. Participant's self-reported 3 dietary behaviours used as markers of healthy eating: frequency of breakfast consumption, frequency of eating at a fast-food restaurant; and SSB intake.	Young adults who placed high importance on alternative production practices consumed more dietary fibre, fewer added sugars, fewer SSBs, 1.3 more servings of fruits and vegetables, and less fat than those who placed low importance on these practices. Nutrition messages around social and environmental implications of food production may be well received by young adults. *Well educated sample. Results might not be generalisable, given the sample from one metropolitan area and a convenience sampling approach. A limitation of this study was the amount of detail collected using a short screener to assess diet.*
Peters et al. (2010)	NA	Theoretical dietary analysis	Describe Australian red meat production by hybridising LCA by detailed on-site process modelling and input-output analysis.	Carbon footprint and total energy consumption of 3 supply chains in 3 different regions in Australia over 2 years.	The increasing proportion of lot-fed beef in Australia is favourable, since this production system generates lower total GHG emissions than grass-fed production; the additional effort in producing and transporting feeds is effectively offset by the increased efficiency of meat production in feedlots

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Pimentel and Pimentel (2003)	NA	Diet modelling	The amount of energy and land use required to provide an average lacto-ovo-vegetarian diet vs an average meat-based diet.	Used US data Two dietary scenarios were • Lacto-ovo-vegetarian diet (plant-based with eggs and dairy) • Meat-based diet. Study looked at US per capita food intake and associated energy and protein with each diet. Fossil energy needed to produce 1kcal of animal protein. Considered land and water resources associated with each diet.	Both diets rely heavily on fossil fuels, so neither are supportive of a future food supply as these resources are non-renewable. The average meat-based diet requires more water, land and energy than a typical lacto-ovo-vegetarian diet.
Reynolds, Mavrakis, et al. (2014)	3 separate studies 1. n= 401 households 2. n= 14 households 3. n= 25 households	Cross-sectional	Provide metrics of food waste by identifying 5 informal food waste disposal routes used by households in Australia: 1. home composting, 2. feeding scraps to pets, 3. sewer disposal, 4. giving to charity, and 5. dumping or incineration.	Used data from 3 Australian studies: 1. Telephone surveys in South Australia; 2. Semi-structured interviews and observations; 3. Interviews and questionnaires. Waste generation rates were calculated, using a weighted average method in conjunction with a Monte-Carlo simulation.	Australian household dispose of 2.6 kg of food waste per week through informal routes (1.7 kg via household composting, 0.2 kg via animals, and 0.6 kg via sewage). Informal food waste is a sizable food waste flow from Australian homes, needing more research and government attention.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Scarborough et al. (2012)	NA	Diet modelling	Model the impact on GHG emissions and mortality from cardiovascular disease and cancer of 3 dietary scenarios in the UK.	The three scenarios were parameterised by fruit, vegetable, fibre, total fat, saturated fat, unsaturated fatty acids, cholesterol and sodium intake using the 2008 Family Food Survey. Monte Carlo simulation generated 95% credible intervals.	• 50% reduction in meat and dairy replaced by fruit, vegetables and cereals =19% reduction in GHG emissions • 75% reduction in cow and sheep meat replaced by pigs and poultry = 9% reduction in GHG emissions • 50% reduction in pigs and poultry replaced with fruit, vegetables and cereals = 3% reduction in GHG emissions. *Lower mortality predicted with a reduction in red meat intake. Authors highlighted need for more work in real-life settings.*
Scarborough et al. (2014)	n= 55,504 (2,041 vegans, 15,751 vegetarians, 8,123 fish- and 29,589 meat-eaters). *Adults aged 20–79 years.* UK	Cohort	Estimate the difference in dietary GHG emissions between self-selected meat-eaters, fish-eaters, vegetarians and vegans in the UK.	Used a validated FFQ in EPIC-Oxford Study. GHG emissions parameters were developed for the underlying food codes using a dataset of GHG emissions for 94 food commodities in the UK, with a weighting for the global warming potential of each component gas.	The age-and-sex-adjusted mean GHG emissions (kg carbon dioxide equivalents/day) were 7.19 for high meat-eaters (>=100 g/d), 5.63 for medium meat-eaters (50-99 g/d), 4.67 for low meat-eaters (<50 g/d), 3.91 for fish-eaters, 3.81 for vegetarians and 2.89 for vegans. *GHG emissions for meat-eaters was about double that of vegans. Reducing meat intake can reduce GHG emissions.*

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Sjors et al. (2016)	n= 166 *Adults 20-63 years* Sweden	Validation	Validate the assessment of GHG emissions from diet using an FFQ compared to a 7-day weighed food record, as well as to evaluate the reproducibility of the FFQ	Participants completed the purpose designed FFQ (at baseline and 3 weeks to measure reproducibility of FFQ) and completed a 7-day weighed food record. Used food photos to assist participants in portion size estimation. Food items were compared against their LCA values.	Meal-Q is a useful tool for examining associations between food habits and carbon dioxide emissions. Authors were able to validate the FFQ against a 7-day weighed food record.
Springmann et al. (2016)	NA	Diet modelling	Quantify the linked health and environmental consequences of dietary changes	Conducted a region specific health model based on dietary and weight-related risk factors with emissions accounting and economic valuation modules	Transitioning toward more plant-based diets (in line with dietary guidelines) could reduce global mortality by 6-10% and food-related greenhouse gas emissions by 29-70% compared with a reference scenario in 2050.
Tukker et al. (2011)	NA	Diet modelling	Estimate the difference in environmental impact between European status quo and 3 simulated diets.	Used input output analysis plus dynamic modelling using CAPRI. Three simulated diets for analysis were: 1. diet aligned with universal dietary recommendations; 2. same pattern with reduced meat consumption; and 3. Mediterranean diet with reduced meat.	Reduction in meat intake will result in the biggest reduction in environmental impacts of dietary choices. All three simulated diets would result in health benefits including reduced risk of obesity, Type 2 Diabetes, cancers and cardiovascular diseases.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
van Dooren, Marinussen, Blonk, Aiking, and Vellinga (2014)	NA	Diet modelling	Explore the possibilities for future integrated dietary guidelines that support consumers to make informed dietary choices based on both ecological and nutritional values.	Tested 6 different diets (current average Dutch, official recommended Dutch, semi-vegetarian, vegetarian, vegan and Mediterranean) using LCA values to measure the impacts on GHG emissions and land use. 10 nutritional indicators used for health rating	The intake of meat, dairy products, extras, such as snacks, sweets, pastries, and beverages, in that order, are largely responsible for low sustainability scores - these foods also contribute to low health scores. Semi- and pesco-vegetarian diets are the options with the optimal synergy between health and sustainability.
Vermeir and Verbeke (2008)	n= 456 *Young adults* Belgium	Empirical research	Investigate the role of individual characteristics, such as confidence and personal values in the behavioural intention formation process.	Used a questionnaire to assess attitudes, behaviours and the role of individual characteristics (e.g. one's confidence and values) related to sustainable products.	Multiple regression models showed that 50% of the variance in intention to consume sustainable dairy foods was explained by the combination of personal attitudes, perceived social influences, perceived consumer effectiveness and perceived availability.
Westhoek et al. (2014)	Europe	Diet modelling	Test the effects of different diets on land use, GHG emissions and nitrogen emissions.	Developed 6 different diets, comprising of either a 25% or 50% reduction in animal foods and placed with plant-based alternatives. Animal-based foods were reduced in different combinations (e.g. 50% in poultry/pig).	A reduction in meat, dairy foods and eggs reduced GHG emissions, land use and would likely reduced cardiovascular disease mortality due to the high reduction in saturated fat, while still meeting protein requirements.
Wilson and Garcia (2011)	n= 68 *Adults* *Staff in health care setting* Canada	Cross-sectional	To assess attitudes, beliefs and behaviours toward environmentally friendly practices in hospital and health care services.	Used questionnaires to collect quantitative data on environmentally friendly initiatives.	Differences in food-related behaviours, beliefs and attitudes suggest a need for education on the environmental impacts of food choices. Dietitians can lead changes in education, practice, and policy development.

Reference	Study sample and setting	Study design	Objective	Methods used	Key findings and *comments*
Wilson et al. (2013)	NA	Diet modelling	To consider optimised solutions to the mix of food items in daily diets for a developed country population.	Modelled 16 diets.	All of the optimised low-cost and low-GHG dietary patterns had likely health advantages over the current New Zealand dietary pattern

2.5 Synergies between a healthy diet and a sustainable diet

There is no agreed definition for what constitutes a ‘healthy and sustainable diet’. Separately, healthy diets conform to the ADGs (NHMRC, 2013), while sustainable diets have been defined by the FAO as “those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations.” (Burlingame & Dernini, 2012, p. 7). The ADGs form the largest body of scientific evidence on nutrition in Australia, providing dietary recommendations and direction for nutrition policy. The benefit of introducing government policies promoting more sustainable diets would help address two major public health issues; poor health and climate change (Bradbear & Friel, 2013; Macdiarmid et al., 2012; Morgan, 2009).

Australia’s 2013 National Food Plan incorporated a chapter on ‘Sustainable Food’ (Department of Agriculture Fisheries and Forestry, 2013) and the 2013 revised ADGs included an Appendix G of Australian Dietary Guidelines on Food, Nutrition and Environmental Sustainability. This appendix highlights ‘environmentally sustainable eating practices’ including: eating seasonal produce, reducing food and packaging waste and avoiding overconsumption of kilojoules (NHMRC, 2013). However, no specific guidelines on eating sustainably exist in Australia despite recognition of its importance since 2003 and the strengthening emerging evidence on the broad benefits of sustainable eating behaviours for both health and the environment (Selvey & Carey, 2013).

Several of the ADGs indirectly form synergies between eating a diet for good health and a sustainable diet to reduce burden on the environment and food system. For example, the overconsumption of kilojoules is discouraged due to the association with overweight, obesity and chronic diseases, but this behaviour also creates an avoidable environmental burden (Bradbear & Friel, 2011; Friel et al., 2013; NHMRC, 2013). The following dietary behaviours were incorporated in this research:

- Animal-based foods (Section 2.5.1)
- Fruits and vegetables, including seasonality (Section 2.5.2)
- Ultra-processed EDNP foods and beverages (Section 2.5.3)
- Individually packaged foods and beverages (Section 2.5.4)
- Food (plate) waste (Section 2.5.5)

2.5.1 Animal-based foods

As the global population grows and there is an increase in income and urbanisation, dietary changes have transitioned from largely plant-based diets to diets higher in animal-based foods and highly processed EDNP foods (Tilman & Clark, 2014; van Hooijdonk & Hettinga, 2015; World Health Organization, 2003). In most climates and settings, meat and dairy foods have more of a negative environmental impact than plant-based foods (Aleksandrowicz et al., 2016; Green et al., 2018; Macdiarmid et al., 2012; Peters et al., 2010; Westhoek et al., 2014), although compared to most EDNP foods animal-based foods provide essential nutrients for good health. Table 2.4 summarises key health and environmental outcomes associated with commonly consumed animal-based foods to give context and understanding to this research. Consideration should be given to varying farming and food production practices as this can vary within and between countries some of Australia's arid land may only be appropriate for cattle and sheep farming (Peters et al., 2010).

Animal-based foods provide a good source of nutrients, such as iron, protein, zinc, vitamin B_{12} and calcium (Aleksandrowicz et al., 2016; NHMRC, 2013). However, diets high in these foods can contain high levels of saturated fat than plant-based alternatives, such as legumes, nuts, seeds and tofu. These plant-based alternatives have similar distinguishing nutrients (with the exception of vitamin B_{12}), are naturally low in saturated fat, high in dietary fibre and meet nutrient requirements if eaten in adequate quantities. A greater intake of these foods would benefit the health of all Australians (NHMRC, 2013), not just people following a vegetarian or vegan diet, and reduce the environmental outputs from ruminant beef and sheep (Aleksandrowicz et al., 2016).

A systematic review examining the LCA values of different fresh foods globally was conducted by Clune and colleagues (2017). The findings from this review supported previous evidence that plant-based foods (including fruits, vegetables, grains, cereals, legumes, nuts and seeds) produce less greenhouse gas emissions than animal-based foods. In summary, ruminant animals had the highest overall global warming potential, followed by processed dairy-foods (butter and cheese), pork, chicken, eggs and then fish. Milk had the lowest GHG emissions of all animal-based foods in this review, although still higher than plant-based foods (Clune et al., 2017).

In Australia, the consumption of milk, yoghurt and cheese is below recommendations with only 10% of Australians, aged 2 years and above, meeting daily food serve recommendations for this food group (Australian Bureau of Statistics, 2014). However, Australian men, in particular, consume large volumes of red meat, with beef constituting the highest amount (Australian Bureau of Statistics, 2012; Bradbear & Friel, 2011; Raphaely & Marinova, 2016). The intake of red and processed meats has been linked to total mortality, cancer mortality and cardiovascular mortality (Sinha, Cross, Graubard, Leitzmann, & Schatzkin, 2009).

Table 2.4 Health and environmental impacts of animal-based foods

Animal-based food	Health impacts	Environmental impacts
Beef cattle and sheep meat	• Rich source of protein, iron, zinc and vitamin B_{12} • Lean red meat is recommended due to high saturated fat content • There is a probable Grade B association between the consumption of >100-120 g of red meat per day and increased risk of colorectal cancer (NHMRC, 2013) • According to the AGTHE one serve of lean red meat is equivalent to 65g cooked weight • Maximum of 455g of red meat per week for health reasons (NHMRC, 2013) • Red meat intake is associated with mortality related to cardiovascular disease and cancers (Sinha et al., 2009)	• Beef cattle and sheep are both ruminant animals • Methane (produced by microbes in the gut during fermentation in ruminant animals) has 21-23 times the global warming potential compared to carbon dioxide (Biswas, Graham, Kelly, & John, 2010; Friel, 2010) • Methane is the biggest contributor to carbon dioxide equivalent emissions in Australia (Friel, 2010) and has a significant impact on Australia's impact on climate change (Peters et al., 2010) • Global LCA values indicate, beef and lamb have a similar global warming potential (Clune et al., 2017) • Lot-fed beef is more favourable over grass-fed cattle in Australia due to the lower GHG-emissions associated with this production method (Peters et al., 2010) • Land used for grazing animals and also land used to grow feed also produces GHG emissions (Friel, 2010) • An Australian study examining the LCA values of sheep meat found on farm-practices are the biggest contributor to GHG emissions (Biswas et al., 2010) • Methane produced during enteric fermentation can be reduced by modifying on-farm practices, such as changing feeds (Biswas et al., 2010)
Pork	• Source of protein, iron, zinc and vitamin B_{12} • One serve of meat is equivalent to 65g cooked (NHMRC, 2013) • Pork is a white meat although classified as a red meat in the ADGs and international literature due to its nutrient composition (NHMRC, 2013) • Remove visible fat to reduce saturated fat intake	• Following beef and sheep meat, pork has the next highest output of greenhouse gases globally (more than chicken, fish, milk and eggs) (Clune et al., 2017) • More energy is required to produce 1kg of pork compared to 1kg of chicken, as chickens are more efficient at converting feed to weight gain (de Vries & De Boer, 2010)

Animal-based food	Health impacts	Environmental impacts
Processed meat and sausages	• Processed meats are associated with increased risk of negative health outcomes, including increased risk of colorectal cancer (Bouvard et al., 2015), total mortality and cardiovascular disease (Sinha et al., 2009) • Classified as EDNP (discretionary) foods in the ADGs due to high amounts of saturated fat and sodium (not included as part of the 'lean meat, poultry, fish and alternatives' food group) • 50g to 60g of processed meat (e.g. salami) is considered one serve (equivalent to about 600kJ) (NHMRC, 2013) • Processed meats are not recommended as a replacement for unprocessed meat (NHMRC, 2013) • Sausages vary in nutrient composition, regular sausages are high in saturated fat and sodium and are classified as EDNP food	• See environmental impacts of beef, sheep and pork above as processed meats are most frequently derived from these meats • These foods also require processing and are often packaged which further increases their demand for resources • Some would argue processed meats are the offcuts that would otherwise not be eaten by humans
Chicken and other poultry	• Source of protein iron, zinc, vitamin B_{12} and essential fatty acids • One serve of lean poultry is 80g cooked weight (NHMRC, 2013) • Lean poultry is recommended (skin removed) • Lower in saturated fat than red meat, also lower in iron • Inconclusive evidence on relationship between poultry intake and cancer risk (NHMRC, 2013)	• Vary depending on the type of farming practices used • Nearly 90% of poultry intake worldwide is chicken meat, followed by turkey, duck and goose meat (MacLeod et al., 2013) • Globally, chicken produces less greenhouse gas emissions than beef, sheep or pork (Clune et al., 2017) • Turkey has a higher global warming potential than chicken but is not as commonly consumed in Australia

Animal-based food	Health impacts	Environmental impacts
Fish/seafood	• Source of protein, iodine, selenium, zinc, iodine and long chain omega 3- fatty acids (NHMRC, 2013) • The AGTHE recommends two serves per week (one serve is equivalent to 100g cooked weight) • The National Heart Foundation of Australia recommends people eat 2-3 serves of fish per week for good heart health and do not recommend fish oil supplements unless people have high blood triglyceride levels (National Heart Foundation of Australia, 2015) • Diets high in fish (2 or more serves were week) have been associated with lower risk of dementia in older adults, cardiovascular diseases and macular degeneration (NHMRC, 2013) • Imported fish to Australia may have lower nutrient density (namely omega-3 fatty acids) than local Australian seafood (NHMRC, 2013)	• Australia now imports about 70% of its fish (NHMRC, 2013) (Selvey & Carey, 2013) • If all Australian's met fish recommendations in the ADGs (need to increase current intake by 40%) the fish supplies could not be sustained (Selvey & Carey, 2013) • Fish have a similar global warming potential (GWP) to chicken but varies depending on species (Clune et al., 2017). • Low GWP: herring and mackerel • Medium GWP: salmon, trout, swordfish and trout • High GWP: Prawns, crayfish • It has been suggested that it is difficult to compare LCA values for fish to land animals as the LCA method is designed for land-based foods (de Vries & De Boer, 2010) • A UK study suggested the public need to be informed of how to choose fish that is certified as 'sustainable' to protect fish stocks (Clonan & Holdsworth, 2012)

Animal-based food	Health impacts	Environmental impacts
Milk, yoghurt and cheese	• Rich source of protein, calcium, riboflavin and vitamin B_{12} • The nutrient profile of milk varies depending on the mammal • Full fat milk yoghurt and cheese contain high amounts with saturated fat. The ADGs recommend people try to choose reduced fat milk, yoghurt and cheese options (NHMRC, 2013) • Replacing foods high in saturated fat with foods high in mono and polyunsaturated fats can improve cardiovascular health biomarkers (Dehghan et al., 2017) • Calcium is more bioavailable from milk, yoghurt and cheese, compared with foods high in oxalates or phytates, such as beans, seeds, spinach and nuts (NHMRC, 2013) • Diets high in calcium can help improve bone density and reduce risk of osteoporosis (NHMRC, 2013) • Reduced prevalence of elevated blood pressure with the intake of milk, yoghurt and cheese (Steffen et al., 2005)	• The GHG emissions (namely methane and nitrous oxide) from the enteric fermentation of cattle (including dairy cows) and while producing their feed, contributes negatively to global warming (Stylianou et al., 2016) • Increased milk yield per cow can reduce GHG emissions and reduce the amount of water and feed required to produce the milk/keep the cow (van Hooijdonk & Hettinga, 2015) • Fluid milk has a higher estimated output of GHG emissions than SSBs (both measured per 119kcal) (Stylianou et al., 2016) • Potential by-products of dairy foods, such as fat removed off milk, can decrease the environmental impact (or spread the burden/GHG emissions) over different food types. For example, using the fat to make cream or butter.
Eggs	• Eggs contain essential nutrients for good health, including protein, vitamin E and D • Eggs are suggested as an alternative to lean meat, poultry and fish (NHMRC, 2013) • One serve of eggs is 2 large eggs (120g) in the AGTHE (NHMRC, 2013) with no set limit of eggs per week • Contrary to previous thoughts, the intake of eggs everyday does not increase risk of cardiovascular disease (NHMRC, 2013)	• Globally 92% of egg production is from chickens (MacLeod et al., 2013) • Most commonly consumed eggs in Australia are chicken eggs • A systematic review of global warming potential internationally found that free range eggs have a slightly greater negative impact on the emissions but still less than beef, sheep or pork (de Vries & De Boer, 2010)

2.5.2 Fruits and vegetables

There are positive health outcomes associated with a diet high in fruits and vegetables and this has been translated in public health messages in Western Australia (LiveLighter, 2018; Pollard et al., 2008). However, to date the added environmental benefits of diets high in plant-based foods opposed to animal-based foods, have not been promoted in messages for consumers.

A diet consistent with the ADGs, high in fruits and vegetables, low in EDNP foods and SSBs and moderate amounts of meat and dairy foods can assist in the prevention of chronic diseases, improve immunity, help maintain a healthy weight and provide additional health benefits (Martínez-González et al., 2011; Morgan, 2009; NHMRC, 2013). The most recent Australian Health Survey found that only 3% of young adults meet the recommended two serves of fruit and five serves of vegetables per day, compared to 9.6% of older adults (Australian Bureau of Statistics, 2012). However, the sample size of this survey inhibits disaggregation of this data for dietary intake by young adults in WA. Previous research found that WA adults eat less than the recommended daily serves of fruit and vegetables (Pollard et al., 2008) and the reasons for this are complex. An 18.8% increase in the cost of fresh fruit and 10.7% increase in the cost of fresh vegetables in WA since 2010 would likely influence the consumption of these foods, especially in individuals on low incomes, such as young adults (Australian Bureau of Statistics, 2013a; Pollard, Savage, Landrigan, Hanbury, & Kerr, 2015). In recent years, changes to the climate have influenced the availability and affordability of fresh food in Australia and globally (Barosh, Friel, Engelhardt, & Chan, 2014; Johnston et al., 2014).

2.5.2.1 Seasonal fruits and vegetables

Diets high in fruit and vegetables are consistent with healthy eating and have a lower environmental impact compared to highly processed foods and animal-based foods (Bradbear & Friel, 2011; Macdiarmid, 2013b). Although the consumption of all fresh fruits and vegetables is encouraged (NHMRC, 2013), produce grown locally and in season further reduces environmental impact as it is less likely to require a climate controlled environment and typically undergoes less processing, packaging, transportation and storage (Larsen et al., 2008; Macdiarmid, 2013b). Fruits and vegetables are typically in season at the same time, for example stone fruits in summer. However, extreme weather events, such as cyclones, floods and droughts, can influence availability. The Department of Agriculture and Food Seasonal Fruit and Vegetable Chart displays an approximate idea of what season fruits and vegetables are typically available (Appendix F).

The distance between where a food is grown (or produced) and where it is consumed is only one factor in determining its environmental impact. This is commonly referred to as 'food miles' or 'paddock to plate'. Recommendations around eating local produce can pose challenges in a country like Australia where food travelling from one side of the country to the other is equivalent to foods travelling between other continents, for example, the distance between Perth and Sydney is 4000 km. These limitations were evidenced in the 2013 WA Food Access and Cost Survey (Pollard, Savage, et al., 2015), which found unpackaged and refrigerated fresh foods in rural and remote areas were of poorer quality and cost significantly more than the same foods sold in urban areas.

Choosing seasonal fruits and vegetables requires specific knowledge of geographical location of origin which is not always evident (NHMRC, 2013) and this information is limited for meals prepared by others (e.g. meals eaten out). By law in Australia, packaged foods need to state the country of origin, yet individual fresh food items can choose to display this information on a sign near the food or a label, such as a sticker on an apple (Food Standards Australia and New Zealand, 2018). Providing this information can increase autonomy and awareness about buying food produced locally.

Accurately assessing seasonal and/or local food intake poses significant challenges including; the additional burden of recording 'place of origin' at time of purchase; consuming prepared food that does not carry this information (e.g. buying a salad at a café) and; the sale of fruits and vegetables all year around due to long term storage and modified atmospheres, regardless of seasonality. As less than 7% of Australians consume the recommended daily serves of fruits and vegetables (Australian Bureau of Statistics, 2012), increasing intake alone, regardless of seasonality, would result in both health and environmental benefits through the displacement of other foods.

People are prepared to buy local produce, although factors such as convenience, price, accessibility and perceived quality also determine food purchases (Lea & Worsley, 2008; Vermeir & Verbeke, 2008). Lea and Worsley (2008) conducted a cross-sectional study assessing the beliefs and behaviours regarding sustainable eating of 223 Australian adults. Purchasing locally produced foods was the most commonly performed food-related environmental behaviour reported by respondents, with 86% of participants reporting "sometimes" doing so. However, the response option of 'sometimes' is difficult to quantify as this may mean once a week to one person or once a month to another. Another Australian study conducted by Dixon and Isaacs (2013), assessed the opinions and intentions of Australians relating to sustainable and nutritious food choices. This study found respondents' intentions to purchase local/Australian produce are driven by their desire to support Australian farmers and the economy, however food prices and household preferences were bigger drivers of food choice (Dixon & Isaacs, 2013). Both of the above studies (Lea and Worsley (2008) and Dixon and Isaacs (2013)), highlight that Australians are aware of the importance of buying local produce mainly to support local farmers and the economy. However, little is known about how such attitudes are reflected in behaviour and whether people are aware of the role these foods play in supporting health and the environment.

2.5.3 Ultra-processed energy-dense nutrient-poor foods and beverages

Processed foods form a large component of the western diet and have been linked to growing rates of overweight and obesity (Monteiro et al., 2010; NHMRC, 2013; Rangan, Schindeler, Hector, Gill, & Webb, 2009; Tavares, Fonseca, Garcia R., & Yokoo, 2012). The definition of food processing is "all methods and techniques used by industry to turn whole fresh foods into food products" (Moubarac et al., 2013, p. 2). Food processing is important to ensure an adequate and safe food supply (Marsh & Bugusu, 2007; Monteiro, 2010), however, high levels of food processing often increases energy density and/or reduces the nutritional value of food due to the addition of fat, sugar or salt.

Ultra-processed foods are defined as those that require minimal, if not any, culinary preparation. They are designed to be durable, appealing and ready-to-eat with minimal to no preparation (Monteiro et al., 2010). These foods are usually packaged after being baked, fried, cured, smoked, canned, sugared or salted, and often contain additives and preservatives. Although some of these foods have added synthetic vitamins and minerals (Monteiro et al., 2010) many contain excessive amounts of saturated fat, added sugar and salt, classifying them as EDNP foods. These ultra-processed EDNP foods provide minimal nutrients and excessive energy in exchange for natural resources and outputs, which impact the environment.

In addition to helping maintain an adequate and safe food supply, processed fruits and vegetables, such as canned products, make a significant contribution to the nutrient intakes of American adults and children (Dwyer, Fulgoni, Clemens, Schmidt, & Freedman, 2012).

Therefore, it needs to be made clear that food processing has a vital role in ensuring a safe, adequate and nutritious food supply (through enrichment and fortification) but highly processed foods, such as a commercial pizza or chocolate bar, that require minimal preparation are nor healthy or environmentally supportive (Dwyer et al., 2012). These ultra-processed foods are formulated to be highly appetising and easy to consume, which is promoted in clever packaging and marketing (Monteiro, 2010). The processing and packaging of these foods places additional burden on the environment, compared to less processed alternatives, due to the water and energy required.

2.5.3.1 Levels of food processing

Methods of food processing have developed with human civilization, such as the use of drying, salting and fermenting that help preserve foods and create a more enjoyable eating experience. Many processed foods and beverages commonly consumed in Australia contain nutrients beneficial to health and are promoted in the ADGs, such as yoghurt, pasta, bread and milk (Monteiro, 2010; NHMRC, 2013). Considering the need to ensure a there is a large safe food supply to feed Australia's growing population, elements of food processing are crucial (Monteiro, 2010). However, since the 1980s there has been a significant increase in the consumption of ultra-processed foods globally. In Australia, young adults are more likely to consume EDNP foods that are convenient, highly processed and packaged, such as meat pies, fried potatoes, pizzas, crisps, lollies, savoury pastries, chocolates and sugar-sweetened soft drinks, compared to older age groups (Rangan et al., 2009). The intake of these EDNP foods have been associated with overweight, obesity and chronic disease risk (World Health Organization, 2003). Considering ultra-processed products are more energy dense than minimally processed foods, the rise in consumption of these foods could be contributing to the global increasing rates of overweight and obesity (Monteiro, 2010).

Key researchers in the area, based at the University of São Paulo in Brazil, developed a food classification system that classifies processed foods into four groups depending on the amount, type and aim of the processing (Table 2.5) (Monteiro et al., 2010; Monteiro et al., 2018). A limitation of this classification system is that it does not consider the processing methods used by farmers when raising animals and cultivating plants.

2.5.3.2 Assessment of ultra-processed foods

Traditional dietary assessment methods, such as 24-hour recalls (24HR), rarely collect or report on details about the extent of food processing (Moubarac et al., 2013). These methods were not deigned with this purpose in mind. However, such dietary information has the potential to inform food manufacturers, public health policies and nutrition messages. Previous studies have relied on household expenditure surveys and semi-quantitative FFQ to assess the intake of ultra-processed foods (Monteiro et al., 2010; Moubarac et al., 2012; Tavares et al., 2012), but to date no studies have investigated the consumption of ultra-processed foods in Australia. This demonstrates the need to assess new methods that can assess ultra-processed EDNP foods.

Table 2.5 NOVA food classification system- levels of processing
(Monteiro et al., 2018)

Group 1 Unprocessed or minimally processed foods.	Group 2 Processed culinary ingredients.	Group 3 Processed foods.	Group 4 Ultra-processed products.
Processes are mostly physical. Preserving or making foods safer, more palatable and accessible. Examples: • Fresh and frozen meat • Fresh or pasteurised milk • Plain yoghurt • Whole or polished grains • Fresh, frozen or dried fruit • Unsweetened fruit juices • Fresh and frozen vegetables • Whole or peeled roots and tubers • Unsalted nuts and seeds • Tea and coffee • Bottled spring water • Grains, legumes	Change the nature of the original. Examples: • Vegetable oils • Animal fats • Sucrose • Flours • Pastas	Examples: • Salted/sugared nuts and seeds • Cured, smoked, salted, pickled meats • Canned fish • Canned or bottles fruits, vegetables and legumes • Freshly made breads	Highly processed, ready to eat foods. • Cookies • Cakes • Chips • Burgers • Sweets • Pizzas • Chicken nuggets • Energy bars • Sugar-sweetened and diet beverages • Mass produced breads • Infant formulas • Instant soups, noodles, desserts

2.5.4 Individually packaged foods and beverages

Food packaging plays a crucial role in maintaining a safe food supply and has the ability to reduce food waste by retaining the effect of food processing to extend shelf life

(Marsh & Bugusu, 2007). Food packaging is important in ensuring a variety of food can be supplied to rural and remote Australian locations, which require vast distances of travel. In addition, Australia's growing population means there are more mouths to feed and a greater need for food to travel. However, packaged foods negatively impact the environment as a result of the resources used in the processing, packaging, transport, storage and the degradation of packaging (Bradbear & Friel, 2011).

Individually packaged foods, such an a yoghurt sachet or can of cola, are designed to be consumed as a single serve, are highly convenient and are becoming more readily available in Australian supermarkets. From a health perspective, not all individually packaged foods are unhealthy (unlike ultra-processed foods that are predominantly energy-dense and nutrient-poor). The novel method developed in this research allows for the assessment of individually packaged foods. Below are two examples of foods that are not classified as 'EDNP' foods in the ADGs but do not align with a sustainable diet because they are individually packaged; 1) artificially sweetened beverages; and 2) bottled water.

Individually packaged artificially-sweetened beverages

Artificially sweetened beverages do not contain energy; therefore do not directly contribute to weight gain. Nevertheless, a review of the literature highlighted that artificially sweetened beverages accelerate dental erosion increase and dental erosion (Tahmassebi, Duggal, Malik-Kotru, & Curzon, 2006). Consuming artificially sweetened beverages is inconsistent with a sustainable diet due to the energy, water and plastic required to process such ultra-processed products, in addition to the disposal of the packaging.

Bottled water

Water is the recommended beverage of choice in Australia, preferably tap water (NHMRC, 2013). To acknowledge the role of food choice on the future of the food supply, Appendix G in the ADGs encourages people to choose food packaging carefully, while acknowledging the role food packaging plays in the food system by ensuring food safety or preserving foods (NHMRC, 2013). Bottled water has no nutritional benefit over tap and is more expensive, therefore Australian's are encouraged to drink tap water over bottled water (NHMRC, 2013). In addition, purchasing bottled water creates an avoidable environmental impact, especially considering Australia has a supply of safe water. Some researchers believe the latest ADGs did not put enough emphasis on the issue of bottled water (Selvey & Carey, 2013). A quantitative study conducted on 3662 Australians (aged 14+ years) collected data on whether bottled water was purchased and consumed within the last seven days (Roy Morgan Research, 2016). This study found Western Australians consume the largest amount of bottled water (30.2% of the WA population), above the national average of 29.7% (Roy Morgan Research, 2016). It has been estimated that in Sweden, another developed country, bottled water contributes 34,000 to 74,000 tonnes of carbon dioxide equivalents every year (Fogelberg, 2013). Although not directly comparable to an Australian context due to other significant differences such as climate, this statistic emphasises the impact of unsustainable and avoidable dietary behaviours.

2.5.4.1 Food packaging and the environment

Food packaging has enabled food to be safely stored for longer periods, assisting with food security in rural and remote areas of Australia and reducing opportunities for food waste (Commonwealth of Australia, 2017). Due to this durability and increased shelf life, packaged foods have become more affordable. However, perishable unpackaged foods, such as fresh fruits and vegetables are becoming more costly (Pollard, Savage, et al., 2015) and are an essential part of a healthy diet and align with a sustainable diet.

The resource inputs and outputs required during the production, recycling and decomposition of food packaging have an environmental cost, although the extent of environmental damage depends on materials and methods (Marsh & Bugusu, 2007). Although most materials used in food packaging are recyclable, there are many factors that influence whether this is possible or feasible (Marsh & Bugusu, 2007). Common materials used in food packaging include plastics, glass, paper, metals and cardboard (Marsh & Bugusu, 2007). Plastic is a commonly used material for food packaging in Australia and some plastics do not decompose, meaning more land is required to hold this waste. Appendix G in the ADGs encourages people to use food packaging appropriately due to the impact on natural resources (NHMRC, 2013), although this is quite broad and the term ‘appropriately’ could be interpreted to suit the consumer. However, the fact it is present in the ADGs means nutrition professionals have a role to play in education and/or informing policy development.

2.5.5 Food waste

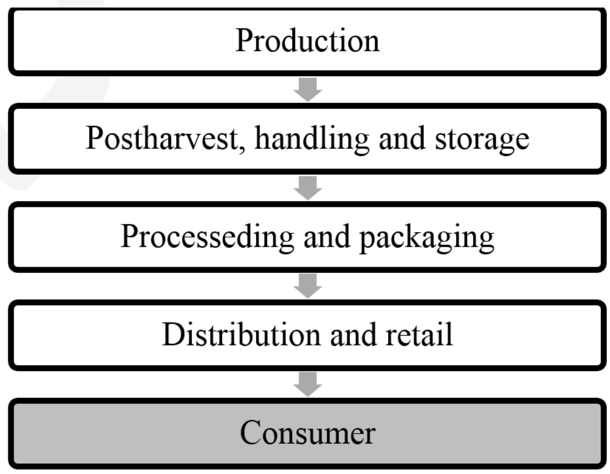
Food waste is a global issue, especially prominent in developed countries, valued at US$940 billion each year (Lipinski et al., 2017). It has been estimated that 30% of food produced globally is wasted (Food and Agriculture Organization, 2011) and food waste alone cost the Australian economy AUD$20 billion each year, approximately $2200 to $3800 per household (Commonwealth of Australia, 2017). The decomposition of food produces greenhouse gases, such as carbon dioxide, negatively affecting the environment. This is in addition to the resources (such as water, electricity and fuel) used in the production, processing, storage, refrigeration and transport of food that is not consumed (Baker, Fear, & Denniss, 2009; Bradbear & Friel, 2011; Environment Protection Authority, 2012; Mason, Boyle, Fyfe, Smith, & Cordell, 2011). Reducing food waste from production to consumption will decrease burden on the food system and is a modifiable behaviour with environmental benefits (Macdiarmid, Lang, & Haines, 2016; Mason et al., 2011; Riley & Buttriss, 2011).

As highlighted by Lang and Barling (2013) the issue of reducing waste has been incorporated into policy since the 1930s, with the United Nation's Food and Agriculture Organisation incorporating a mandate for food waste reduction in 1945 (Parfitt, Barthel, & Macnaughton, 2010). The United Kingdom's Waste and Resources Action Programme developed a campaign "Love Food Hate Waste" to encourage people to reduce the amount of food they waste in their household (Macdiarmid et al., 2016). This campaign was complemented with a proposed Food Waste (Reduction) Bill in UK parliament, however, was not a priority or passed (Macdiarmid et al., 2016). Despite global actions in the area, Australia only set a formal food waste reduction goal in 2017 to half food waste by 2030 (Commonwealth of Australia, 2017). The US set the same target of a 50% reduction by 2030 although their policy was introduced two years earlier (United States Environmental Protection Agency, 2017).

2.5.5.1 Types of food waste

Food waste can occur at many points within the food supply. Figure 2.2 shows the potential opportunities in which food losses and food waste can occur. Consumer food waste includes food that has become rotten in the fridge and thrown away, food purchased and not eaten, food scraps (such as orange peels, fat removed off meat), and unfinished food that is thrown away.

Figure 2.2 Opportunities for food wastage (FAO, 2011)



Consumer food waste is high in developed countries. It has been estimated that 61% of total food wastage occurs at the consumption level in North America and Oceania (including Australia), compared to approximately 5% in some developing countries (Lipinski et al., 2017). However, food wastage occurring at the production, distribution and handling level is less in developed than developing countries in general (Lipinski et al., 2017), likely due to the technology and resources available. Hence, there is a need to focus on strategies to address consumer waste in Australia, as has been done with campaigns such as the Waste and Resources Action Programme in the UK (Macdiarmid et al., 2016).

Consumers often discard edible food because of poor perceptions of when a food is no longer safe to eat after the ‘best before’ date stamp (Department of Agriculture Fisheries and Forestry, 2013). The disposal of fresh fruits and vegetables is more common than disposing of other foods in developed countries, including Australia (Food and Agriculture Organization, 2011; Parfitt et al., 2010). The perishability of fruits and vegetables items may influence purchasing habits and why people consume inadequate amounts of these foods.

The term ‘plate waste’ is not restricted to food served on an actual plate but any food that is served and not consumed, such as left over chips in a packet or half a chocolate bar. Some plate waste is unavoidable, such as inedible meat bones or banana skin. However, *edible* plate waste is avoidable (Lang & Barling, 2013) and has been suggested as a reason why consumer waste is more prevalent in developing countries due to the ability to afford to buy and waste food (Food and Agriculture Organization, 2011; Parfitt et al., 2010).

Whether edible or inedible, some food waste is compostable, although this may not be possible if such ingredients are in a mixed dish. For example, tomatoes are compostable, but tomatoes in spaghetti bolognese are not, due to other ingredients present such as beef. A systematic assessment of dietary patterns in Italy and their influence on environmental sustainability stated that food waste, from spoiled or disregarded household food, was not an issue in relation to GHG emissions due to the fact it is often composted and reused in agriculture (Pairotti et al., 2015). Although this may be an accurate statement in an Italian context, in Australia it has been reported that approximately 3.1 million tonnes of edible food is thrown away into landfill each year, and this is not including the commercial and industrial sector of the food chain. Although there are incentives in approximately 500 local Australian governments areas to compost food waste, through reimbursements on compost bins and worm farms (Commonwealth of Australia, 2017) the unnecessary disposal of food is still a major social issue that would benefit from community education and encouragement.

2.5.5.2 Food waste in Australia

Food waste plays a significant negative role in Australia's economy costing approximately AUD$20 billion dollars each year (Commonwealth of Australia, 2017). It has been estimated that Australian's waste approximately 361 kg of food each year (Bradbear & Friel, 2011). In November 2017, a National Food Waste Strategy was launched in Australia with the aim of halving food waste by the year 2030 (Commonwealth of Australia, 2017). This was a significant step toward reducing food waste compared to Australia's previous 2009 National Waste Policy, which comprised of strategies designed to reduce the amount of waste for social, environmental and economic benefits to 2020, but did not include a specific focus on food waste (Department of Environment, 2013).

A representative sample of 1644 Australian adults were surveyed regarding wasteful consumption and asked to retrospectively estimate the amount of money they spent on fresh, frozen and take-away food they did not consume (as detailed in Table 2.3) (Hamilton et al., 2005). Findings showed 38% of young adults aged 18 to 24 years waste more than $30 on fresh produce per fortnight, compared to only 7% of adults over the age of 70 years (Hamilton et al., 2005). This study also found that Australians threw away $5.3 billion worth of food including; fresh food ($2.9 billion), frozen food ($241 million), take-away food ($630 million), unfinished beverages ($596 million) and leftover food ($876 million)

(Hamilton et al., 2005). With Queensland wasting the most amount of food ($638/annum), followed by Australian Capital Territory ($635/annum) and Western Australia ($584/annum) (Hamilton et al., 2005). The knowledge, attitudes and behaviours regarding food waste were assessed by Researchers in New South Wales in 2012 (Environment Protection Authority, 2012). This study involved telephone or online interviews with 1200 subjects and found that young adults were more likely to believe that a busy lifestyle makes it hard to avoid food waste (Environment Protection Authority, 2012).

Household level programs have been developed in Australia to increase awareness around food waste, for example the '*Love Food Hate Waste*' program in NSW (Environment Protection Authority, 2012) or '*Wipe out Waste*' in South Australia (Green Industries South Australia, 2018). Recently, momentum around food and packaging waste was gained as a result of a documentary series titled *'War on Waste'* screened on national television (Australian Broadcasting Corporation, 2017). The 2013 ADGs recommend people plan meals and moderate portion sizes as methods of reducing food waste and saving money (NHMRC, 2013).

2.5.5.3 Evidence on consumer plate waste in Australia

There is little data on consumer plate waste. One UK study provided food diaries to a representative sample of 948 households and asked them to estimate the volume or weight of food wasted for six consecutive days and document how that food was disposed of (rubbish bin, compost, fed to pets etc.) (Quested, Easteal, & Ingle, 2013). However, this study had a high non-completion rate with 20% of kitchen diaries not being returned (Quested et al., 2013), which was likely due to the amount of time and effort required on behalf of the respondent. In addition, the methodology used in this study did not capture plate waste outside the home, and eating out is common in Australia. On average, Australian households spend about AUD$80 a week on dining out (Australian Bureau of Statistics, 2017), therefore food behaviours outside the home should be measured when assessing plate waste. Evidence on the strengths and limitations of methods used to assess consumer food waste are outlined in Section 2.9.

Australians are motivated to reduce the amount of food they waste for financial saving predominantly, followed by wanting to protect the environment (41%) and lastly humanitarian reasons (27%) (Baker et al., 2009). Regardless of such motivations to reduce food waste, it is unknown if individuals are aware of how much edible plate waste they generate. This data may be important in changing consumer behaviours.

2.6 Determinants of food choice

Factors influencing whether one is encouraged or discouraged to consume a healthy diet is complex, with a magnitude of individual, cultural and environmental influences and cannot be considered in isolation. To gain a broader picture of H&S dietary behaviours, it is vital to consider what influences and motivates individual food and beverage consumption. This section of the literature review outlines factors that potentially influence compliance with a H&S diet including; knowledge and attitudes; perception of current intake; eating frequency; and some environmental influences.

Dietary behaviours are often engrained early in life and influenced by numerous factors, making behaviour change challenging (Nestle et al., 1998). A diet high in plant-based foods can help prevent chronic diseases and aligns with a H&S diet (Burlingame & Dernini, 2012; Martínez-González et al., 2011; World Health Organization, 2003). Despite public health messages to encourage fruit and vegetable consumption in WA (LiveLighter, 2018; Pollard et al., 2008), the intake of these foods remains inadequate (Table 2.2). One reason could be the strong influence of the food environment on food choice (Caspi, Sorensen, Subramanian, & Kawachi, 2012). Changes to policies (such as what food is available in a school canteen) or legislation (such as mandatory food labelling, taxes or restrictions on EDNP food marketing to children) can help create a supportive environment to make healthier food choices and lead to public health benefits in the long term. However, in the area of H&S diets, there is a lack of evidence on what people are currently doing and how important they believe the issue is, making a case to policy makers difficult. Further research on what influences, challenges and motivates people to eat more foods consistent with a H&S diet requires attention as the benefits go beyond health to the economy and environment.

2.6.1 Influence of knowledge, attitudes and beliefs on food choice

Education plays a key role in nutrition knowledge and food literacy. In addition, the attitudes, values and beliefs that people possess influences food choice (Nestle et al., 1998). The perceived influence of food on health is a motivator to consuming foods for some, but not all, people. Previous studies investigating attitudes toward sustainable production methods have found a positive association with improved diet quality, as defined by increased fruit and vegetable intake and reduced SSB and fast food intake (Pelletier et al., 2013). However, attitudes toward the impact of foods on the environment did not appear to motivate food choice. A UK study of 842 adults given self-administered questionnaires found health and ethical reasons for reducing meat, dairy and egg intake is more of a motivator than the environmental impacts of these foods (Clonan et al., 2015). A qualitative Australian study of 29 shoppers examined attitudes and perceptions towards eating more plant-based and less animal-based foods (Hoek, Pearson, James, Lawrence, & Friel, 2017). Using both an electronic survey and telephone interview, findings showed people were aware of the environmental impacts of highly processed and packaged foods but had poor knowledge about the need to eat less animal-based foods for environmental reasons and apprehensions about doing so. Although these findings raise the issue of needing to increase public knowledge of sustainable food choices, this study did not assess actual dietary intake to see how beliefs and attitudes were being translated into behaviours that may be aligned with a H&S diet. Providing people with personalised feedback on their food intake and the environment impacts of their dietary behaviours may increase awareness and be a motivator to adopt healthier and more sustainable diets.

2.6.2 Environmental influences on food choice

The reasons why people choose to eat what they do varies considerably between individuals depending on numerous physical, psychological and environmental factors including; education level, attitudes, food preferences, beliefs, location, exposure to marketing and socio-economic status (Nestle et al., 1998). This section discusses the environmental influences on food choice that may influence adherence to a H&S diet.

2.6.2.1 Food cost, availability and quality

The increasing price of healthy foods compared to highly processed and packaged EDNP foods is a driver of poor food choices. The cost disparity between healthy and unhealthy foods means that integrating environmental considerations into dietary recommendations becomes even more important to protect the environment and the future of the food supply (Drewnowski, 2010a). The appeal of EDNP foods and beverages is often driven by cost, convenience, availability, taste, marketing and promotion. The food choices of people who may be struggling financially would be heavily influenced by the inverse relationship between the cost of food ($/kg) and the energy density (MJ/kg) (Drewnowski, 2004). Stronger evidence in this area of health could influence policy development to improve diet quality, current health status, and aid in the prevention of chronic diseases (Pollard, Daly, Moore, & Binns, 2013; Rangan et al., 2009).

A triennial WA survey, the Food Access and Cost Survey (FACS) monitors the cost, quality and availability of foods in supermarkets, community stores and roadhouses state-wide (Pollard, Savage, et al., 2015). Findings from the 2013 FACS were consistent with previous years which showed how EDNP foods are affordable and widely available, in contrast to fresh fruit and vegetables which are often costly and not always available outside the capital city of Perth (Landrigan, Kerr, Dhaliwal, Savage, & Pollard, 2017; Landrigan & Pollard, 2010; Pollard, Savage, et al., 2015). These findings support ongoing national health surveys in Australia which highlight the increased prevalence of overweight and obesity rates (linked to diets high in EDNP foods and low in fruits and vegetables) in rural, remote, and low socio-economic status areas of WA (Australian Bureau of Statistics, 2015).

2.6.3 Perception of current dietary intake

Exploring perceptions and attitudes towards EDNP food and SSB intake may provide evidence for the need for more tailored messages and interventions. Discrepancies between perceived and actual diet quality have been found in previous studies. A cross-sectional study of 24HR collected during the US National Health and Examination Survey (NHANES); found a divide between perceived diet quality and those meeting dietary recommendations (Powell-Wiley, Miller, Agyemang, Agurs-Collins, & Reedy, 2014). Several other studies have found people have unrealistic perceptions of their fat, fruit and vegetable intake, and this may create barriers for improving dietary intake (Bogers, Brug, van Assema, & Dagnelie, 2004; Brug, van Assema, Kok, Lenderink, & Glanz, 1994; Lechner, Brug, & De Vries, 1997; Pollard, Daly, et al., 2009). A cross-sectional study of 1201 college students using an online survey found, those who perceived their friends and family to regularly consume fast food and SSB had a significantly higher intake compared to those who perceived their friends and family to consume smaller amounts (Pelletier, Graham, & Laska, 2014). Studies of individuals' perceptions of fat intake versus actual fat intake in the Netherlands and the US found that the majority of adults had little awareness of the amount of fat they consumed (Glanz, Brug, & van Assema, 1997).

A cross-sectional study of 1108 subjects, aged 16+ years, in WA found young adults were less likely to report eating the recommended amount of vegetables than older age groups (Pollard, Daly, et al., 2009). This study also found knowledge about serve size recommendations was related to reported consumption, confirming that an overly optimistic assessment of current intakes can result in complacency (Pollard, Daly, et al., 2009). There is limited evidence between how people perceive and feel about their intake versus their actual dietary intake collected using objective dietary assessment methods. In summary, the above studies highlight the disconnect between what people believe they are eating and what food they are actually eating.

2.6.4 Eating frequency and healthy eating

Obesity rates in Australia are increasing with more people moving from being classified as overweight (BMI 25 - 29.9 kg/m^2) into the 'obese' category (BMI ≥30 kg/m^2) (Australian Bureau of Statistics, 2012). Increasing portion sizes and the excessive intake of EDNP foods and SSBs have been linked with increasing rates of overweight and obesity; however, the number of daily eating occasions, or eating frequency (EF), may be a contributing factor. Table 2.6 summarises previous studies assessing EF and its associations with dietary intake and health, and the methods to do so. Some studies have found that dietary habits which include more 'snacking' or 'grazing' are associated with overweight (Duffey & Popkin, 2011; Leech, Worsley, Timperio, & McNaughton, 2017). A key researcher in this area, Richard Mattes, proposed that environmental and metabolic signals may play a greater influence on how often people eat compared to feelings of hunger and more research on the health effects of EF are required to challenge the emphasis put on portion size and weight gain (Mattes, 2014b).

There is a lack of consistent findings in this area of nutrition research. An increased number of eating occasions (EOs) have been associated with higher BMI (Duffey & Popkin, 2011; Howarth, Huang, Roberts, Lin, & McCrory, 2007), reduced BMI (Aljuraiban et al., 2015; Drummond, Crombie, Cursiter, & Kirk, 1998), reduced overall energy intake or increased nutrient density of the diet (Aljuraiban et al., 2015; Ritchie, 2012). A cross-sectional Australian study of 2775 young adults found the proportion of people meeting dietary recommendations increased with the number of daily eating occasions (Smith et al., 2012a). Studies showing such contradictory findings highlight the need to further investigate the influence of EF on body weight and dietary intake.

The lack of consistency in results relating to EF, diet quality and BMI is likely due to the absence of consensus on terminology and definitions (Hess, Jonnalagadda, & Slavin, 2016) and the variety of self-report methods used to assess eating occasions. The terms 'meal' and 'snack' raise issues due to perceptions of what constitutes these occasions (Hess, Rao, & Slavin, 2017). Calls for a neutral definition to assist further research have been suggested by researchers, including terms such as 'feeding frequency' or 'ingestive frequency' which encompass both food and beverage intake (Leech, Worsley, Timperio, & McNaughton, 2015a; Mattes, 2014a; Mattes, 2014b). In this research, the term 'eating occasion' applies to times in which foods and/or beverages were consumed and the number of eating occasions is referred to as 'eating frequency'.

Previous studies investigating eating occasions have classified them by:

- Specific time intervals (e.g. within a 15 minute) (Aljuraiban et al., 2015; Drummond et al., 1998; Duffey & Popkin, 2011; Popkin & Duffey, 2010) or one hour period (Howarth et al., 2007)
- Type of food was consumed (Drummond et al., 1998)
- Time in which food was consumed (e.g. between 12-2pm)
- Energy density of the food or beverage (Leech et al., 2015a)
- Proportion of total energy intake provided at the eating occasion (Ritchie, 2012; Rossbach et al., 2016)
- A participant classification system whereby the respondent states whether the eating occasion was a 'snack' or 'meal' (Duffey & Popkin, 2011; Popkin & Duffey, 2010) or specifically reported as 'breakfast', 'lunch' or 'dinner' (Fayet-Moore, McConnell, Kim, & Mathias, 2017; Howarth et al., 2007).

Some studies excluded all beverages from the analysis of eating occasions (Aljuraiban et al., 2015) while others counted eating occasions where more than half a pint of milk (250mL) was consumed (Drummond et al., 1998). The variables that were adjusted for in each study were dependent on the data available and have been outlined in Table 2.6. It has been suggested that misreporting energy intake has the potential to affect any findings between food intakes and eating patterns (Leech, Livingstone, Worsley, Timperio, & McNaughton, 2016). However, underreporting intake is a limitation of most dietary assessment methods (Macdiarmid & Blundell, 1998) and should be considered when interpreting results in nutritional epidemiology.

2.6.4.1 Assessment of eating frequency

The assessment of daily eating occasions often heavily relies on memory or self-reported eating times (Leech, Worsley, Timperio, & McNaughton, 2015b). Collecting such dietary information can create extra burden for people on top of estimating or recording foods and beverages consumed and their volume. The self-reported methods used to assess EF, such as the 24HR method (Aljuraiban et al., 2015; Evans, Jacques, Dallal, Sacheck, & Must, 2015; Fayet-Moore et al., 2017; Leech et al., 2015a; Smith et al., 2012a; Smith et al., 2012b; Zizza & Xu, 2012), often rely on the recall ability of the participant. Another method that has been used to assess EF is the weighed food record (Drummond et al., 1998; Ritchie, 2012), which involves participants electronically or manually recording what and how much they eat or drink. Although it is assumed people will complete this is real time, this is often not the case and many will complete as a recall at the end of the day (Boushey et al., 2009).

Image-based and image-assisted dietary assessment methods may be suitable to assess EF without placing additional burden on participants (Aflague et al., 2015; Ahmad, Khanna, Kerr, Boushey, & Delp, 2014; Boushey et al., 2015; Boushey et al., 2009; Kerr et al., 2016). The purpose built mFR application (App) automatically records the time and date of each image, allowing for researchers to confirm the time and number of EOs using metadata without involving the participant. This removes the need for participants to record this data and has the potential to reduce the influence of social desirability bias, whereby respondents report on what they believe the researchers will want to hear or see, either consciously or subconsciously (Cadmus-Bertram & Patterson, 2013). Overall, research examining EF and associated health outcomes lacks consistencies in terminology and study methodologies.

Table 2.6 Summary of studies assessing eating frequency (EF) and/or the effect of eating occasions (EOs) on health

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Aljuraiban et al. (2015)	n= 2,696 *Adults aged 40-59 years* US and UK	Cross-sectional study	• 24HR • EF was defined as frequency of eating occasions (EOs) • EOs were any reported consumption of solid meals and snacks, with a minimum gap of 15 minutes between occasions • EOs were classified into the following categories: < 4, 4 to < 5, 5 to < 6, and ≥6 within 24 hours • Excluded all beverages including water, fruit juice, soda, alcoholic beverages, tea, and coffee from the EOs to avoid overestimation of the total number of EOs per 24 hours • Used Nutrient Rich Food Index 9.3 (NRF9.3) value to measure nutrient density. Combined with dietary energy density (kcal/g) to measure diet quality • The NRF9.3 has been validated against the Healthy Eating Index	• Total energy intake • Age • BMI	• 6 or more EOs associated with: • lower BMI • higher nutrient density\lower total kJ intake • lower energy density

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Drummond et al. (1998)	n=95 *Adults aged 20- 55 years*	Cross-sectional study	• 7-day estimated written food record • Participant recorded time food was consumed • An ‘eating occasion’ was defined as any occasion where food was consumed (to avoid use of terms ‘snack’ or ‘meal’) • Snack was defined as anything consumed outside of a ‘regular’ mealtime of breakfast, lunch or dinner, or a snack item eaten instead of a meal • If ≥2 EOs took place within 15 minutes it was only counted as one EO • Beverages only were not counted as an eating occasions unless more than ½ pint of milk was consumed. • List of snacks included foods such as a packet of nuts, chocolate bar, piece of fruit, yoghurt or sweets • BMI > 30kg/m^2 excluded from analysis	• Energy intake	• In men, EF was inversely related to body weight (no link in women) • Higher EF was related to leanness in men and this may have been associated with high physical activity levels • Men appeared to compensate accurately for increased EF by reducing the size of subsequent eating episodes • In women, even in the absence of energy intake compensation, the higher energy intake associated with high EF appears to have been balanced by greater energy expenditure from activity, sufficient to prevent an increase in body weight.

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Duffey and Popkin (2011)	n= 44,754 (data from 4 surveys) *Adults aged 19+ years*	Cross-sectional study	• Combination of 24HR and 2-day food records • Meals and snacks were self-defined by respondents in both the USDA and NHANES surveys • Meals were defined by the respondent as breakfast/brunch, lunch, and dinner/supper, while the snack category included those EOs defined by the respondent as "snack," plus related snacking occasions (i.e., food and/or coffee/beverage breaks) • All occasions that were identified as snacks but were consumed within 15 min of each other were combined into a single snacking event • Beverages consumed alone counted as snacks	• Sex • Race/ethnicity	• Increased EF was associated with increased BMI

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Evans et al. (2015)	n= 176 *Children aged 9-15 years* USA	Analysed cross-sectional and prospective relationships	• 24HR • Used Healthy Eating Index 2005 to measure diet quality • Meals and snacks •	• Age • Sex • Physical activity • Race/ethnicity • School • Free or reduced-price lunch • Maternal education	• In 9-11 year olds, as total EOs increased (snacks and meals) so did diet quality • In 12-15 year olds, as the number of 'meals' increased, so did their Healthy Eating Index (HEI-2005) score (p= 0.01) • Number of meals and snacks was positively associated with increased overall energy intake • The relationship between diet quality and number of EOs differed by ages • Whereas when the number of 'snacks' increased, the HEI-2005 score significantly reduced (p= 0.006).
Fayet-Moore et al. (2017)	n= 8,258 *Children aged 14–18 years*	Cross-sectional study	• 24HR • Used Australian 2011–2012 National Nutrition and Physical Activity Survey • Participants defined EOs from 11 pre-defined options: breakfast, brunch, morning tea, lunch, afternoon tea, dinner, supper, snack, beverage/drink, extended consumption and other	• Energy intake • Underreporting	• Least amount of subjects consumed breakfast • SSB intake among adolescents was distributed across all EOs, with the lowest prevalence at breakfast (6.7%) and the highest at other EOs combined (23%).

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Leech et al. (2016)	n= 5,242 *Adults aged 19+ years*	Cross-sectional study	• 24HR (x2) • Used 2011-2012 National Nutrition and Physical Activity Survey • Validated USDA automated multiple 5-pass method	• Total energy intake • Income • Age • Country of birth • Education • Alcohol intake • Smoking status • Dieting • Reported eating more or less than usual • Sedentary behavior • Physical activity	• Greater EF of all EOs was associated with higher Dietary Guidelines Index scores for fruit, dairy foods and variety. • Number of meals in a day is associated with an increase in micronutrient intake and overall diet quality (but not snacks) • Greater number of daily snacks was association with higher added sugar and EDNP food intake.
Leech et al. (2017)	n= 4,050 *Adults aged 19+ years*	Cross-sectional study	• 24HR (x2) • Used NNPAS • Validated USDA automated multiple 5-pass method • EO was defined as any occasion where food or drink provided a minimum energy content of 210 kJ (50 kcal) and was separated in time from the surrounding EOs by 15 minutes	• Energy intake: Energy expenditure	• Frequency of all EOs, meals (women only) and snacks was positively associated with waist circumference and BMI (all $p < 0.01$) • Snacks, but not meal frequency, were associated with overweight/obesity

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Llaurado, Albar, Giralt, Sola, and Evans (2016)	n= 884 *Adolescents aged 11-18 years*	Cross-sectional study	• 3-4 day semi-weighted dietary record • UK National Diet and Nutrition Survey • Diet Quality Index for adolescents (DQI-A) • Participants recorded time food/beverages were consumed • Categorised into three timeframes • Looking at effect of snacking and eating frequency on diet quality	• Age • Sex	• Higher EF was associated with improved diet quality in adolescents
Murakami and Livingstone (2016)	n= 19,427 *Adults aged 20+ years*	Cross-sectional study	• 24HR (x2) • Data from US National Health and Nutrition Examination Survey 2003-2012 • EOs providing ≥50 kcal were divided into either meals or snacks on the basis of contribution to daily energy intake (15% or <15%), self-report, and time (e.g. 6am to 10am) • Diet quality was assessed using the Healthy Eating Index-2010 (HEI-2010)	• Age • Race/ethnicity • Education • Family poverty income ration • Smoking • Physical activity • Weight • Dietary reporting status • Survey cycle	• Higher EF was positively associated with higher • HEI-2010 in both men and women • All measures of meal frequency and snack frequency were positively associated with HEI-2010 in both sexes

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Popkin and Duffey (2010)	n= 28,404 *children aged 2-18 years* n= 36,846 *adults aged 19+ years*	Cross-sectional study	• 24HR • USDA's Automated Multiple-Pass Method • Respondents named type and time of EO • Snack foods consumed within 15 min of each other were counted as a single snacking occasion • Time interval between start time of each EO was calculated into mean number of minutes between EOs • If respondents defined EO as both a snack and meal, it was counted as a meal	• Demographic shifts over time	• EF increased over the previous 30 years among all ages • Energy intake, particularly from snacking, increased for adults and children in all percentiles of the distribution • Time between EOs decreased by 1 h for adults and children
Ritchie (2012)	n= 2,372 *Girls aged 9–10 to 19–20 years*	Longitudinal study	• 3 day written food record (2 weekdays, 1 weekend day) • Meal comprised of ≥15% of total kcal were consumed • Snack comprised of <15% of total kcal • Aimed to assess the prospective relationships of an objective measure of EF with adiposity	• Baseline adiposity • Race • Parental education • Physical activity • TV/video viewing • Total energy intake • Dieting for weight loss	• Increased EF was associated with decreased BMI, decreased energy intake or increased nutrient density

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Rossbach et al. (2016)	n= 1,246 *Children aged 3-18 years*	Cohort study	• 3-day weighed food record • Data collected from 1985-2014 • EOs were labelled as meals (>10% daily total energy intake per EO) or snacks (≤10% of daily total energy intake)	• Total energy intake • Number of weekdays per record • Body weight • Parental overweight • Maternal educational/ employment	• The duration of nightly fasting reduces with age, likely due to children sleeping for shorter periods.
Smith et al. (2012a)	n= 1,273 men n= 1,502 women *Adults aged 26 - 36 years*	Cross-sectional study	• Participants provided with a meal pattern chart (with hourly intervals) to record when they had eaten the previous day. • Dietary intake compared with the Australian Guide to Healthy Eating	• Age • Education • Physical activity • Waist circumference	• Most men ate 3 to 5 times per day and most women ate 4 to 6 times • Higher number of EOs was associated with reduced cardiometabolic risk factors in men (although many associations were mediated by waist circumference) • No significant trends were observed in women
Zizza, Siega-Riz, and Popkin (2001)	n= 8,493 *Adults aged 19-29 years*	Cross-sectional study	• 24HR multiple pass method • USDAs representative surveys from 1977-78, 1994-1996 • EOs were determined by the respondent (not the researchers) by the type and time • All snacks eaten within a 15-minute period were counted as one EO	• Sex • Age • Percentage of poverty • Education	• Energy density of snacks increased from between 1977-78 and 1994-96 • Increase in high fat salty snacks • Proportion of daily energy intake from snacks increased from 20-23%

Reference	Sample	Study design	Method used	Adjusted for:	Key findings
Zizza and Xu (2012)	n= 11,209 *Adults aged 20+ years*	Cross-sectional study	• 24HR • Data from the National Health and Nutrition Examination Survey 1999-2004 • Diet quality was assessed using the Healthy Eating Index-2005 (HEI-2005)	• Sex • Age • BMI • Race • Education • Smoking • Physical Activity • Consumption of 3 meals/day • Chronic diseases • Energy contribution from meals	• Snacking was associated with higher total Healthy Eating Index 2005 scores • Total fruit, whole fruit, whole grains, milk, oils, and sodium were positively associated with snacking frequency • Inverse associations between snacking frequency and total vegetable; meat and beans; and the energy from solid fat, alcohol, and added sugars

2.7 Monitoring dietary intake

Dietary data is vital in guiding nutrition policy, informing best practice and determining diet disease relationships (Subar et al., 2015). The quality of dietary intake data is a reflection of the dietary assessment method used. Therefore, when interpreting evidence, critiquing the method used in data collection is an important first step. The relevance and importance of collecting data on dietary intake has been criticised in recent times (Archer & Blair, 2015) encouraging key researchers to highlight the value of dietary assessment (Subar et al., 2015).

Brief assessment instruments (or screeners), commonly used in population surveillance, focus on specific diet and nutrition behaviours (Section 2.8.1) (Thompson & Subar, 2013). These typically use a short questionnaire or several questions to assess behaviour (Kirkpatrick et al., 2014). More detailed dietary assessment methods, such as food records and FFQs, provide data on what individuals are eating (see Section 2.8 for strengths and limitations of dietary assessment methods). However, they are not frequently used for population-based nutrition monitoring in Australia due to the time and financial burden on participants and researchers. The following section of the literature review examines available dietary assessment methods, and summarises by outlining their ability to assess sustainable dietary behaviours.

2.7.1 Population-based nutrition monitoring

Population-based nutrition monitoring is imperative in gathering representative data to guide public health nutrition campaigns and policy (Pollard et al., 2013). Nevertheless, Australia lacks reliable and up to date data to inform policy as population nutrition monitoring is undertaken sporadically and infrequently. The most recent National Health Survey, which collected dietary intake data using the 24HR method, was conducted in 2011/12. The previous National Nutrition Survey was conducted in 1995. Considering these surveys contain a sample of adequate size to generalise to the Australian population, the situation regarding their infrequency is of concern and feasible accurate methods to measure dietary behaviours could be more appealing to funding bodies and increase chances of more frequent monitoring.

2.8 Methods to assess dietary intake

A variety of methods are used to assess elements of the food supply, from the production and supply of foods, to individual food choices and dietary practices (Thompson & Subar, 2013). To ensure policies, interventions and recommendations are targeted appropriately, it is important to accurately assess dietary behaviours to establish associations. However, there are many challenges that accompany dietary assessment methods (Kirkpatrick et al., 2014) and considerations which need to be taken into account when choosing which dietary assessment method to use.

Studies observing the dietary behaviours of individuals and populations in free-living environments are rare. Therefore, methods to assess diet often rely on self- reporting intake and behaviours, and such subjectivity is accompanied by varying types and levels of measurement error (National Institutes of Health, 2018). The term 'measurement error' refers to the difference between what people report doing and what they actually did (National Institutes of Health, 2018). The level of measurement error can be influenced by the dietary assessment method itself, as well as one's knowledge, attitudes and cognitive abilities. Influences on which dietary assessment method researchers choose is influenced by: the type and level of measurement error; cost; availability; validation of the method in the desired population group and; time and resources available for data collection. When reporting on findings, researchers should acknowledge the potential for measurement error in their chosen dietary assessment method.

This research focusses on the assessment of the H&S dietary behaviours of individuals using the mobile food record (mFR). This section of the literature review will describe commonly used dietary assessment methods, highlight their advantages, limitations and recent innovations, and discuss their ability to assess the H&S dietary behaviours of focus in this research. Table 2.7 summarises strengths and limitations of available dietary assessment methods.

Table 2.7 Dietary assessment methods vs mobile food record

Adapted from (Burke & Deakin, 2015; Cadmus-Bertram & Patterson, 2013; Kirkpatrick et al., 2014; National Cancer Institute, 2015)

Assessment Method		**Food Frequency Questionnaire**		**24-HR Dietary Recall**		**Food Record**		**Mobile Food Record**
Mode	**Screeners**	**Paper-based**	**Self-administered electronically**	**Interview-lead/ paper-based**	**Self-administered electronically**	**Paper-based**	**Digital**	**App**
Respondent burden	Low	Low to moderate	Low to moderate	Low to moderate	Low to moderate	High	High	Moderate
Researcher burden	Low	Moderate	Low	High	Low	High	Moderate	Moderate
Scope of diet	Select components	Select components	Select components	Total diet	Total diet	Total diet	Total diet	Total diet
Time frame	Long term	Long term	Long term	Short term	Short term	Short term	Short term	Short term
Measurement error	Systematic	Systematic	Systematic	Random	Random	Random	Random	Random
Reactivity bias potential	Low	Low	Low	Low	Low	High	High	Moderate
Analysis time (approx.)				½ hr		1 hr		½ hr
Cognitive difficulty	Moderate	Moderate	Moderate	Moderate	High	High	High	Low
Diet-disease relationships	×	✓		×		Too costly		✓ ?
Nutrient analysis	×	✓ ? energy		✓		✓		✓ ?
Food group analysis		✓ dependent on food list	✓ dependent on food list	✓	✓	✓	✓	✓
Episodic foods		Dependent on food list		×	×	✓	✓	✓
Respondent training required	Nil	✓	✓	✓	✓	✓	✓	✓Self-administered training videos

2.8.1 Brief dietary assessment instruments/screeners

Brief dietary assessment instruments, also referred to as screeners, focus on specific diet and nutrition behaviours and are commonly used in population surveillance (Thompson & Subar, 2013). These typically consist of a short questionnaire or several questions to collect information on specific elements of diet over a period, often long term (e.g. past month), opposed to total dietary intake (Kirkpatrick et al., 2014; National Cancer Institute, 2015). Screeners are often used to study associations between dietary intake and other variables in prospective studies or retrospective case-control studies (National Cancer Institute, 2015). In these circumstances, screeners can be appealing to researchers, especially if more detailed dietary assessment methods are too costly or time consuming (Thompson & Subar, 2013). They may also be appealing for use in studies whereby dietary outcomes are not the main topic of interest. However, screeners are not recommended to monitor changes in dietary behaviours over time due to their lack of sensitivity to detect variation (Thompson & Subar, 2013).

Screeners are often used to assess specific components of diet (most commonly fruits, vegetables and fats), eating behaviours and knowledge (Thompson & Subar, 2013). They are quick to administer and hence, less costly. However, screeners are accompanied by a large amount of systematic error as a result of the limited amount of detail collected and the need for the participant to have the cognitive ability to estimate dietary behaviours over a longer period (Kirkpatrick et al., 2014; Thompson & Subar, 2013). To assist in reducing burden on researchers and minimising opportunities for human error, screeners have been adapted for electronic use, such as computer-assisted telephone interviews used in the Nutrition Monitoring Survey Series (NMSS) (Pollard et al., 2013).

Over 130 screeners assessing different components of diet have been validated in certain population groups and the National Cancer Institute in the US has created an online register of such tools (National Cancer Institute, 2015; National Cancer Institute, 2017). Although validation of dietary assessment methods is important in determining level of error, it is often undertaken by comparing findings to a more detailed method, such as 24HR, which are accompanied by their own level of error (Kirkpatrick et al., 2014). Other than the low cost of validating screeners using this method, a possible reason is that there are no recovery biomarkers for elements of diet commonly assessed using screeners, such as fast food, fruits or vegetables (Kirkpatrick et al., 2014). It is recommended that even validated screeners are adapted for specific population groups as they are not directly transferrable between populations and cultures, due to variations in dietary behaviours (Thompson & Subar, 2013).

2.8.2 24-hour recalls

The 24HR is a commonly used dietary assessment method due to its ability to collect data on intake over the preceding 24 hour period in a timely manner (Thompson & Subar, 2013). The 24HR can be administered by an interviewer or self-administered. Interviewer led 24HR can take place in person or by telephone and involve probes to assist respondents in reporting details of food consumption (including preparation methods) and any forgotten foods or beverages to reduce underreporting. Previous research suggests a well-trained interviewer, or a well-developed self-administered version of the 24HR, is important for accuracy as people report 25% greater energy intake if probed appropriately (Thompson & Subar, 2013).

The 24HR typically records only food and beverage intake, but additional information on dietary behaviours can be obtained, such as approximate time of eating and use of nutritional supplements. An advantage of this method is that people complete it retrospectively, therefore are not knowingly recording their food intake, which reduces risk of reactivity bias. Reactivity bias occurs when a participant alters their dietary behaviours in response to recording their intake, which is more common in methods collected in real-time, such as a food record (National Institutes of Health, 2018). While recall bias is when there are errors in recalling foods and beverages previously consumed, which is a more common limitation of retrospective dietary assessment methods including the 24HR (Thompson & Subar, 2013). The act of underreporting unfavourable dietary behaviours and overestimating intake of perceived healthy foods, as a result of respondent knowledge, is referred to as social desirability bias (Cadmus-Bertram & Patterson, 2013). This can occur either intentionally or unintentionally and can also influence responses to questions regarding the previous day's intake.

2.8.2.1 Automated Multiple-Pass Method

Advancements in the 24HR method include the Automated Multiple Pass Method (AMPM), developed by the US Department of Agriculture and implemented in population surveillance, such as the NHANES (Centers for Disease Control and Prevention, 2015; Thompson & Subar, 2013).The AMPM is an electronic version of the traditional interviewer led 24HR designed to reduce researcher burden. This method usually takes 30 to 45 minutes to complete.

The AMPM includes multiple levels of probing by revisiting dietary intake more than once during the interview to assist in probing for forgotten foods. This involves five steps (or passes) including:

1. A ‘quick list’ of foods consumed by the participant without any interviewer input or probing
2. A ‘forgotten food list’ of foods that are commonly forgotten by participants
3. Recording of eating occasions whereby the participant attempts to recall what time the food was consumed and label it, such as a ‘meal’ or ‘snack’
4. A detailed description of each food consumed and a review of what the participant has reported
5. A final probe by the interviewer to ensure all foods and beverages have been recalled (Moshfegh et al., 2008; Thompson & Subar, 2013).

A study of 524 US adults, aged 30 to 69 years, compared reported energy intakes from three 24HRs, collected using the AMPM, against energy expenditure measured using doubly labelled water. This study found about 20% of participants underreported energy intake using the AMPM, with a higher proportion of those classified as overweight or obese doing so. On average, energy intake was underreported by 11%, less than the results found in the OPEN study (12–14% in men and 16–20% in women) (Subar et al., 2003).

2.8.2.2 Self- Administered 24-hour Dietary Recall

Additional advancements in the 24HR method include the development of online self-administered 24HR. An example of such tool is the Automated Self-Administered 24-hour Dietary Recall (ASA24) system (National Institutes of Health, 2015). This web-based tool enables respondents to complete the recall in their own time and allows researchers to collect additional information on diet if required, such as the use of nutritional supplements. The ASA24 take approximately 25 minutes to complete a recall without supplements and 32 minutes when collecting data on supplement intake (National Institutes of Health, 2015). Although this tool was designed for self-directed online use, a telephone helpline is required to assist both researchers and respondents who encounter difficulties when using the online ASA24. Therefore, even with the electronic adaptation, and hence no need for a trained interviewer to conduct the recall, the ongoing need for a telephone helpline indicates human involvement is still required when using this tool.

A comparison study of 1081 US adults compared the use of the interviewer administered AMPM to the ASA24 (Thompson et al., 2015). This study found 70% of the participants, aged 20 to 70 years, preferred using the ASA24 and it was lower cost method for researchers to collect dietary intake data (Thompson et al., 2015). These findings strengthen the argument for self-administered dietary assessment methods using technology.

The ASA24 can currently be used free of charge by residents in the US and Canada due to funding arrangements, making this method particularly appealing to researchers who include dietary assessment as one element of a multifaceted research project or have limited financial resources. In recent years the ASA24 has been adapted for use in Australia, led by Professor Sarah McNaughton at the Institute for Physical Activity and Nutrition at Deakin University (National Institutes of Health, 2015). The ASA24-Australia system was released in 2016 and takes respondents about 28 minutes to complete. This version utilises Australian nutrient databases, and visual cues for portion sizes have been adapted to reflect reported food intakes in the most recent Australian Health Survey 2011/12. This online dietary assessment tool is now available to Australian researchers and can be used in large epidemiological studies.

Additional studies using the 24HR method in conjunction with a wearable camera have shown promising results for reducing the underreporting of dietary intake (Gemming et al., 2014). These studies are discussed in Section 2.8.5 on mobile methods to assist dietary assessment below.

2.8.2.3 Limitations of the 24HR

The 24HR method relies on respondents having sound food knowledge, the ability to recall with accuracy and the ability to estimate portion size (Thompson & Subar, 2013). This method does not capture day-to-day variation in individual dietary behaviours, for example, unhealthy foods and beverages are more commonly consumed on weekends than days during the week (An, 2016; National Cancer Institute, 2015; Yang, Black, Barr, & Vatanparast, 2014), as it is only over a 24 hour period. Recording dietary intake over multiple consecutive days provides an estimate of day-to-day variation.

The most recent Australian Health Survey used an interviewer administered 24HR to collect data on the foods and beverages consumed on the previous day (Australian Bureau of Statistics, 2012). Using a trained interviewer increases costs, however, it enables probes to be tailored to the respondent. It has been estimated that the level of underreporting has increased between the 1995 and 2011/12 Australian Health Surveys, with a greater increase in men than women (Australian Bureau of Statistics, 2015). Underreporting energy intake and over-reporting fruit and vegetable intake is a common occurrence in dietary assessment (Macdiarmid & Blundell, 1998). Estimating energy intake for individuals on a population level using the 24HR method is not recommended due to the amount of measurement error (Subar et al., 2015). Measuring the intake of EDNP foods may be a more accurate indicator of excessive energy consumption.

2.8.3 Food frequency questionnaires

Food frequency questionnaires (FFQs) require participants to recall usual frequency of consumption of foods and beverages over a designated period of time, usually the preceding month or year (National Cancer Institute, 2015). FFQs are most commonly self-administered in a paper-based or electronic format (National Cancer Institute, 2015). Electronic versions reduce researcher burden and costs associated with data entry and coding (National Cancer Institute, 2015). FFQs usually contain 100+ line items and take 30 to 60 minutes to complete, however, this may vary significantly depending on key factors, such as whether it is self-administered or interviewer administered; the number of foods items included; the complexity of dietary intake and; the respondent's literacy levels and cognitive ability (National Cancer Institute, 2015). Targeted FFQs contain approximately 15 to 30 items and measure a single food group or nutrient of interest, and in some cases these are considered to be 'screeners' (Thompson & Subar, 2013).

FFQs can vary in the level of dietary intake data collected but they all include a finite list of foods (Kirkpatrick et al., 2014). The list of foods included in an FFQ should be adapted to the target audience and dietary behaviours of interest, otherwise may not accurately represent consumption (Kirkpatrick et al., 2014). Some FFQs do not ask the participant to report quantities of foods or beverages, only frequency of intake (referred to as non-quantitative FFQs), while other FFQs use a standard portion size for all foods (Riboli et al., 2002) or offer multiple portion sizes of each food for the participant to select from (Liese et al., 2015). The Multiethnic Cohort (MEC) Study used a self-administered FFQ containing three to ten portion size options for each food item listed, and asked participants to recall intake over the previous 12 months (Liese et al., 2015). Although a comprehensive method, researchers in the area have suggested that the length of an FFQ has potential to effect responses and increase error (Thompson & Subar, 2013). The predescriptor used when reporting on a type of FFQ (such as ‘semi-quantitative’, ‘non-quantitative’ or ‘quantitative’) highlights the methods of collecting portion size of foods or beverages, and does not apply as a descriptor of the total results.

There are a number of limitations associated with FFQs. One limitation is that portion sizes consumed by people are likely to change from one eating occasion to another and such changes are not reflected in the data. Another is that there are a number of complexities relating to whether details on the frequency of single food items is assessed for food items in combination, for example milk by itself, milk in porridge, milk in macaroni cheese or in soups. Asking about total milk intake in isolation risks missing milk in mixed dishes, however asking about all mixed dishes can overestimated milk intake. Additional limitations associated with FFQs are; the level of systematic error; the overestimation of intake (especially in free-living individuals who do not have regular eating habits); the reliance on memory; the influence of social desirability bias; the poor perception of portion sizes; and lastly, self-administered FFQs require the respondent to be literate. The Observing Protein and Energy Nutrition (OPEN) study on 484 men and women (aged 40 to 69 years) examined the level of underreporting using FFQs and 24HRs, against doubly labelled water and urinary nitrogen (Subar et al., 2003). This study found women and men both underreported energy intake by 30-34% and 31-36%, respectively. Levels of underreporting for the 24HR in both sexes was less (16-20% for women and 12-14% for men) (Subar et al., 2003), indicating the 24HR may provide a more accurate measure of energy intake compared with the FFQ.

2.8.4 Food records

A food record, also referred to as a food diary, is a self-reported account of all foods and beverages consumed by a respondent over a period of one to seven days (Thompson & Subar, 2013). Written food records, traditionally completed in a paper format, do not contain a finite list of foods and beverages to choose from (National Cancer Institute, 2015), making them less restrictive than screeners or FFQ. Using food records respondents are asked to either estimate the amount of food consumed or measure foods and beverages using kitchen scales or volume measures, such as one cup (National Cancer Institute, 2015; Thompson & Subar, 2013). It has been estimated that food records take at least 15 minutes to complete each day (National Cancer Institute, 2015), although this can vary according to the level of detail requested, complexity of meals, number of eating occasions and the physical and cognitive ability of respondents.

Before commencing a food record, participants need to be trained on the level of detail required, such as the inclusion of brand names and food types (Thompson & Subar, 2013). Participants are encouraged to write down the volumes of foods and beverages consumed in real time to minimise reliance on memory and retrospective estimation (Thompson & Subar, 2013). Unlike screeners, 24HRs and FFQs, food records are completed in real-time, which reduces the cognitive task of remembering intake.

The main sources of error associated with food records is random error, driven by variations in dietary intake over days and reactivity bias (Kirkpatrick et al., 2014). Reactivity bias is when respondents underreport the intake of unhealthy foods and overestimate the intake of perceived healthy foods due to the act of recording itself.

2.8.5 Mobile methods for dietary assessment

The use of images in dietary assessment is a rapidly advancing field. Internationally, researchers are conducting studies using images in a variety of ways to capture food and beverage intake, including the use of wearable cameras (Gemming, Doherty, Utter, Shields, & Ni Mhurchu, 2015; Gemming et al., 2014; Pettitt et al., 2016), and mobile devices (Aflague et al., 2015; Boushey et al., 2015; Kerr et al., 2012; Six et al., 2010). Assessing dietary behaviours using mobile methods has the potential for widespread application due to the high rates of mobile device usage in both developed and developing countries (Burrows et al., 2017). The following section examines; the use of mobile devices in dietary assessment (Section 2.8.5.1); the differences between image assisted vs image based methods (Section 2.8.5.2); the mobile food record (Section 2.8.5.3) and; lastly an automated versus training analyst approach to analysing the images (Section 2.8.5.4).

2.8.5.1 Use of mobile devices in dietary assessment

Due to high mobile phone usage, utilising these devices to capture prospective dietary intake can be more convenient than traditional methods (Rangan et al., 2015). The use of technology in dietary assessment can be a more appropriate option for some population groups and can reduce the time, financial and other resources required for electronic data entry and analysis. Whether it be a conversion from a traditional dietary assessment method to an electronic version, as is the case with the ASA24 (National Institutes of Health, 2015) or the development of a new method, such as the mFR (Kerr et al., 2012), the use of technology is pertinent due to the digital world we live in. Electronic versions of traditional pen and paper dietary assessment methods inevitably reduce burden on researchers by reducing data entry and coding times, and misinterpretations of handwriting or spelling.

Varying levels of researcher and respondent burden accompany all dietary assessment methods, yet technology-based dietary assessment methods may be more appealing to participants due to the frequent use of mobile devices. A global longitudinal study of 37,000 consumers conducted by Deloitte in 2014, found smartphone adoption is higher in Australia than other developed countries, including the US and the United Kingdom (UK), with 76% of those who owned a mobile telephone in Australia owning a smartphone (Deloitte Touche Tohmatsu, 2014). Of Australian respondents (n=2000) young people, aged 18 to 24 years, check their mobile phones the most (63 times per day on average) and this gradually declined with age (Deloitte Touche Tohmatsu, 2014). Therefore, uniting the frequent usage of mobile technology with dietary assessment is likely to decrease participant burden due to the point of engagement, increasing the likelihood of collecting food intake data in real time. Although smartphone ownership in Australia is high and increasing, there are members of the community who do not own a mobile device with an in-built camera feature. These people are most likely to be of low-socio economic status or from vulnerable groups, such as the elderly or Aboriginal and Torres Strait Islanders.

Digital food records can now be recorded directly into an electronic database, such as mobile Apps including *MyFitnessPal (MyFitnessPal, 2018)* or *Easy Diet Diary (Easy Diet Diary, 2016)*. *Easy Diet Diary* is the only publicly available digital food record that uses an Australian nutrient database. This mode of recording saves researchers time in data entry and coding, although requires the same level of involvement and detail from participants. These methods do not remove the reliance on respondents to be both motivated to complete the food record and also literate (Thompson & Subar, 2013).

2.8.5.2 Image-assisted vs image-based dietary assessment methods

Images have been used to accompany traditional dietary assessment methods for more than three decades (Boushey, Spoden, Zhu, Delp, & Kerr, 2017), such as images of example serve sizes to accompany an FFQ. However, these images are static and respondents may not be able to relate them to their own dietary behaviours (Boushey, Spoden, Zhu, et al., 2017). Today, images can be captured by the respondent and used in dietary assessment to support another self-reported method (referred to as image-assisted) or to capture all foods and beverages consumed (referred to as image-based) (Gemming, Utter, & Ni Mhurchu, 2015).

Image-based food records use images to collect all dietary intake data and is a relatively new method. There are a number of different ways to use images, whether that is with a portable device (such as a mobile phone) or with a wearable device (such as a camera around one's neck or attached to an earpiece). Using a mobile device to capture images allows for the assessment of additional eating behaviours, such as location and time of eating, in low literacy groups (Harray et al., 2015; Thompson & Subar, 2013).

2.8.5.3 The mobile food record (mFR)

The mobile food record (mFR), an image-based method, is a purpose built App that uses a mobile device's camera feature to collect 'before' and 'after' eating images of all eating occasions. When using the mFR participants are asked to take an image of their food or beverage on an eating vessel (for example, plate, bowl, glass, container or box) with a reference (fiducial) marker in the bottom left corner of the image to assists in portion size estimation (Six et al., 2010).

All eating images are sent directly to an external server so participants are unable to review or edit them. The mFR has been tested in research projects involving users aged 3 to 65 years and shows high levels of acceptability, usability and potential for upscaling (Aflague et al., 2015; Boushey et al., 2015; Boushey, Spoden, Delp, et al., 2017; Daugherty et al., 2012; Kerr et al., 2016). The mFR does not require users to undergo intensive training, outside of teaching them how to download the App and capture an image. Prompts appear on the App if the angle of the device is not correct (should be between 45 and 60 degrees for consistency) or if the fiducial marker is not present. The mFR is likely to be more socially acceptable than weighing and recording all foods consumed, especially when eating out.

The mFR is taken in real time and due to the use of technology; alerts can appear on one's device to remind them to take an image. These alerts can be modified by the user and tailored to the times they usually eat. Furthermore, the mFR has the ability to have set alerts at times within the day to prompt the user to record any forgotten foods or beverages. Forgotten foods can be recorded retrospectively in the notes section of a mobile device or with pen and paper (Kerr et al., 2016). Recent innovations in the mFR include the potential for ecological momentary assessments. These can pop up on one's mobile device in real time to assess experiences and behaviours in a free-living environment (Shiffman, Stone, & Hufford, 2008), such as assessing attitudes or hunger levels. Additional advancements include an ‘ate it all button’ on the mFR which removes the need for participants to take an ‘after eating’ image; further reducing participant burden. A consideration of this feature in relation to this research is that it cannot capture inedible plate waste, such as meat bones or orange peel. However, only edible plate waste was an objective of the present study.

A cross-sectional analysis of 45 community dwelling adults, aged 21 to 65 years, examined the accuracy of energy reporting between the mFR and doubly labelled water (Boushey, Spoden, Delp, et al., 2017). Participants in this study were asked to capture ‘before’ and ‘after’ images of all foods and beverages consumed over 7.5 days, longer than previous studies using the mFR (Kerr et al., 2016). Three trained analysts independently of one another assessed images of all eating occasions and total energy expenditure was measured using doubly labelled water. The underreporting of energy intake was estimated to be 12% for men and 11% for women (Boushey, Spoden, Delp, et al., 2017). This study was unable to find systematic biases associated with the mFR.

The ability for the mFR to collect real time dietary intake data from illiterate respondents is a strength of this method. This element is particularly advantageous when collecting data from disadvantaged minority groups. While Australia is fortunate enough to have high levels of literacy, about 14% of 15 to 74 year olds have low literacy levels (Australian Bureau of Statistics, 2013c) and it is important to capture disadvantaged population groups in nutrition research. Images taken using the mFR can be reviewed by a trained analyst or automated (Boushey, Spoden, Zhu, et al., 2017).

2.8.5.4 Automated vs training analyst approach

As outlined in a review by Boushey and colleagues (2017), clarifying the contents of food and beverage images can be conducted by either a trained analyst or by automated methods. The trained analyst approach involves clarification either with or without the participant. Reviewing images with participants allows the trained analyst to confirm ambiguous foods or beverages, such as whether a glass of clear bubbly liquid is sparking water, lemonade or a gin and tonic. Therefore, is more likely to result in an accurate assessment of energy intake. A study assessing the accuracy of a trained analyst in estimated energy intake from images captured using the mFR against the doubly labelled water method found a mean percentage of underreporting comparable to other image-based dietary assessment methods and traditional food records (Boushey, Spoden, Delp, et al., 2017). This study involved adults aged 21 to 65 years and showed high usability and acceptability of the mFR in this group.

An automated approach to review eating images is a promising method, which can reduce researcher burden. This approach can either involve the participant (by probing them to clarify if the foods have been tagged by the program correctly within the App) or a trained analyst (assigning tags to foods items in an image) (Boushey, Spoden, Zhu, et al., 2017). Although evaluations of the mFR to date have shown promise as an accurate dietary assessment method with high usability and acceptance, no studies have used image-based dietary assessment method, to assess the elements of a sustainable diet considered in this research.

2.8.6 Assessment of healthy and sustainable dietary behaviours

Although there are dietary assessment methods validated for specific purposes and population groups (Subar et al., 2015), there is a need to improve methods to assess the intake of EDNP foods and beverages; foods directly associated with a sustainable diet (Nelson & Lytle, 2009). The mFR has greater potential to capture H&S dietary behaviours, compared with a weighed or estimated food record, because it is less burdensome on respondents. In addition, the mFR collects visual data on portion size, plate waste and individual packaging without the reliance on portion size estimation or weighing foods before and after eating, memory or illiteracy. This section examines the ability of each of the dietary assessment methods to assess H&S dietary behaviours (summarised in Table 2.8).

2.8.6.1 Using Screeners to assess healthy and sustainable diets

An advantage of using screeners to assess attitudes and behaviours related to a H&S diet include the ability to gather data from large sample sizes for a low cost in comparison to other methods. However, screeners assessing dietary intake have been shown to result in significant fluctuations from actual intake due to their simplicity and reliance on memory and retrospective portion size estimation (Thompson & Subar, 2013). Although commonly used to assess fruit and vegetable intake (a sustainable dietary behaviour), screeners are unable to assess food (plate) waste, individual food packaging, overall dietary intake and eating occasions. Therefore, they are not the optimum method for assessing the characteristics of a H&S diet.

2.8.6.2 Using 24-hour recalls to assess healthy and sustainable diets

The 24HR method has been used to assess compliance to the ADGs in the past (Australian Bureau of Statistics, 2012). In during so, dietary behaviours that align with a sustainable diet, such as fruit, vegetables, animal-based foods and EDNP food and beverage intake were assessed. However, due to the reliance on memory and retrospective portion size estimation, the 24HR is a less comprehensive method to assess the intake of these foods (compared to more detailed methods that can collect data on day-to-day variations). In addition, the accuracy of collecting dietary behaviours beyond purely food intake would need to be considered. For example, using this method to assess individual food packaging and plate waste would further increase reliance on memory and the time required to complete the 24HR.

2.8.6.3 Using food frequency questionnaires to assess healthy and sustainable diets

FFQs are designed to assess particular styles or patterns of eating over long periods. However, the ability for people to recall food intake over the previous week, month or few months can pose significant challenges, and additional dietary behaviours related to a sustainable diet (such as the use of individually packaged foods, seasonal produce or plate waste) would pose further challenges, resulting in inaccurate data. An FFQ specifically designed to assess diet-related GHG emissions was developed and validated against a 7-day weighed food record collected in adults aged 20 to 63 years in Sweden (Sjors et al., 2016). This study measured the food intake of participants against the LCA values of 65 foods and found an acceptable level of agreement between the two dietary assessment methods. However, aspects of a sustainable diet were not captured by participants in this study. Although general food waste was adjusted for using previous studies' findings and food packaging was considered in LCA values, this study did not assess individual food packaging or edible plate waste (Sjors et al., 2016). In addition, this study could not be replicated in an Australian context due to the limited LCA data available, and a set list of 65 foods is unlikely to capture the variety in the Australian food supply.

2.8.6.4 Using food records to assess healthy and sustainable diets

A food record has the ability to assess elements of a H&S diet as it can capture an infinite number of foods, and self-reported dietary behaviours, such as asking the participant to write down whether they had any leftover food on their plate, and if so, the volume (estimated or weighed). Previous studies assessing plate waste have used kitchen scales to weigh food waste (Quested et al., 2013). This method creates a significant amount of burden for participants (as it would require them to take scales when eating outside the home) and as a result, effect compliance.

Table 2.8 Comparison of the ability of different methods to assess healthy and sustainable diets

Adapted from (Cadmus-Bertram & Patterson, 2013; National Cancer Institute, 2015)

Assessment Method		Food Frequency Questionnaire		24-HR Dietary Recall		Food Record		Mobile Food Record
Mode	**Screeners**	**Paper-based**	**Self-administered electronically**	**Interview-lead/ paper-based**	**Self-administered electronically**	**Paper-based**	**Digital**	**App**
Food group analysis		✓ dependent on food list	✓ dependent on food list	✓	✓	✓	✓	✓
Portion size accuracy		Variable	Variable	Variable	Variable	✓ If weighed	✓ If weighed	✓ ??
Eating frequency[a]	×	×	×	✓Self-report	✓ Self-report	✓ Self-report	✓ Self-report	✓ objective meta data
Individually packaged foods	×	×	×	✓Self-report	✓ Self-report	✓ Self-report	✓ Self-report	✓
Ultra-processed EDNP foods	✓	✓	✓	✓	✓	✓	✓	✓
Plate waste	×	×	×	✓Self-report	✓ Self-report	✓ Self-report	✓ Self-report	✓

[a] Ability to assess eating frequency by assessing daily eating occasions as separate events.

2.9 Methods to assess consumer food waste

Global food waste makes a significant impact on the environment and is often considered an issue separate to nutrition (as outlined in Section 2.5.5). However, the impact of food waste on food insecurity has the potential to be reduced by increasing public awareness through campaigns and advocacy, hence nutritionists and dietitians play a role (Australian Broadcasting Corporation, 2017; Food and Agriculture Organization, 2011; LiveLighter, 2018; New South Wales Environment Protection Authority). Although throwing food away is common practice in all levels of the food chain (Food and Agriculture Organization, 2011) (Figure 2.2), there have been limited advances in accurately assessing consumer food waste, especially plate waste. A likely contributor to this lack of evidence is the realm of challenges associated with assessing food waste in individuals, namely the time and practicality.

2.9.1 Assessing household food waste

The most commonly used method for measuring household food waste in Australia is physical waste audits (Mason et al., 2011). However, this method cannot decipher between edible plate waste (e.g. unfinished pasta on a plate), unused food waste (e.g. off eggs in the fridge), and unavoidable food waste (e.g. meat bones or banana skin), which in some cases cannot be consumed or composted. Rubbish bin audits are a labour intensive and unpleasant method to assess food waste.

An Australian study assessing food waste practices used an online tool to survey 1603 main household grocery buyers, defined as the person responsible for most, if not all, the grocery shopping (Baker et al., 2009). This survey used single response answers to gather evidence on the monetary value of food thrown away in the previous week (Baker et al., 2009). Baker and colleagues (2009) stated the main grocery buyer would have the most knowledge of the monetary value of the food wasted, however, a limitation of this study is that one person in a household is unable to report on food waste outside the home, such as uneaten school lunches. An earlier study conducted by Hamilton et al. (2005) identified discrepancies between reported and actual fresh food waste, whereby households reported throwing out AUD$4.6 billion of fresh food per year but a rubbish bin audit suggested a figure closer to AUD$8 billion per year. This evidence emphasises the need for accurate food waste assessment methods that do not rely on estimation or memory.

2.9.2 Assessing consumer plate waste

Studies on consumer plate waste have been conducted in controlled environments, such as residential care facilities (Grieger & Nowson, 2007), hospitals (Williams & Walton, 2011) or school/university canteens (Whitehair, Shanklin, & Brannon, 2013). There is minimal evidence on plate waste in free-living individuals, acknowledged by Mason and colleagues as an area of research with a lack of sufficient data (Mason et al., 2011).

2.9.3 Assessing consumer attitudes toward food waste

Australians are concerned about food waste with 83% of households being 'somewhat' or 'very concerned' about the volume of food they throw away (Baker et al., 2009). This raises the issue of social desirability bias (people reporting what they believe is the correct thing to do) when assessing food waste (Cadmus-Bertram & Patterson, 2013). In summary, food waste is common in Australia, although of concern to many Australians. Current methods to assess plate waste are likely to result in underreporting or poor recording compliance due to the amount of effort required.

2.10 Dietary patterns

In nutritional epidemiology, there has been a shift in focus away from specific nutrients and foods to dietary patterns due to people not eating foods and nutrients in isolation (Cespedes & Hu, 2015). Dietary patterns can be measured against a diet quality index (DQI) as this method can address multicollinearity between components of diets and the complexities associated with eating a particular way (Liese et al., 2015).

Thus far, research into dietary patterns has had the primary aim of comparing dietary intake to poor health outcomes. This type of research has received well-deserved funding and acknowledgement in the US, namely with the National Cancer Institute's Dietary Patterns Methods Project (Liese et al., 2015). The Dietary Patterns Methods Project was commenced in 2012 with the aim of comparing DQI scores to cardiovascular disease and cancer mortality, to help inform the 2015 Dietary Guidelines for Americans (Liese et al., 2015). Projects such as these highlight the need to conduct research looking at dietary patterns and measured against an index to inform policy.

Considering whole food groups and dietary patterns, opposed to the intake of individual foods or nutrients, is an effective way of looking at H&S diets. The review of research into sustainable diets nationally and internationally has highlighted the lack of evidence on how current behaviours adhere to a sustainable diet, most likely due to funding limitations and no purpose designed dietary assessment method. A review of how current dietary assessment methods can assess sustainable diets has been outlined in Section 2.8.6.

2.11 Diet quality indices

As previously outlined, there has been a shift in nutrition research and dietary guidelines toward a dietary patterns focus, opposed to focussing on single dietary components or nutrients in isolation. This is due to people not eating single foods, but combinations of foods that can interact (Waijers, Feskens, & Ocke, 2007). Diet quality indices (DQIs) are developed to measure dietary patterns; conformance with a particular diet or way of eating; and associated health outcomes. Index scores can be used to monitor adherence to dietary guidelines in populations over time and target nutrition messages (McNaughton, Ball, Crawford, & Mishra, 2008). A strength of DQIs is that they consider the multidimensional nature of diets and apply weighting factors to each component to calculate a final adherence score. DQIs are unique in that they highlight the complexities and synergies in diets by identifying correlations among different constituents of diet, therefore provide guidance on many aspects of a diet.

Diet quality indices are designed to monitor food or nutrient intake and predict the effect of dietary behaviours on health outcomes. However, as the evidence of the food supply's impact on the environment strengthens there is an opportunity to explore new DQIs to measure impacts of dietary behaviours on the environment. Indexes need to be culturally acceptable and locally appropriate indexes to accurately assess sustainable diets (Johnston et al., 2014), however no such index exists. Sjors et al. (2016) developed an FFQ to measure the GHG emissions of diets and validated it against a 7-day weighed food record. This FFQ included dairy products, such as milk, yoghurt, cocoa, cheese (hard and soft), ice cream, and dishes rich in dairy products such as pancakes and pizza. An index measuring compliance with a H&S diet would enable the measurement of the impact of dietary behaviours on health outcomes and also the food system to help inform policy makers (Johnston et al., 2014). This section outlines relevant DQIs (and dietary behaviours they include which relate to a sustainable diet, if any), and a review of the literature available for the development and evaluation of indices.

2.11.1 Developing diet quality indices

Developing and validating indices for use in dietary assessment can assist in; guiding nutrition messages and interventions; population nutrition monitoring; informing policy makers; monitoring the effectiveness of programs and; nutrition research (Guenther, Reedy, & Krebs-Smith, 2008). However, differences in the food supply, dietary recommendations and food consumption patterns mean DQIs need to be country specific (Collins et al., 2015). Examples of validated DQIs include the Healthy Eating Index (Guenther, Reedy, & Krebs-Smith, 2008), Mediterranean Diet Score (Trichopoulou, Costacou, Bamia, & Trichopoulos, 2003), Diet Quality Index (Patterson, Haines, & Popkin, 1994) and Dietary Approaches to Stop Hypertension Score (Harrington et al., 2013). Further details about DQIs, including Australian specific indices, relevant to this research are outlined in Table 2.9.

A systematic review of 15 cohort studies that used DQIs to measure diet quality against health outcomes was conducted by Schwingshackl and Hoffmann (2015). This review found that dietary patterns with a high score using the Dietary Approaches to Stop Hypertension Score, Alternate Healthy Eating Index and Healthy Eating Index reduce people’s risk of all-cause mortality, cardiovascular disease and Type 2 Diabetes by 22%, and reduce cancer risk by 15% (Schwingshackl & Hoffmann, 2015). Environmental outcomes related to dietary behaviours were not incorporated into these indices.

Diet quality indices are being used more often in research to measure intakes due to the lesser participant and researcher burden (Collins et al., 2015). There are two types of dietary patterns- empirically derived dietary patterns and theoretically derived dietary patterns. The variables chosen to be included in a DQI are a compromise between what information is available and what information is practical to include, which is often driven by the dietary assessment method used to collect the data. Therefore, deciding on the dietary components included and excluded involves an element of researcher subjectivity (Waijers et al., 2007). Previous scores applied to dietary intake data have been collected using traditional methods such as an FFQ or 24HR (Collins et al., 2015).

2.11.2 Assigning weighting to components of a diet quality index

A review of predefined diet quality scores by Waijers and colleagues (2007) highlighted that when developing an index, researchers should take into account: what variables are included and what the cut off value for each index item is; and what score/weighting is assigned to each item. In the development of some indices, the median intake for each variable is the cut off value. This is not necessarily related to recommended levels of intake for good health (for example, dietary recommendations) (Waijers et al., 2007). Alternatively, some researchers have determined the scoring of components of their index on what current views of ‘what is healthy’ or current dietary guidelines for good health. For example, assigning a maximum number of points if recommendations are reached (McNaughton et al., 2008). A review of diet quality scores raised an important point, that is it preferable if scoring ranges (continuous scales) are used opposed to simple cut offs (binary scales) because more foods have a ‘U shaped’ effect when considering intake (Waijers et al., 2007). For example, one serve of red meat provides nutrients for good health but the consumption of five serves of red meat per day would pose significant negative health and environmental impacts over time. Continuous scales allow for more variability and provide more sensitivity within the index score, however, a benefit of a truncated, or binary scale, is that it can alleviate some problems with measurement error.

A binary scale involves cut off values for each component of the index (e.g. above and below one serve of fruit). A score of ‘0’ is assigned if intake is below the cut off amount or ‘1 if intake is above the specified amount. When assigning values cut off values for unhealthy foods, such as EDNP foods and beverages, the scoring would be opposite (e.g. ≥ 2 serves EDNP foods per day = 0 points, < 2 EDNP food serves per day = 1 point). This approach to scoring DQIs relies heavily on how the cut off value was determined, especially when consumption is low. For example, if the recommended five serves of vegetables a day were used in Australia (as per the AGTHE recommendations), very few participants would score a point due to less than seven per cent of the Australian population reaching this recommendation (Australian Bureau of Statistics, 2012). Therefore a graded system is preferable.

In the scoring and interpretation of DQI scores, many studies confound for overall energy intake, as people who consume large volumes of food are more likely to accrue more points. However, there are errors associated with adjusting for kilojoule intake due to the misreporting of energy intake being between 4% and 37% (Boushey, Spoden, Zhu, et al., 2017).

Dietary variety should be considered and included in a scoring system, however, variety can be detected in the DQI score if food groups are categorised as separate items. Some DQIs have been developed with equal weighting to each component of the index (Pot, Richards, Prynne, & Stephen, 2014), while others have unequal weighting to separate components (Guenther et al., 2014; Roy, Hebden, Rangan, & Allman-Farinelli, 2016). Many researchers do not address their rationale behind weighting of different components due to the difficulty in substantiating their decisions and subjectivity involved (Waijers et al., 2007).

2.11.3 Evaluating diet quality indices

Validation studies are important and required to help measure accuracy, reliability and reproducibility of an index, as well as whether a DQI measures what it aims to and can assess diet and disease associations (Newby et al., 2003). However, a gold standard must exist to ensure DQIs are validated appropriately and a validated DQI does not imply that it is then transferable to any population group (Collins et al., 2015). Regardless of whether a DQI has been validated, the measurement error associated with the dietary assessment method itself will be reflected in an index and an individual's overall DQI score can mask what is going on with elements within it.

If an index algorithm is universal and well documented, the index score should not vary if the same data is used. This becomes challenging if the same foods or food groups are coded differently between datasets or the nutrient composition database changes due to improvements or the food supply. These factors should be carefully considered when conducting test re-test reliability on an index. Table 2.9 provides details of relevant diet quality indices, including Australian specific diet quality indices. This table includes the variables measured using each index, the location, and population in which each method has been applied, and the elements of a H&S diet assessed using each method.

Table 2.9 Diet quality indices relevant to healthy and/or sustainable diets

Diet Quality Index	Reference	Outcomes measured	Sample and setting	Method and evaluation	Elements of a healthy and sustainable diet assessed
Australian Recommended Food Score	Collins et al. (2015)	Measuring adherence to the ADGs. Modelled on US Recommended Food Score	n= 96 *Adults aged 30-70 years* Australia	Score was derived from a subset of 70 items (from a 120 item semi-quantitative FFQ) then correlated with nutrient intakes from 120-item FFQ Tested reproducibility by assessing 0 and 5 month follow up	• ADG food groups • Packaged snacks • Processed fatty meats
Australian Child and Adolescent Recommended Food Score	Marshall, Watson, Burrows, Guest, and Collins (2012)	Measuring adherence to the ADGs. Modelled on US Recommended Food Score	n= 691 *Children aged 9-12 years* Australia	Evaluated against nutrient intakes collected using 120-item FFQ	• ADG food groups
Healthy Eating Index for Australian adults	Roy et al. (2016)	Measuring adherence to the 2013 ADGs 11 items (5 food groups, 4 nutrients, variety, water)	n= 100 *Young adults aged 18-34 years* Australia	Applied to both written food records and FFQ Used different weightings for components (either 5 or 10)	• Fruits and vegetables • EDNP foods & alcohol • Meat • Dairy
Healthy Eating Index (HEI)	Kennedy, Ohls, Carlson, and Fleming (1995)	To assess overall dietary quality	n= 7,463 *Children and adults aged 2+ years* US	10 component index (4 nutrients, 5 food groups and dietary variety) Evaluated against energy and nutrient intakes	• Fruits and vegetables • Meat and milk

Diet Quality Index	Reference	Outcomes measured	Sample and setting	Method and evaluation	Elements of a healthy and sustainable diet assessed
	Guenther, Reedy, and Krebs-Smith (2008) Guenther, Reedy, Krebs-Smith, and Reeve (2008)	Develop and evaluate the HEI- 2005 Conformance with 2005 Dietary Guidelines for Americans	n= 8,650 *Children and adults aged 2+ years* US	Used 24HRs collected during 2001-2002 NHANES Evaluated reliability and validity Individual components of HEI-2005 provide unique information to overall score	• Fruits and vegetables • Meat and milk • Seafood • Empty calories from saturated fat, sodium, alcohol and added sugars
	Guenther et al. (2014)	Conformance with 2010 Dietary Guidelines for Americans	n= 8,262 *Children and adults aged 2+ years* US	Used two 24HR collected during 2003-2004 NHANES	• Fruits and vegetables • Meat and milk • Seafood • Empty calories/EDNP
Alternate Healthy Eating Index	McCullough and Willett (2006)	Assess chronic disease risk (CVD, cancer) Adherence to Dietary Guidelines for Americans	n= 105,886 *Adults aged 30-75 years* US	9 components Data collected from 1984-1990 Used 130-item semi-quantitative FFQ	• Assigned higher weighting for eating poultry and fish, opposed to red or processed meat • Fruits and vegetables • Non-meat protein foods • Dairy products

Diet Quality Index	Reference	Outcomes measured	Sample and setting	Method and evaluation	Elements of a healthy and sustainable diet assessed
	Akbaraly et al. (2011)	Assess association with mortality risk	n= 7,319 *Adults aged 39-63 years* UK	Dietary data collected using 127-item semi-quantitative FFQ Found people in highest tertile (compared with lowest) had a 25% reduced risk of all-cause mortality Non-animal protein intake was independent contributor to lower mortality risk	• Fruits and vegetables • Non-meat protein foods • Red and white meat • Alcohol intake
Mediterranean Diet Score	Trichopoulou et al. (2003)	Adherence to Mediterranean diet	n= 22,043 *Adults aged 20-86 years* Greece	Dietary data collected validated FFQ (with standard photographs of portion sizes to assist) 10-point Mediterranean diet score	• Fruits and vegetables • Legumes and nuts • Animal-based foods (meat, dairy, fish, eggs) • Sweets
	Carter, Roberts, Salter, and Eaton (2010)	Specific biomarkers for CVD prevention	n= 13,197 *Adults aged 18-90 years* US	FFQs and 24HR Index scores analysed in tertiles 11 components in score (aligned with Mediterranean diet)	• Fruits and vegetables • Animal-based foods • Alcohol
	Levitan et al. (2013)	Adherence to Mediterranean and DASH diet Association with heart failure	n= 3,215 *Women* US	Dietary intake data collected using FFQs	• Mediterranean Diet Score • Fruits and vegetables • Nuts and legumes • Fish • Red and processed meat

Diet Quality Index	Reference	Outcomes measured	Sample and setting	Method and evaluation	Elements of a healthy and sustainable diet assessed
	Mertens et al. (2014)	Associations between Mediterranean Diet Score and blood lipid profiles (as biomarkers for CVD)	n= 1,213 *Adults aged 18-75 years* Netherlands	Dietary intake data collected using 3-day weighed food record Few associations were found	• Fruits and vegetables • Nuts and legumes • Fish, meat, dairy • Alcohol
Diet Quality Index	Kim, Haines, Siega-Riz, and Popkin (2003)	Monitoring of diet quality across two countries (China and US)	n= 18,121 (8,352 from China, 9,769 from US) *Adults aged 20+ years*	Created DQI-International Used diet quality data collected in each respective country Diet assessed by: China three 24HR (consecutive days) US two 24HR (non-consecutive days) Cross-national comparisons Able to detect dietary habits specific to countries	• Fruits and vegetables • Protein sources (including meat, poultry, fish, dairy, beans, eggs) • EDNP foods
	Drake et al. (2011)	Adherence to Swedish Nutrition Recommendations	n= 13,016 *Adults* Sweden	Dietary assessed by a 7-day food record and 168-item FFQ Six components to index Cross-sectional analysis of cohort study	• Fruits and vegetables • Fish and shellfish
	Patterson et al. (1994)	Measure adherence to recommendations in Diet and Health, published by National Academy of Sciences	n= 5,484 *Adults aged 21+ years* US	Used data from 1987/88 Nationwide Food Consumption Survey Used eight diet variables Assessed single nutrients	

Diet Quality Index	Reference	Outcomes measured	Sample and setting	Method and evaluation	Elements of a healthy and sustainable diet assessed
Dietary Approaches to Stop Hypertension (DASH) diet score	Miller et al. (2013)	Measure associations between compliance with the DASH diet and colorectal cancer using four variations of DASH indices developed	n= 491,841 *Adults aged 50-71 years* US	Dietary intake data collected using 124-item semi-quantitative FFQ Estimated frequency of standard portions over the previous 12 months	The 4 different DASH indices contained a variety of components. The foods related to a H&S diet were: • Fruits and vegetables • Dairy foods • Non-animal protein foods • Meat, poultry, fish and eggs • Processed meat • SSBs and Alcohol • Sweets
	Harrington et al. (2013)	To assess association between DASH diet score and blood pressure	n= 2,047 *Adults aged 47-73 years* Ireland	Dietary intake data collected using standard FFQs Estimated frequency of standard portions over the previous 12 months	• Fruits, vegetables and legumes • Sweet and salty snacks • Low fat dairy foods • Red meat
	Levitan et al. (2013)	Adherence to Mediterranean and DASH diet Association with heart failure	n= 3,215 *Women* US	Dietary intake data collected using FFQs	DASH diet score • Fruits and vegetables • Nuts and legumes • Reduced fat dairy

Diet Quality Index	Reference	Outcomes measured	Sample and setting	Method and evaluation	Elements of a healthy and sustainable diet assessed
Nutrient Rich Food Index	Drewnowski (2010b)	12 nutrients (9 negative and 3 positive nutrients) Aimed to identify nutritious foods at affordable costs	N/A	Used datasets from US Department of Agriculture on food prices and nutrient compositions	• Animal-based foods • Fruits and vegetables • EDNP foods • Non-animal protein sources
Healthy Diet Indicator	Jankovic et al. (2015)	Adherence to WHO dietary recommendations Association with CVD mortality	n= 281,874 *Adults aged 60+ years* US and Europe	Used data from 10 cohort studies Each study used either an FFQ or validated food recall	• Fruits and vegetables
Eating Choices Index	Pot et al. (2014)	4-item index (breakfast, fruit, milk, bread)	n= 2,256 *Adults aged 43 years* UK	Aimed to develop a short questionnaire and evaluated it against nutrient intakes from 5 day food records (records ≥3 days were included)	• Fruit • Milk

2.12 Summary of the literature review

The two concepts of a diet for good health and a diet supportive of the environment are widely considered in isolation (Institute of Medicine, 2014), although the evidence linking dietary behaviours to GHG emissions is strengthening and agriculture contributes approximately 16% of Australia's total GHG emissions (Department of Primary Industries and Regional Development, 2017). Evidence supports the theory that people can lower the environmental impact of their food choices by adopting a more sustainable diet, without sacrificing nutrient intake, and in many scenarios improving health and reducing risk of diet related diseases. The strengthening evidence base has guided countries to adopt sustainable diet recommendations for their populations into national policy, but to date Australia's progressions in this area of nutrition are minor.

Adherence to the Australian Dietary Guidelines is low in the Australian population, especially in young adults, with people consuming inadequate amounts of fruits and vegetables and excessive amounts of energy-dense nutrient-poor foods and beverages. There is little evidence on how the current dietary behaviours of Australian's align with a sustainable diet.

Studies assessing attitudes and knowledge toward sustainable dietary behaviours show that Australians are concerned and aware of the issues but studies have not examined whether these attitudes are translated to sustainable dietary behaviours. Current methods available to assess diet are not optimal for assessing sustainable dietary behaviours. Image-based food records have potential to accurately do so without placing unrealistic burden on participants and researchers. Diet quality indices measure adherence to dietary patterns or recommendations and help inform research and policy. To date, no diet quality index has been developed with the purpose of measuring adherence to a healthy and sustainable diet.

Chapter 3 Attitudes toward a sustainable food supply

3.1 Introduction

This chapter provides the final manuscript, after addressing the reviewers' comments, of the published article on attitudes toward a sustainable food supply. The methodology and results detailed in this paper address objective one of this research – *to determine the factors associated with measures of adults' support for a sustainable food supply using WA population-based survey data.*

The candidate was responsible for formulating the research question, designing the study, coordinating the analyses, creating the data tables; writing the draft manuscript; coordinating co-author feedback; submitting the manuscript to Elsevier, addressing reviewers' comments and; subsequent submissions. This manuscript has been reproduced with permission (Appendix B, Section B.1).

The overall findings of this research indicate that WA adults hold a high level of concern regarding the influence of the food supply on the environment, and feel that government should be better regulating the issue. Select dietary behaviours, which align with a healthy and sustainable diet, were collected using a brief dietary assessment instrument . Appendix J contains the relevant questions used from the NMSS 2009 and 2012 surveys. The novel findings of this study showed attitudes are not associated with dietary behaviours supportive of the environment, highlighting a translation issue from attitudes to dietary choice.

Reference:

Harray, A. J., Meng, X., Kerr, D. A., & Pollard, C. M. (2018). Healthy and sustainable diets: Community concern about the effect of the future food environments and support for government regulating sustainable food supplies in Western Australia. *Appetite*. 125, 225-232.

ARTICLE: Healthy and sustainable diets: Community concern about the effect of the future food environments and support for government regulating sustainable food supplies in Western Australia.

3.2 Abstract

Objective: To determine the level of community concern about future food supplies and perception of the importance placed on government regulation over the supply of environmentally friendly food and identify dietary and other factors associated with these beliefs in Western Australia.

Design: Data from the 2009 and 2012 Nutrition Monitoring Survey Series computer-assisted telephone interviews were pooled. Level of concern about the effect of the environment on future food supplies and importance of government regulating the supply of environmentally friendly food were measured. Multivariate regression analysed potential associations with sociodemographic variables, dietary health consciousness, weight status and self-reported intake of eight foods consistent with a sustainable diet.

Setting: Western Australia.

Subjects: Community-dwelling adults aged 18–64 years ($n = 2832$).

Results: Seventy nine per cent of Western Australians were ‘quite’ or ‘very’ concerned about the effect of the environment on future food supplies. Respondents who paid less attention to the health aspects of their diet were less likely than those who were health conscious (‘quite’ or ‘very’ concerned) (OR = 0.53, 95% CI [0.35, 0.8] and 0.38 [0.17, 0.81] respectively). The majority of respondents (85.3%) thought it was ‘quite’ or ‘very’ important that government had regulatory control over an environmentally friendly food supply. Women were more likely than men to rate regulatory control as ‘quite’ or ‘very’ important’ (OR = 1.63, 95% CI [1.09, 2.44], $p = .02$). Multiple regression modeling found that no other factors predicted concern or importance.

Conclusions: There is a high level of community concern about the impact of the environment on future food supplies and most people believe it is important that the government regulates the issue. These attitudes dominate regardless of sociodemographic characteristics, weight status or sustainable dietary behaviours.

3.3 Background

Diet-related chronic diseases, such as coronary heart disease, are the leading causes of preventable death in Australia and many other Western countries (Australian Institute of Health and Welfare, 2015; World Health Organization, 2014). The economic burden on Australia's health system attributed to diet-related diseases is significant, with overweight and obesity costing approximately AUD $21 billion annually (Colagiuri et al., 2010). Yet, the current neo-liberal Western Australian political environment, with deregulation a priority, means making regulatory changes to better control and improve the food supply is challenging (Pollard et al., 2013).

A sustainable food supply is essential to ensure adequate nutritious food for current and future generations. Despite challenging environmental conditions at times, for example hot conditions and drought, Australia is food secure and continues to attract a strong global demand for food exporting AUD$31.8 billion and importing only AUD$11.6 billion in 2012-13 (Department of Agriculture, 2014). Western Australia exports approximately 80% of its agricultural production, prominently grains and cereals, meat (including live animal exports), dairy foods, fruits and vegetables, and processed foods (Department of Primary Industries and Regional Development, 2017). It has been suggested that the increasing pressure on farmers operating in this neo-liberal environment limits Australia's capacity to maintain current food production, food security and exports into the future (Lawrence, Richards, & Lyons, 2013). The relevance of the food supply and environmental sustainability to public health is not a new issue (Gussow & Clancy, 1986), yet it is complex, and often contested There is increasing evidence that choosing foods consistent with dietary guidelines will likely result in a lower environmental impact (Nelson, Hamm, Hu, Abrams, & Griffin, 2016). Considerations of sustainable diets, that in addition to being healthy also protect the environment to ensure the future of a safe, adequate, and nutritious food supply, are increasing in Australia (Bradbear & Friel, 2011; Bradbear & Friel, 2013; Friel et al., 2013) and internationally (Burlingame & Dernini, 2012; Watts et al., 2015). The current EATLancet Commission on Food, Planet and Health (Rockström et al., 2016) aims to build the evidence for healthy and sustainable dietary recommendations while countries like Sweden have already adopted sustainable diet recommendations into their national dietary guidelines (Livsmedelsverket National Food Agency Sweden, 2015) and America has placed greater emphasis on healthy and sustainable food choices (United States Department of Health and Human Services and United States Department of Agriculture, 2015). The ADGs have included special considerations of the sustainability of food systems over the last three decades, incorporated as separate evidence chapters (NHMRC, 2003). The most recent revision in 2013 proposed a specific guideline advising Australians to eat for environmental sustainability and health; however, this guideline was highly contested by industry and did not eventuate. Instead an Appendix on Food, Nutrition and Environmental Sustainability containing key messages for minimising the environmental impact of dietary choices as well as promoting health through reducing food and packaging waste, not consuming excess kilojoules and choosing fruits and vegetables in season was included (NHMRC, 2013).

A sustainable diet is defined as being healthy and safe, but with greater complexity and dependence on several factors including food access and availability, geographical location and agricultural practices (Burlingame & Dernini, 2012). It is widely accepted that the consumption of excess kilojoules, most of which are highly processed and packaged energy-dense nutrient-poor foods in Australia, creates an avoidable environmental burden and contributes to overweight and obesity (Bradbear & Friel, 2011; Larsen et al., 2008; NHMRC, 2013; Riley & Buttriss, 2011). There is increasing evidence supporting the greater environmental impact of meat and dairy foods compared to plant-based foods, regardless of potentially high nutrient values (Bradbear & Friel, 2011; Macdiarmid et al., 2012; Reynolds, Buckley, et al., 2014; Springmann et al., 2016). The general public however, differ in their understanding of the potential impact of dietary practices on the environment. An Australian study found that people believed food packaging has a greater impact on the environment than the consumption of meat (Lea & Worsley, 2008). Data shows that this is often not the case with agricultural and farming practices placing greater pressure on biodiversity than resources used in developing and disposing of food packaging (Bradbear & Friel, 2011). A UK study found that although awareness of the impact of meat on environmental sustainability was high, human health and animal welfare were greater motivators to reduce meat intake than environmental sustainability (Clonan et al., 2015).

Government food policy and regulation aims to protect public health and safety by shaping the food supply, from production through to marketing and promotion through standards and controls (Joint FAO/WHO Codex Alimentarius Commission, 2016; Thow et al., 2010). The Australian Policy Cycle highlights the importance of stakeholder consultations, including considerations of consumer attitudes, concerns and support for policy options in policy and regular decision making (Bridgman & Davis, 2004).

Consumer concerns are considered during the policy initiation and development process, as is the potential impact of policy or regulatory controls on food choices, dietary patterns and health. Yet, little is known of public concern about a sustainable food supply in Australia or whether there is support for tighter government control. Effective policy action needs to be informed by an understanding of consumer concerns regarding the issue, motivations for change and support for policy options. There is a policy interest in consumer information to support the coupling of healthy and sustainable dietary advice, and inform potential actions to protect the food supply. In Australia, there is little, if any, population-based evidence on people's perceptions about environmentally friendly food and how, or if, these attitudes translate to food choices.

The Department of Health in Western Australia's triennial Nutrition Monitoring Survey Series (NMSS) investigates consumer attitudes, knowledge and behaviours related to the ADGs (Pollard, Harray, Daly, & Kerr, 2015). The objectives of this study were to determine the level of community concern about impacts on future food supplies and the perception of the importance placed on government regulation over the supply of environmentally friendly food, and identify dietary and other factors associated with the these beliefs.

3.4 Methods

Sample

Data from the NMSS 2009 and 2012 computer-assisted telephone interviews of a representative sample of Western Australian adults, aged 18 to 64 years, were pooled for analysis. Informed consent was obtained from all respondents. A full explanation of the survey methodology is described elsewhere (Pollard, Harray, et al., 2015; Rockström et al.). In brief, sample selection involved a stratified random sample extracted from the electronic White Pages for Western Australia by area of residence. If more than one adult in a household met the inclusion criteria, the person with the most recent birthday was selected to participate in the survey. The response rate (completed/contacted) was 81.6% and 82.4% for 2009 and 2012, respectively (Pollard, McStay, & Meng, 2015).

Measures

The two main outcome measures in this study were concern about the environmental impact on future food supplies and importance of government regulation over an environmentally friendly food supply, measured using two single response questions:

1. How important would you say it is that the government has control over or regulates the supply of environmentally friendly food? *Single response options:* Not at all important; not very important; neither important nor unimportant; quite important; or very important.
2. How concerned would you say you are about the effect of the environment on the future of food supplies? *Single response options:* Not very concerned; somewhat concerned; neither unconcerned nor concerned; quite concerned; or very concerned.

Factors potentially associated with dietary attitudes and behaviours included: sociodemographic variables (age, sex, education, employment, household income, area of residence, country of birth); weight status based on self-reported height and weight categorised into Body Mass Index (with a factor applied to correct for under-reporting of weight and over-reporting of height (Hayes, Kortt, Clarke, & Brandrup, 2008); dietary health consciousness, current eating behaviours relating to a sustainable diet (based on self-reported intake of fruits, vegetables, vegetable variety, red meat, fish, dairy foods, bottled water, sugar-sweetened and diet/intense-sweetened beverages on the day prior to the survey).

The eight self-reported dietary intake questions were chosen to reflect compliance with a healthy *and* sustainable diet (Harray et al., 2015). Categorical cut-offs were set for the amounts of each of these food groups eaten on the day prior to reflect sustainable eating behaviours consistent with the Australian food selection guide daily intake recommendations (Australian Guide to Healthy Eating) (NHMRC, 2013) and consumption levels as determined by the NMSS (Pollard, Harray, et al., 2015): meat (above or below one standard 65 g serving of cooked red meat); vegetables (median ≤ or > two 75 g servings); and sugar sweetened or diet/intense sweetened beverages (consumer or non-consumer). The authors determined the cut-offs, for example, for vegetables, the cut-off of two or less servings per day was chosen rather than the aspirational recommendation of five or more servings per day, because the median consumption was three servings per day and it was hypothesised that the sample size at the two serving cut-off would enable the potential to detect those respondents who were likely to eat a more healthful diet, as well as consider sustainable dietary practices. The categorisation of non-consumer versus consumer for sugar-sweetened beverages, diet beverages, and bottled water as unsupportive of a sustainable diet, were based on the beverage's energy contribution and/or their levels of processing, packaging and contributing to landfill.

Dietary health consciousness was determined by asking, "Which of the following best describes how you feel about your diet?" *Single response options*: "pay a lot of attention to the health aspects of the food I eat"; "take a bit of notice of the health aspects of the food I eat"; or "don't think much about the health aspects of the food I eat".

Statistical analysis

Data were pooled and weighted to account for sample design and post adjusted for age, sex and geographic area of 2011 Estimated Resident Population of Western Australia. Body Mass Index (BMI) was calculated from self-reported height and weight, adjusted to account for possible reporting bias prior to calculation of BMI (Hayes et al., 2008).

Descriptive statistics report the prevalence of attitudes regarding the effect of environment on future of food supply and government control or regulation of environmental friendly food. Binary logistic regression was used to explore factors associated with respondents' concern regarding the effect of environment on future food supplies [low level of concern included 'not very, somewhat and neither' versus 'quite and very' concerned] and attitude toward government regulation of an environmentally friendly food supply ['not at all, not very important and neither' versus 'quite and very' important). The full model includes variables that have a p value < .20 in a univariate analysis. Both backward elimination and forward selection manner were used in the model building process and only variables with a p value < .05 retained in the final model and reported. Survey module of Stata software version 12.0 (StataCorp LP, College Station, TX) was used for all analyses.

3.5 Results

The characteristics of the survey population are shown in Table 3.1. Overall concern for the effect of the environment on future food supplies was high and increasing, with 78.6% of all respondents rating themselves as 'quite' or 'very' concerned (Table 3.2). The proportion who were 'very' concerned was significantly higher; in 2012 than in 2009 (p = .001), in women than men (p< .001), in those aged 35 years and older (p< .001), in fruit consumers compared to those who did not eat fruit the day prior (p = .004), and in those who paid a lot of attention to the health aspects of their diet ($p < .001$). The full binary logistic regression model found that dietary health consciousness was the only variable associated with concern about the effect of the environment on future food supplies. Compared to those who paid 'a lot of attention', respondents who said they 'take a bit of notice' or 'don't really think about it' were less likely to be 'quite' or 'very' (OR= 0.53, 95% CI [0.35, 0.8] and 0.38 [0.17, 0.81] respectively, all $p < .05$), not shown.

Table 3.1 Sample demographics, attitudes and weight status
Nutrition Monitoring Survey Series, Western Australia 2009 & 2012

Characteristic		**2009 (*n* = 1284)**	**2012 (*n* = 1548)**	**Total % [a] (*n* = 2832)**
Sex	Female	830	1,005	49.8
	Male	454	543	50.2
Age	18-34 years	251	210	38.1
	35-44 years	340	377	22.7
	45-54 years	356	466	21.6
	55-64 years	337	495	17.7
Area of residence	Metropolitan	965	1,011	79.3
	Remote areas	29	82	3.6
	Rural areas	290	455	17.1
Education	Less than high school	221	211	10.8
	High school	178	198	16.7
	Trade/Certificate/Diploma	481	632	37.8
	University degree	399	504	34.5
	Missing	5	3	0.2
Household income ($AUD)	Up to $60,000	349	346	19.7
	$60,001-$140,000	619	754	49.3
	Over $140,000	195	270	18.4
	Don't know/unsure/refused	121	178	12.6
Employment status	Currently not in paid employment	364	408	27.9
	Currently in paid employment	920	1,139	72.1
	Missing	0	1	0
Country of birth	Australia	867	1,122	69.3
	UK/Ireland	202	221	12.7
	Other countries	214	205	17.9
	Missing	1	0	0
BMI (kg/m^2)	Underweight (<18.5)	1.2	1.2	1.2
	Normal weight (18.5–24.9)	35.3	33.8	34.5
	Overweight (≥25-29.9)	37.5	36.9	37.2
	Obese (≥30)	20.9	23.7	22.3
	Not provided	5.2	4.5	4.8

Dietary health consciousness	Pay a lot of attention	43.2	41.9	42.5
	Take a bit of notice	50.0	50.2	50.1
	Don't think much	6.8	7.7	7.3

[a] Percentages were weighted for probability of selection and adjusted by age, sex and geographic area to the 2011 Estimated Resident Population of Western Australia

Table 3.2 Concern about the effect of the environment on future food supplies by sociodemographic variables, behaviours, attitudes and weight status
Nutrition Monitoring Survey Series, Western Australia 2009 & 2012 combined

Characteristic		n	Not very % [95% CI]	Somewhat % [95% CI]	Neither % [95% CI]	Quite % [95% CI]	Very % [95% CI]	p value
Year	2009	1265	9.1 [6.8 - 12.0]	9.7 [7.8 - 12.0]	4.4 [3.2 - 5.9]	29.4 [26.2 - 32.8]	47.5 [44.0 - 51.0]	.001
	2012	897	6.0 [4.4 - 8.2]	8.0 [5.6 - 11.2]	4.1 [2.6 - 6.5]	21.8 [18.1 - 26.1]	60.0 [55.4 - 64.6]	
Sex	Female	1423	5.5 [4.1 - 7.2]	9.0 [7.0 - 11.6]	3.5 [2.5 - 4.9]	24.2 [21.3 - 27.4]	57.7 [54.2 - 61.2]	.001
	Men	739	10.5 [7.6 - 14.3]	9.2 [7.0 - 11.9]	5.1 [3.5 - 7.2]	29.2 [25.2 - 33.5]	46.1 [41.7 - 50.6]	
	Persons	2162	8.0 [6.3 - 10.0]	9.1 [7.6 - 10.9]	4.3 [3.3 - 5.5]	26.7 [24.2 - 29.3]	51.9 [49.1 - 54.7]	
Age	18-34 years	373	10.8 [7.2 - 15.7]	9.9 [6.9 - 13.9]	5.2 [3.4 - 8.0]	31.0 [25.8 - 36.8]	43.2 [37.4 - 49.1]	< .001
	35-44 years	569	6.8 [4.6 - 10.1]	10.5 [7.7 - 14.2]	3.5 [2.0 - 6.0]	24.7 [20.6 - 29.2]	54.5 [49.5 - 59.4]	
	45-54 years	622	7.0 [4.7 - 10.3]	7.5 [5.3 - 10.5]	2.8 [1.7 - 4.7]	24.0 [20.2 - 28.2]	58.6 [53.8 - 63.3]	
	55-64 years	598	4.7 [3.0 - 7.3]	7.6 [5.4 - 10.5]	5.2 [3.4 - 7.8]	23.3 [19.7 - 27.4]	59.2 [54.6 - 63.7]	
Area of residence	Metropolitan	1341	8.0 [6.0 - 10.6]	8.9 [7.1 - 11.1]	4.2 [3.1 - 5.6]	26.7 [23.8 - 29.9]	52.2 [48.8 - 55.5]	.97
	Rest of state	821	7.9 [6.0 - 10.3]	9.8 [7.3 - 13.0]	4.7 [3.0 - 7.3]	26.7 [22.9 - 30.8]	50.9 [46.5 - 55.4]	
Country of birth	Australia	1536	7.3 [5.6 - 9.5]	10.1 [8.1 - 12.4]	4.4 [3.3 - 6.0]	26.1 [23.2 - 29.3]	52.0 [48.6 - 55.4]	.39
	Outside of Australia	625	9.4 [6.2 - 14.1]	7.1 [4.9 - 10.2]	3.8 [2.4 - 5.9]	28.0 [23.4 - 33.0]	51.7 [46.5 - 56.9]	
Highest education	Less than year 12	346	3.4 [1.5 - 7.4]	9.2 [5.5 - 15.1]	5.1 [2.6 - 9.8]	25.2 [20.1 - 31.1]	57.0 [50.2 - 63.6]	.15
	Year 12	285	9.3 [4.5 - 18.4]	11.5 [7.7 - 16.9]	3.3 [1.6 - 6.9]	30.1 [23.1 - 38.0]	45.7 [38.0 - 53.7]	
	TAFE/Trade/ Diploma	862	8.5 [6.1 - 11.6]	9.6 [7.0 - 12.9]	4.8 [3.3 - 6.9]	22.0 [18.6 - 25.9]	55.1 [50.6 - 59.4]	
	Tertiary	662	8.3 [5.7 - 11.9]	7.2 [5.1 - 10.2]	4.0 [2.4 - 6.4]	30.7 [26.2 - 35.7]	49.8 [44.7 - 54.8]	
Employment status	Currently in paid employment	1574	9.4 [5.9 - 14.7]	9.2 [6.5 - 12.9]	3.5 [2.1 - 5.7]	25.3 [20.5 - 30.7]	52.6 [46.9 - 58.2]	.70

Characteristic		n	Not very % [95% CI]	Somewhat % [95% CI]	Neither % [95% CI]	Quite % [95% CI]	Very % [95% CI]	p value
	Currently not in paid employment	588	7.4 [5.7 - 9.5]	9.1 [7.3 - 11.2]	4.6 [3.5 - 6.2]	27.3 [24.4 - 30.3]	51.6 [48.4 - 54.8]	
Household income ($AUD)	Up to $60,000	558	8.3 [4.5 - 14.8]	8.6 [5.3 - 13.7]	3.7 [2.0 - 6.8]	23.8 [18.8 - 29.6]	55.7 [49.2 - 61.9]	.45
	$60,001-$140,000	1061	6.9 [5.0 - 9.4]	9.1 [7.2 - 11.5]	3.9 [2.7 - 5.6]	28.4 [25.0 - 32.1]	51.7 [47.8 - 55.6]	
	Above $140,000	327	9.0 [5.4 - 14.6]	8.1 [5.1 - 12.8]	3.6 [1.8 - 7.1]	30.2 [24.1 - 37.1]	49.0 [42.4 - 55.7]	
	Don’t know / unsure / missing	216	10.6 [5.7 - 18.8]	11.3 [6.7 - 18.6]	7.9 [4.6 - 13.1]	20.3 [13.7 - 29.0]	50.0 [40.8 - 59.2]	
Self-reported dietary intake on day prior to survey								
Fruit	Non-consumer (14%)	311	14.5 [8.9 - 22.5]	8.0 [4.9 - 12.8]	6.0 [3.5 - 10.4]	28.9 [22.6 - 36.1]	42.6 [35.5 - 50.0]	.004
	Consumer (86%)	1845	6.8 [5.2 - 8.7]	9.3 [7.6 - 11.3]	3.9 [2.9 - 5.2]	26.3 [23.6 - 29.2]	53.7 [50.6 - 56.8]	
Vegetables	≤ 2 serves (43%)	921	10.5 [7.6 - 14.4]	9.5 [7.3 - 12.3]	5.2 [3.6 - 7.4]	24.5 [21.0 - 28.5]	50.2 [45.9 - 54.6]	.28
	> 2 serves (57%)	1217	5.9 [4.2 - 8.2]	8.7 [6.6 - 11.3]	3.6 [2.5 - 5.1]	28.1 [24.7 - 31.7]	53.8 [49.9 - 57.6]	
Vegetable variety	≤ 3 types	885	10.2 [7.3 – 14.1]	8.9 [6.7 – 11.7]	4.8 [3.3 – 6.8]	26.9 [23.0 – 31.1]	49.3 [44.8 – 53.7]	.11
	> 3 types	1264	6.1 [4.5 – 8.2]	9.4 [7.4 – 12.0]	3.9 [2.7 – 5.6]	26.4 [23.3 – 29.8]	54.1 [50.4 – 57.8]	
Meat (2012 only)	≤ 1 serve (86%)	768	5.3 [3.4 - 8.1]	7.5 [5.1 - 10.8]	4.3 [2.3 - 7.8]	20.6 [16.2 - 25.8]	62.4 [56.7 - 67.7]	.33
	> 1 serve (14%)	129	3.6 [1.4 - 8.7]	12.0 [4.5 - 28.3]	4.0 [1.5 - 10.2]	30.1 [17.9 - 45.8]	50.3 [36.3 - 64.3]	
Fish (2012 only)	≤ 1 serve (94%)	844	4.1 [2.8 - 6.0]	8.9 [6.0 - 12.9]	4.4 [2.5 - 7.5]	22.1 [17.6 - 27.3]	60.5 [54.8 - 65.9]	.08
	> 1 serve (6%)	53	14.9 [4.7 - 38.0]	1.5 [0.5 - 5.0]	2.3 [0.4 - 12.4]	24.7 [9.6 - 50.4]	56.6 [34.8 - 76.1]	
Dairy foods	≤ 2 serves (55%)	1192	9.2 [6.8 – 12.4]	8.4 [6.5 – 10.7]	4.3 [3.0 – 6.0]	27.3 [24.1 – 30.9]	50.8 [47.0 – 54.6]	.40
	> 2 serves (45%)	970	6.5 [4.5 – 9.1]	10.0 [7.6 – 13.1]	4.3 [3.0 – 6.3]	25.9 [22.3 – 30.0]	53.2 [49.0 – 57.5]	
Soft and diet drinks	Non-consumer (70%)	1520	10.2 [7.3 - 14.2]	10.2 [7.3 - 14.1]	3.9 [2.4 - 6.4]	25.8 [21.6 - 30.4]	49.9 [44.8 - 54.9]	.31
	Consumer (30%)	642	6.9 [5.0 - 9.4]	8.6 [6.9 - 10.6]	4.5 [3.3 - 6.0]	27.2 [24.2 - 30.4]	52.9 [49.5 - 56.3]	

Characteristic		n	Not very % [95% CI]	Somewhat % [95% CI]	Neither % [95% CI]	Quite % [95% CI]	Very % [95% CI]	p value
Bottled water	Non-consumer (80%)	1607	3.8 [2.0 - 6.9]	9.2 [5.5 - 14.9]	5.5 [3.1 - 9.3]	27.7 [22.2 - 34.0]	53.9 [47.5 - 60.2]	.17
	Consumer (20%)	399	8.6 [6.6 - 11.1]	9.1 [7.4 - 11.1]	3.9 [2.8 - 5.2]	25.8 [23.0 - 28.9]	52.6 [49.3 - 55.9]	
Dietary health consciousness	Pay a lot of attention	1062	4.6 [3.2 - 6.5]	7.0 [5.2 - 9.4]	3.7 [2.5 - 5.5]	25.8 [22.4 - 29.6]	58.9 [54.8 - 62.8]	< .001
	Take a bit of notice	985	9.8 [7.1 - 13.3]	10.8 [8.4 - 13.9]	4.7 [3.3 - 6.6]	28.3 [24.6 - 32.3]	46.4 [42.3 - 50.6]	
	Don't think about it	115	16.2 [8.4 - 28.7]	9.7 [4.9 - 18.3]	5.2 [2.2 - 12.1]	21.2 [12.9 - 32.8]	47.7 [35.7 - 59.9]	
BMI (kg/m^2)	Healthy weight (<25)	657	6.6 [3.8 - 11.3]	10.5 [7.5 - 14.5]	4.8 [3.2 - 7.0]	27.1 [22.4 - 32.2]	51.1 [45.7 - 56.5]	.75
	Overweight (≥25-29.9)	833	9.4 [7.0 - 12.6]	8.0 [6.0 - 10.5]	4.1 [2.6 - 6.4]	26.6 [22.9 - 30.6]	52.0 [47.7 - 56.2]	
	Obese (≥30)	549	7.2 [4.8 - 10.7]	8.3 [5.7 - 11.9]	4.4 [2.6 - 7.1]	25.0 [20.5 - 30.1]	55.2 [49.8 - 60.5]	

Estimates were weighted for probability of selection and adjusted by age, sex and geographic area to the 2011 Estimated Resident Population of Western Australia. *p* values were derived from design-based Pearson chi-square test.

Table 3.3 shows the majority of respondents in both 2009 and 2012 believed it was ‘quite’ or ‘very’ important for the government to control or regulate an environmentally friendly food supply, 84.6% and 86.0%, respectively. There was a significant difference in the proportion of respondents who reported being ‘quite’ or ‘very’ important in 2012 (p = .04), but not in 2009. Women were more likely to rate this issue as ‘very’ important than men (p< .001). Over half (52.1%) of respondents with a household income below AUD$60,000 per annum rated government control as ‘very’ important compared with only 36.2% of households with an income above AUD$140,000 ($p$ = .002). Those living in Western Australia’s capital city, Perth, were significantly more likely to rate government regulation as ‘quite’ or ‘very’ important, compared with those living in the rest of the state (p = .01). Respondents classified as having a healthy body weight or less (BMI < 25 kg/m^2) were more likely to rate regulation as ‘quite’ important than those who were classified as overweight or obese (p< .001). Binary logistic regression modeling revealed women were more likely than men to believe government regulation was ‘quite/very’ important (OR=1.63, 95% CI [1.09, 2.44], p = .02), not shown.

To test the relationship between the two questions of interest, the ‘level of concern’ variable was added to the multivariable logistic regression model. Level of concern remained significant independent of sex (overall p< 0.001, and p=0.01 and p< 0.001 for those ‘quite’ and ‘very’ concerned respectively). These results show that respondents who were concerned about the effect of the environment on future food supplies are more likely to want more government control over the issue.

Table 3.3 Importance placed on government control or regulation of an environmentally friendly food supply by sociodemographic variables, behaviours, attitudes and weight status

Nutrition Monitoring Survey Series, Western Australia, 2009 & 2012 (n=2142)

Characteristic		n	Not at all % [95% CI]	Not very % [95% CI]	Neither % [95% CI]	Quite % [95% CI]	Very % [95% CI]	p value
Year	2009	1255	3.1 [2.2 - 4.3]	7.2 [5.4 - 9.5]	5.1 [3.8 - 6.7]	39.6 [36.1 - 43.3]	45.0 [41.5 - 48.6]	.04
	2012	887	4.4 [2.8 - 6.8]	3.9 [2.7 - 5.8]	5.6 [4.0 - 7.8]	36.3 [32.0 - 40.9]	49.7 [45.1 - 54.4]	
Sex	Female	1411	1.7 [1.1 - 2.5]	4.2 [3.1 - 5.7]	5.9 [4.6 - 7.6]	37.6 [34.2 - 41.1]	50.6 [47.1 - 54.1]	< .001
	Men	731	5.4 [3.9 - 7.4]	7.9 [5.7 - 10.8]	4.6 [3.2 - 6.6]	39.3 [35.0 - 43.8]	42.8 [38.4 - 47.3]	
	Persons	2142	3.5 [2.7 - 4.6]	6.1 [4.8 - 7.6]	5.3 [4.2 - 6.5]	38.5 [35.7 - 41.3]	46.7 [43.8 - 49.5]	
Age (years)	18-34	374	2.0 [0.9 - 4.1]	7.0 [4.5 - 10.7]	5.1 [3.3 - 7.9]	44.3 [38.5 - 50.2]	41.6 [35.9 - 47.6]	.005
	35-44	559	3.1 [1.7 - 5.4]	5.1 [3.2 - 8.1]	4.8 [3.2 - 7.1]	36.4 [31.6 - 41.5]	50.6 [45.6 - 55.6]	
	45-54	618	4.6 [2.9 - 7.4]	5.0 [3.4 - 7.4]	5.8 [4.0 - 8.3]	37.4 [32.8 - 42.2]	47.2 [42.4 - 52.0]	
	55-64	591	6.2 [4.3 - 9.0]	6.6 [4.5 - 9.6]	5.4 [3.7 - 8.0]	29.9 [25.9 - 34.3]	51.8 [47.1 - 56.5]	
Area of residence	Metropolitan	1328	3.5 [2.5 - 4.8]	6.2 [4.7 - 8.2]	4.4 [3.3 - 5.8]	38.7 [35.4 - 42.1]	47.3 [43.9 - 50.7]	.01
	Rest of state	814	3.9 [2.6 - 5.6]	5.5 [4.0 - 7.6]	8.6 [6.2 - 11.9]	37.6 [33.4 - 42.0]	44.4 [40.3 - 48.6]	
Country of birth	Australia	1526	3.9 [2.9 - 5.3]	6.5 [5.0 - 8.5]	5.9 [4.6 - 7.4]	38.0 [34.7 - 41.4]	45.7 [42.3 - 49.1]	.35
	Outside of Australia	616	2.7 [1.6 - 4.8]	5.1 [3.2 - 8.1]	3.9 [2.4 - 6.4]	39.5 [34.4 - 44.8]	48.7 [43.5 - 54.0]	
Highest education	Less than year 12	347	4.2 [2.4 - 7.5]	4.9 [2.4 - 9.7]	4.9 [3.1 - 7.7]	33.5 [27.4 - 40.2]	52.4 [45.7 - 59.0]	.24
	Year 12	286	2.3 [1.0 - 5.6]	8.1 [4.6 - 13.9]	6.2 [3.6 - 10.4]	39.0 [31.2 - 47.4]	44.4 [36.7 - 52.3]	
	TAFE/Trade/ Diploma	846	2.9 [1.8 - 4.6]	4.0 [2.8 - 5.9]	5.8 [4.0 - 8.2]	39.6 [35.3 - 44.0]	47.8 [43.4 - 52.2]	
	Tertiary	658	4.7 [3.1 - 7.0]	7.7 [5.3 - 11.0]	4.4 [3.0 - 6.3]	38.8 [34.0 - 43.8]	44.5 [39.4 - 49.6]	

Characteristic		n	Not at all % [95% CI]	Not very % [95% CI]	Neither % [95% CI]	Quite % [95% CI]	Very % [95% CI]	p value
Employment status	Currently in paid employment	1563	1.9 [1.0 - 3.4]	6.7 [4.4 - 10.3]	4.6 [3.0 - 7.0]	42.5 [36.7 - 48.4]	44.3 [38.7 - 50.0]	.11
	Currently not in paid employment	579	4.2 [3.2 - 5.6]	5.8 [4.4 - 7.6]	5.5 [4.3 - 7.0]	36.9 [33.8 - 40.1]	47.6 [44.3 - 50.9]	
Household income ($AUD)	Up to $60,000	549	2.8 [1.7 - 4.7]	3.8 [2.1 - 6.6]	5.9 [3.8 - 9.1]	35.4 [29.3 - 42.0]	52.1 [45.7 - 58.5]	.002
	$60,001-$140,000	1058	3.4 [2.3 - 4.9]	5.6 [4.0 - 8.0]	4.5 [3.2 - 6.3]	37.4 [33.7 - 41.2]	49.1 [45.2 - 53.1]	
	Above $140,000	325	5.3 [3.0 - 9.3]	11.9 [7.8 - 17.9]	5.1 [3.2 - 8.2]	41.5 [34.8 - 48.4]	36.2 [30.2 - 42.6]	
	Don’t know / unsure / missing	210	3.1 [1.2 - 8.2]	3.8 [2.0 - 7.1]	7.4 [4.4 - 12.2]	44.5 [35.2 - 54.1]	41.2 [32.4 - 50.5]	
Self-reported dietary intake on day prior to survey								
Fruit	Non-consumer (15%)	312	3.3 [1.7 - 6.1]	8.3 [4.6 - 14.5]	5.8 [3.4 - 9.6]	35.8 [28.8 - 43.5]	46.8 [39.3 - 54.4]	.66
	Consumer (85%)	1823	3.6 [2.7 - 4.8]	5.7 [4.4 - 7.3]	5.2 [4.1 - 6.5]	38.7 [35.7 - 41.8]	46.9 [43.8 - 50.0]	
Vegetables	≤ 2 serves (43%)	910	3.5 [2.4 - 5.1]	6.8 [4.8 - 9.5]	5.5 [3.9 - 7.8]	39.6 [35.4 - 43.9]	44.7 [40.4 - 49.0]	.77
	> 2 serves (57%)	1210	3.7 [2.5 - 5.3]	5.6 [4.0 - 7.6]	5.0 [3.8 - 6.5]	37.9 [34.2 - 41.8]	47.9 [44.1 - 51.7]	
Vegetable variety	≤ 3 types (41%)	876	2.1 [1.2 – 3.6]	7.2 [5.1 – 10.1]	4.5 [3.1 – 6.5]	40.1 [35.7 – 44.6]	46.1 [41.7 – 50.6]	.02
	> 3 types (59%)	1252	4.8 [3.6 – 6.5]	5.0 [3.7 – 6.8]	6.0 [4.6 – 7.7]	36.9 [33.4 – 40.5]	47.3 [43.7 – 51.0]	
Meat (2012 only)	≤ 1 serve (85%)	756	4.7 [2.6 - 8.2]	2.9 [1.8 - 4.6]	5.5 [3.8 - 8.0]	37.4 [32.0 - 43.1]	49.5 [43.9 - 55.2]	.47
	> 1 serve (15%)	131	4.1 [1.4 - 11.8]	7.3 [2.7 - 18.2]	3.5 [1.4 - 8.7]	38.5 [25.5 - 53.3]	46.6 [32.8 - 60.9]	
Fish (2012 only)	≤ 1 serve (94%)	834	4.2 [2.5 - 7.0]	3.7 [2.3 - 6.1]	5.3 [3.6 - 7.6]	37.0 [31.6 - 42.6]	49.9 [44.4 - 55.4]	.64
	> 1 serve (6%)	53	8.9 [1.5 - 38.1]	3.3 [0.6 - 16.3]	3.7 [1.0 - 12.5]	45.1 [25.7 - 66.1]	38.9 [21.2 - 60.1]	
Dairy foods	≤ 2 serves (55%)	1186	3.3 [2.3 – 4.8]	6.2 [4.5 – 8.4]	5.2 [3.9 – 6.9]	40.0 [36.2 – 43.9]	45.3 [41.5 – 49.2]	.78
	> 2 serves (45%)	956	3.8 [2.6 – 5.6]	5.9 [4.1 – 8.5]	5.3 [3.8 – 7.3]	36.6 [32.5 – 40.9]	48.3 [44.1 – 52.6]	

Characteristic		n	Not at all % [95% CI]	Not very % [95% CI]	Neither % [95% CI]	Quite % [95% CI]	Very % [95% CI]	p value
Soft and diet drinks	Non-consumer (70%)	1510	4.2 [2.7 - 6.4]	4.8 [2.8 - 8.0]	4.5 [3.0 - 6.8]	36.3 [31.6 - 41.3]	50.2 [45.2 - 55.3]	.27
	Consumer (30%)	632	3.3 [2.3 - 4.5]	6.7 [5.2 - 8.6]	5.6 [4.3 - 7.2]	39.5 [36.2 - 43.0]	44.9 [41.6 - 48.3]	
Bottled water	Non-consumer (80%)	1592	1.7 [0.8 - 3.5]	8.5 [5.3 - 13.4]	5.2 [3.3 - 8.2]	36.9 [30.9 - 43.4]	47.7 [41.4 - 54.0]	.17
	Consumer (20%)	396	3.9 [2.9 - 5.3]	5.5 [4.2 - 7.2]	5.1 [3.9 - 6.6]	39.0 [35.8 - 42.3]	46.5 [43.2 - 49.8]	
Dietary health consciousness	Pay a lot of attention	1051	4.0 [2.7 - 5.9]	5.9 [4.2 - 8.4]	4.1 [2.9 - 5.7]	34.8 [31.0 - 38.7]	51.2 [47.1 - 55.2]	.046
	Take a bit of notice	978	3.2 [2.2 - 4.8]	6.0 [4.4 - 8.2]	5.4 [3.9 - 7.3]	42.4 [38.2 - 46.7]	43.0 [38.9 - 47.2]	
	Don’t think much	113	2.8 [1.2 - 6.5]	7.0 [2.2 - 20.2]	11.6 [6.2 - 20.6]	34.0 [23.7 - 46.1]	44.6 [32.9 - 57.0]	
BMI (kg/m^2)	Healthy weight or less (<25)	651	0.8 [0.4 - 1.7]	6.3 [4.1 - 9.6]	4.6 [3.1 - 6.7]	42.2 [36.9 - 47.7]	46.2 [40.8 - 51.6]	< .001
	Overweight (25-29.9)	821	5.9 [4.1 - 8.4]	6.7 [4.8 - 9.5]	5.2 [3.7 - 7.3]	35.0 [30.9 - 39.3]	47.2 [43.0 - 51.6]	
	Obese (≥30)	546	3.9 [2.6 - 5.9]	4.3 [2.6 - 6.8]	6.8 [4.5 - 10.3]	38.9 [33.8 - 44.3]	46.1 [40.9 - 51.4]	

Estimates were weighted for probability of selection and adjusted by age, sex and geographic area to the 2011 Estimated Resident Population of Western Australia. *p* values were derived from design-based Pearson chi-square test.

3.6 Discussion

This study aimed to determine factors associated with Western Australian adults' concern about future food supplies and importance placed on regulation of environmentally friendly food. The results indicate a high and increasing concern across the population about the impact of the environment on future food supplies, and a high level of importance placed on government regulating the supply of foods to support the environment.

Dietary health consciousness was the only factor associated with concern about the effect of the environment on future food supplies when factors such as body weight, sociodemographic characteristics and current dietary behaviours were taken into account. Respondents with low levels of dietary health consciousness were a third less likely than those paying a lot of attention to be very concerned about the effect of the environment on future food supplies. It is possible that dietary health consciousness reflects a general broad concern about food and health, including consideration of the source of food. Further research is needed to identify the drivers of and barriers to higher levels of dietary health consciousness.

Previous studies have found that those with a high level of concern about the environment were likely consumers of diets high in fruit (Reynolds, Buckley, et al., 2014) and this was consistent with the current study findings. Diets high in fruit and vegetables, low in added sugar and fast food are associated with the importance placed on sustainable food production practices (Pelletier et al., 2013). The current study found a high level of community support for government involvement in the regulation of an environmentally sustainable food supply in Western Australia. Regulatory options that could reduce the impact of the food supply on the environment include taxes on landfill, tightening trade laws, farming practices and food production methods. Governments could also regulate for carbon footprint levels on packaged food labels to assist consumers to make environmentally friendly food choices at the point of food selection (Lang, Barling, & Caraher, 2009).

Most of Australia's population does not adhere to dietary recommendations, for example, in 2011/12 only seven per cent ate the recommended two servings of fruit and five servings of vegetables per day (Australian Bureau of Statistics, 2014). This is despite the effort of health promotion campaigns between 2001 and 2005, which aimed to increase consumption of fruit and vegetables (Pollard et al., 2008). Such campaigns focused on the health benefits and ease of increasing a serving of vegetables and resulted in increased population intake at the time of delivery. The current study findings suggest that a message regarding both a healthy *and* sustainable food choices may resonate with the Western Australian community.

The results from this study found limited association between the intake of key foods related to a sustainable dietary pattern and attitudes towards environmentally friendly food. This could be due to limited, if any, awareness or understanding of what constitutes environmentally friendly food choices. To date in Australia there has been no public health campaigns educating people on what they can do to consume a sustainable diet. Given the high level of concern placed on the future food supply and importance of regulation of environmentally friendly food, public education campaigns promoting the nexus between a diet that is healthy for consumers and the environment may contribute to more healthful eating. This attitude-behavioural intention gap has been explored internationally in young people and found intentions to consume sustainable food is influenced by social pressure, perceived availability and knowledge of what constitutes sustainable food choices (Vermeir & Verbeke, 2006). To target future education programs to encourage healthy *and* sustainable dietary behaviours, further research is needed to investigate whether adults are more likely to adopt sustainable dietary behaviours if they are concerned about the effect of the environment on the future food supply, and which dietary changes they are amenable to.

A South Australian focus group study of 47 adults investigating community trust in the regulation of food production and supply found those living in metropolitan areas were more likely than those in rural areas to believe tighter regulation of the food supply is required (Meyer, Coveney, Henderson, Ward, & Taylor, 2012). These findings are consistent with the current study which shows that respondents residing in metropolitan areas were more likely than those in regional and remote areas to rate government regulation as ‘very’ important ($p = 0.01$).

Lower income households were more likely to rate government control and regulation over an environmentally friendly food supply as ‘very’ important (52.1%) than high-income households (36.2%) ($p = .002$). Women were more likely to place importance on government regulation over an environmentally friendly food supply. In Western Australian households women are more likely to take responsibility for choosing, purchasing and preparing foods for the home (Pollard, Harray, et al., 2015), therefore they may have a higher interest and concern in the overall food environment.

The level of importance placed on government regulatory control may also be related to awareness of the importance and seriousness of the environmental impact of food, or a lack of knowledge about what government regulation and control would involve. If the latter was a factor, these populations may have a greater desire for a body to regulate issues relating to the food supply, hence their response (Wilson, Meyer, Coveney, Henderson, & Ward, 2014). Regardless, our findings of a high level of importance Western Australian adults place on government regulation, suggests that policy makers should be confident when regulating this issue more and be encouraged to communicate any current actions in this area to the public. The findings of this study should be of interest to Government sectors with an interest in and who can influence sustainability and health, for example, Department's or Ministries of Health, Education, Primary Industries and Regional Development, Agriculture and Food, and Finance. Our findings suggest incorporating a specific dietary guideline on sustainable *and* healthy dietary practices into the next revision of the ADGs is warranted. Reporting on population perceptions of current policy issues related to diet and the food supply is a strength of this research.

There are a number of limitations that should be taken into consideration when interpreting the findings. Self-reported responses to the attitudinal questions may be influenced by social desirability, a sense of social responsibility as a result of increasing global awareness of sustainability and its importance (Vermeir & Verbeke, 2006). Respondents may have answered the questions in a way they believe they should (as a result of their knowledge), either intentionally or unintentionally (Cadmus-Bertram & Patterson, 2013). The possibility of social desirability bias may be a limitation of the survey question, however, the bias would exist across both surveys and about one quarter of respondents did not show concern. Another limitation is the potential for differing interpretations of the term 'environmentally friendly food'. However, the term was derived based on responses to open-ended questions asked in previous surveys, which asked about problems or concerns with the diet. The term 'environmentally friendly food' was not explained further, for example describing diets made up mostly of plant-based foods or minimally processed or packaged foods. It is recommended that this type of specification be made in future surveys. The median vegetable consumption of three servings a day in this study was comparable to those of the most recent national dietary survey based on 24 hour food recall, which found adult men and women consumed a daily mean of 2.3 serves and 2.5 serves of vegetables, respectively (Australian Bureau of Statistics, 2015). The finding of limited association with consumption of median fruit, vegetables or meat intake in the analyses could be attributed to the cut-off values as discussed in the methods section. Further research incorporating a wider range of sustainable dietary behaviours, such a food waste habits, fruit and vegetable seasonality and types of meat, poultry and fish consumed, in addition to a more comprehensive dietary assessment method, would be useful to gain an more in-depth understanding of associations between attitudes and behaviours relating to environmentally friendly food. There is a need for ongoing research to support the agricultural, farming and food manufacturing practices that support an environmentally sustainable food supply.

3.7 Conclusion

Strengthening evidence on the impact of food production, processing and consumption habits on the environment is complemented by the high and increasing level of concern Western Australian adults place on an environmentally friendly food supply and the importance of government regulation of the issue. These findings support government efforts to regulate the supply of foods that support the environment. They also support the need to inform the community on how they can translate their concerns into healthier and more sustainable food choices. Further research to explore people's behaviour around healthy *and* sustainable diets and potential barriers to sustainable food consumption is recommended. Inclusion of specific dietary advice for a sustainable and healthy diet should be a priority in the next iteration of the Australian Dietary Guidelines.

3.8 Funding

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3.9 Author contributions to manuscript

A.J.H was responsible for formulating the research question, designing the study and writing the manuscript. X.M was responsible for the statistical analysis. D.A.K was responsible for helping formulate the research question and designing the study. C.M.P was responsible for helping formulate the research question and designing the study. All authors reviewed the manuscript.

3.10 Acknowledgements

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3.11 Conflicts of interest

None of the authors have any conflicts of interest regarding the study, analysis or results of this manuscript.

3.12 Summary

Prior to this study, there was no information available on the attitudes of Western Australian adults towards environmentally friendly foods and the importance placed on government regulation of the issue. The findings in this study highlight that the issue has the attention of consumers but there is a disconnect between people's attitudes and how these translate to more sustainable food choices. The high level of concern and importance Western Australian adults place on the supply and regulation of environmentally friendly foods demonstrates that this is a topical area of nutrition, policy makers should be aware of the issue and support should be provided to assist the public in translating these concerns into food choice.

Chapter 4 Outcomes of the Connecting Health and Technology (CHAT) study

4.1 Introduction

This chapter provides the final manuscript, after addressing the reviewers' comments, of the published article on the outcomes of the Connecting Health and Technology (CHAT) study. The CHAT study assessed the intake of fruits, vegetables and EDNP foods and vegetables, all of which are related to a healthy and sustainable diet. This thesis involved a secondary analysis of the data collected during the CHAT study, and this chapter provides a background to help address objectives two to five of this research:

Objective two - Evaluate perceptions toward current energy-dense nutrient-poor food and beverage intake, compared to actual intake data collected using a 4-day image-based mobile food record.

Objective three - Determine the association between eating frequency and the intake of foods related to a healthy and sustainable diet, as defined by the consumption of fruits, vegetables and energy-dense nutrient-poor foods and beverages.

Objective four - Develop a Healthy and Sustainable Diet Index to measure key components of a healthy and sustainable diet using images.

Objective five - Apply and evaluate the Healthy and Sustainable Diet Index using 4-day image-based mobile food records.

The candidate was a Research Assistant on the CHAT study and was involved in; the recruitment, screening and training of participants; the collection of anthropometric data and questionnaires; confirmation of mFR image contents with all participants; analysis of all mFRs for both visits (including food group analysis of fruits, vegetable, EDNP food and beverage servings); development of all tailored dietary feedback for the intervention group (including their current average food group intake and improvements that could be made); data entry and data analysis and; she contributed to writing up the results and reviewing the below manuscript. See Appendix B, Section B.3 for a declaration of author contributions. This manuscript has been reproduced with permission.

Reference:

Kerr, D. A., Harray, A. J., Pollard, C. M., Dhaliwal, S. S., Delp, E. J., Howat, P. A., Pickering, M. R., Ahmad, Z., Meng, X., Pratt, I. S., Wright, J. L., Kerr, K. R., & Boushey, C. J. (2016). The connecting health and technology study: a 6-month randomized controlled trial to improve nutrition behaviours using a mobile food record and text messaging support in young adults. *The International Journal of Behavioral Nutrition and Physical Activity*, 13(1), 52.

ARTICLE: The Connecting Health and Technology Study: A 6-month randomized controlled trial to improve nutrition behaviours using a mobile food record and text messaging support in young adults.

Deborah A Kerr, Amelia J Harray, Christina M Pollard, Satvinder S Dhaliwal, Edward J Delp, Peter A Howat, Mark R Pickering, Ziad Ahmad, Xingqiong Meng, Iain S Pratt, Janine L Wright, Katherine R Kerr, Carol J Boushey.

4.2 Abstract

Background: Early adulthood represents the transition to independent living which is a period when changes in diet and body weight are likely to occur. This presents an ideal time for health interventions to reduce the effect of health problems and risk factors for chronic disease in later life. As young adults are high users of mobile devices, interventions that use this technology may improve engagement. The Connecting Health and Technology study aimed to evaluate the effectiveness of tailored dietary feedback and weekly text messaging to improve dietary intake of fruit, vegetables and junk food over 6 months among a population-based sample of men and women (aged 18 to 30 years).

Methods: A three-arm, parallel, randomized control trial was conducted. After baseline assessments, participants were randomized to one of three groups: A) dietary feedback and weekly text messages, B) dietary feedback only, or C) control group. Dietary intake was assessed using a mobile food record App (mFR) where participants captured images of foods and beverages consumed over 4-days at baseline and post-intervention. The primary outcomes were changes in serves of fruits, vegetables, energy-dense nutrient-poor (EDNP) foods and sugar-sweetened beverages (SSB). The intervention effects were assessed using linear mixed effect models for change in food group serves.

Results: Young adults (n=247) were randomized to group A (n=82), group B (n=83), or group C (n=82). Overall, no changes in food group serves for either intervention groups were observed. An unanticipated outcome was a mean weight reduction of 1.7 kg ($p< 0.05$) among the dietary feedback only. Men who received dietary feedback only, significantly reduced their serves of EDNP foods by a mean of 1.4 serves/day ($p< 0.05$). Women who received dietary feedback only significantly reduced their intake of SSB ($p< 0.05$) by an average of 0.2 serves/day compared with controls.

Conclusions: Tailored dietary feedback only resulted in a decrease in EDNP foods in men and SSB in women, together with a reduction in body weight. Using a mobile food record for dietary assessment and tailored feedback has great potential for future health promotion interventions targeting diet and weight in young adults.

Trial Registration: Australian Clinical Trials Registry Registration number: ACTRN12612000250831 (Date of registration: February 29th 2012).

Keywords: Mobile food record; novel technology; dietary assessment; interventions; text messaging; young adult; tailoring; energy-dense nutrient poor foods; sugar-sweetened beverages; fruit; vegetables; junk food.

4.3 Background

There is convincing evidence of the importance of regularly eating a healthful diet for the prevention of chronic diseases and excessive weight gain in adulthood, particularly a diet high in fruits and vegetables and that limits energy-dense nutrient-poor (EDNP) foods and beverages (Malik, Pan, Willett, & Hu, 2013). Chronic diseases, such as obesity, cardiovascular disease and some cancers are diet related (World Health Organisation, 2011) and interventions targeting early adulthood may reduce the effect of health problems and risk factors for chronic disease in later life. In 2011, over half of young adults aged 18 to 24 years and 59% of 25 to 34 year olds in Western Australia were classified as either overweight or obese (Australian Bureau of Statistics, 2013b). Weight gain in early adulthood has been attributed to less physical activity and excess energy intake as well as the obesogenic environment (Swinburn et al., 2015). In Australia, teenagers and young adults consume more energy dense nutrient poor foods (EDNP) such as fast food, chocolate, chips, meat pies, pizzas and sugar-sweetened beverages (SSB) than other age groups and are less likely than older adults to meet the Australian guidelines of at least two 150 gram serves of fruit and five 75 gram serves of vegetables a day (Australian Bureau of Statistics, 2014). These statistics may result from the challenges of early adulthood being a time of transitioning to independent living and starting a family.

In a systematic review of lifestyle interventions for preventing weight gain in young adults, Hebden et al. (Hebden, Chey, & Allman-Farinelli, 2012) recommended future trials include dietary self-monitoring and tailored feedback to increase the personal relevance to the individual. Dietary self-monitoring is commonly undertaken as a written food record by asking the person to record the types of amounts of all foods and beverages consumed over one or more days. The act of recording appears to raise a person's awareness of what they are eating and has been shown to be an effective behaviour change strategy (Burke, Wang, & Sevick, 2011). However, many weight loss studies where food records have been used for self-monitoring fail to include sufficient detail for assessment of diet to be undertaken or measures of adherence, such as the day and time of recording (Burke et al., 2011). Food records, also referred to as food diaries, can provide an assessment of overall dietary intake, including details of the foods consumed and food combinations eaten together (Rosner & Gore, 2001) but tend to be less acceptable in young people due to the recording burden (Boushey et al., 2009). With mobile technology being more readily accessible, digital and image-based diet assessment methods may address some of these limitations, allowing for simultaneous dietary assessment and self-monitoring. Given the level of interest in mobile technology amongst young adults, collecting dietary intake data using mobile devices may have more appeal and lead to improved cooperation in this age group. An additional advantage is the detailed information collected can form the basis of tailored dietary feedback for the individual. Tailoring is a form of communication personalised to the individual based on characteristics unique to that person and derived from individual assessment (Kreuter & Skinner, 2000). A key element of successful tailoring is to provide personally relevant feedback that can assist people to identify the dietary changes most likely to improve their health (Krebs, Prochaska, & Rossi, 2010). Tailoring has shown positive effects in changing diet and physical activity behaviours (Broekhuizen, Kroeze, van Poppel, Oenema, & Brug, 2012; Kroeze, Werkman, & Brug, 2006). Tailored dietary feedback has been delivered by mail and web but to date, text messaging as a mode of delivery for feedback has been relatively unexplored. Most studies have based their tailored feedback on brief instruments that use only a few questions to assess diet rather than more detailed dietary records (Broekhuizen et al., 2012). A systematic review of dietary assessment methods used to evaluate interventions found that dietary components, such as fruits, vegetables, sugar-sweetened beverages and fast food, were most often assessed by single questions or brief instruments (Kirkpatrick et al., 2014). This limits the type and quality of feedback that can be provided to the participant. However, more detailed methods such as paper-based food records can be more burdensome for the participant leading to poorer acceptability.

In response to these concerns with dietary assessment, the investigators have developed an image-based dietary assessment system known as Technology Assisted Dietary Assessment or TADA (Bosch, Zhu, Khanna, Boushey, & Delp, 2011; Zhu, Bosch, Khanna, Boushey, & Delp, 2015). The mobile food record (mFR) App uses a camera to capture before and after images of food and beverages consumed. The Connecting Health and Technology (CHAT) study was the first intervention study to assess diet with the mFR and provide tailored dietary feedback with text messaging support to engage participants in making dietary changes. The CHAT study was undertaken as a 6-month randomized control trial (RCT) among young adults to investigate the effectiveness of tailored feedback and weekly text messaging as a method to increase serves of fruits and vegetables and decrease serves of EDNP food and SSB compared with a group receiving only tailored dietary feedback and a control group who did not receive any dietary feedback or text messages.

4.4 Methods

Design

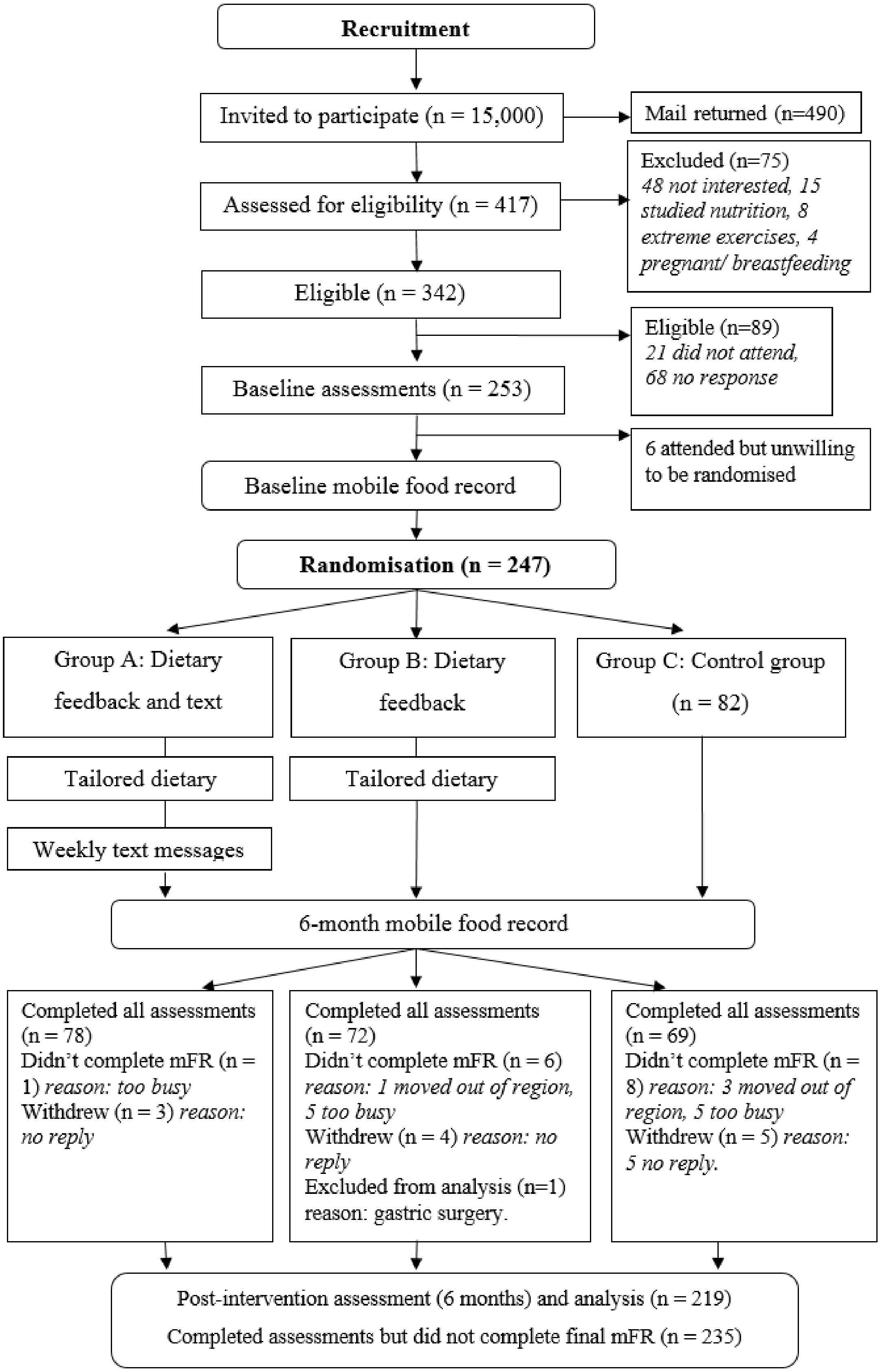
The study was a 6-month RCT to evaluate the effectiveness of a tailored dietary feedback and text messaging support in young adults aged 18 to 30 years (Figure 4.1). The trial was registered (Australian Clinical Trials Registry Registration number ACTRN12612000250831) and the protocol published (Kerr et al., 2012). The tailored intervention was based on self-determination theory (SDT) and informed by motivational interviewing (MI) (Deci & Ryan, 2012; Patrick & Williams, 2012; Vansteenkiste & Sheldon, 2006). The project was referred to as the Connecting Health and Technology (CHAT) study. The project protocol was approved by the Curtin University Human Research Ethics Committee and the Department of Health, Western Australia Human Research Ethics Committee and all participants signed an informed consent.

Participants

Young adults aged 18 to 30 years were recruited from the Federal Electoral Roll, a compulsory enrolment system for Australians aged over 18 years. They were selected from 57 suburbs within the Perth metropolitan area to provide representation across socio-economic status (Australian Bureau of Statistics, 2008). A printed letter of invitation was mailed out by an independent company, as the researchers were not permitted direct access to the mailing list. After receiving the letter of invitation, those who wished to take part in the study contacted the research team by email, mobile telephone (text or voice), landline telephone or the study website. Other recruitment methods supplemented the mail out and included advertising on the University website, flyers posted on campus and referrals from friends or colleagues. The majority of participants were recruited through the electoral roll mail out (approximately 73%).

Participants were screened for eligibility by completing a web form or by telephone and were aged between 18 to 30 years as of their last birthday and owned a mobile telephone. Exclusion criteria applied if people were unable to complete the 6 month study, undertaking extreme forms of exercise (for example, marathon training) or on a special diet (for example, strict weight loss diet or following a restrictive diet that excluded food groups), currently studying or had studied nutrition, pregnant or breastfeeding, unable to attend the study centre to complete the face-to-face assessments or if they had any serious illnesses. A participant flow diagram (Figure 4.1) outlines the reasons for exclusion.

Figure 4.1 Participant flow diagram



Data collection

Participants who met the selection criteria were invited to attend two face-to-face baseline data collection visits one week apart. At the first visit they had their height and weight measured, completed written questionnaires and underwent training on how to use the mFR App for the collection of dietary information. One of three research staff conducted each training session on how to: connect to Wi-Fi for sending images; take a practice image of plastic food replicas; and send the before and after image pair to the back-end server. Participants were instructed to record their food and beverage intake using the mFR for four consecutive days (Wednesday to Saturday) with the investigator-supplied iPod Touch (iOS6) loaded with the mFR App. When taking an image, participants were instructed to include a reference device known as a fiducial marker (shown in Figure 4.2) to assist with food identification and portion size estimation. They were instructed to record food and beverage items not captured using the iPod notes section or in a small booklet provided.

Figure 4.2 View of the website with before and after images of an eating occasion and metadata from the mobile food record images

The mFR App had an automated feature to detect the presence of the fiducial marker and alerted participants if the fiducial marker was missing from the image. An angle-detection algorithm assisted participants to take the image at the correct angle by a light turning green when the angle of the mobile device was positioned between 45 and 60 degrees from the horizontal plane. Once captured, the images were not accessible to the participant. The mFR App and the back-end server were adapted for use in this project (Kerr et al., 2012; Zhu et al., 2015). In the current study, the trained analyst confirmed the contents of the images and probed for any forgotten recordings with participants. Previous work with the mFR, showed no difference between the reported energy intake and estimated energy requirements (Schap & Boushey, 2011). The back-end server was password protected and images were stored with a unique password protected participant ID that was entered into the mFR App by the researcher. The App performed automatic uploading of food and beverage images collected by participants when in Wi-Fi range. If participants did not have access to Wi-Fi, their images were stored securely in the App until a Wi-Fi connection was made.

A week later participants attended a second baseline visit to return the iPod Touch and complete additional written questionnaires. At this visit the research dietitian interviewed each participant to verify the content of the images and probe for any forgotten food and beverages. A computer software generated randomisation table was then used to assign each participant to one of three treatment groups 1) combined dietary feedback and weekly text messages, 2) dietary feedback, or 3) control group. Sequence generation was conducted by a biostatistician not involved in the implementation of the trial on site, and therefore was not in contact with the study participants. The control group recorded their dietary intake using the mFR at baseline and again at 6 months completion but did not receive dietary feedback until the end of the study. At six months, all participants completed questionnaires, the 4-day mFR and had their weight measured. All participants received a $20 gift voucher of their choice at baseline and six months and were entered into a prize draw to win an iPad, iPod or shopping voucher at the end of the study.

Dietary analysis

A trained analyst (a research dietitian) viewed the before and after images simultaneously for food identification and estimation of amount eaten. When needed the trained analyst clarified with participants the contents of the images and checked for any forgotten food or beverages not reported. The trained analyst assessed the 4-day mFRs using a quality scoring of food items by food group (serves of fruits, vegetables and EDNP food and beverages according to the Australian Guide to Healthy Eating standard serves (AGHE) (Smith, Kellett, & Schmerlaib, 1998). AGHE serving sizes specify one serve of fruit is equivalent to 150 grams, one serve of vegetables is equivalent to 75 grams, and one serve of EDNP foods or beverages is equivalent to the amount of approximately 600 kilojoules (143 kilocalories). Note that the AGHE includes fried potato as an EDNP food not a vegetable serve. A purpose-built Microsoft Access data table was developed for food and beverages data entry with linked categories for food group, food type and serving size. The same trained analyst entered all data from the mobile food record for both the baseline and final visit. The time taken to enter each 4-day record varied between 20 and 30 minutes. To assist with portion size estimation the trained analyst used the fiducial marker in the image served as a reference for size. For each participant, an average serve per day was calculated for fruits, vegetables, SSB, EDNP foods and alcohol.

Dietary feedback messages

Once the scoring was complete, two tailored dietary feedback text messages (Figure 4.3) were constructed for the intervention participants, i.e., the dietary feedback and weekly text messages group and the dietary feedback only group, with one message for fruits and vegetables and the other for EDNP food and SSB. A standard message template was used for each dietary feedback text message but modified for each participant according to the results of the dietary analysis (Figure 4.3). For the fruit and vegetable message, a scripted message was devised for three levels of intake: (1) low: 0 to < 3.5 servings of fruits and vegetables; (2) medium: 3.5 to < 7 servings of fruits and vegetables; and (3) met recommendation: at least 2 servings of fruits and 5 servings of vegetables per day. For EDNP serves, a library of messages was developed and modified according to the participant's dietary intake for EDNP serves. For example, "…could you try eating less sugary foods?"; "could you try eating less fast food or takeaway foods?". As there is no recommended servings for EDNP foods and beverages, 0 to 3 serves were considered a low intake and the message included the text "looks like you are on the right track". At EDNP serves of 3 or more per day, the message was personalised with key sources of EDNP serves identified from the mobile food record. For example, the message in Figure 4.3: "could you try swapping sugary drinks for diet drinks/water?" indicates that for this individual sugary drinks were a key source of EDNP serves. In developing the text messages several tailoring strategies were used. The message was personalised with the individual's name and the feedback strategy was descriptive and evaluative (Hawkins, Kreuter, Resnicow, Fishbein, & Dijkstra, 2008). The language and tone of voice of the dietary feedback messages were based on results of message preference testing with focus groups (Pollard et al., 2016) and designed to be an autonomous supportive style of communication (Resnicow et al., 2008). The two text messages were sent one week apart, using an automatic text message delivery system. Alcohol intake was not addressed in the message as this was not the target behaviour for the intervention.

Figure 4.3 **Examples of the tailored dietary feedback text messages on fruits and vegetables and energy-dense nutrient-poor foods, for the intervention arms: dietary feedback and text messaging; dietary feedback only**

Fruit & Vegetable Message	Energy-Dense Nutrient-Poor Message
Low Intake [a] Hi Sarah, it's Kate from CHAT with your feedback. So how did you score? Ave fruit serves = 0.5, ave veg serves = 1. Your fruit serves varied from 0 - 1, veg from 0 - 2 over 4 days. What's the goal again? 2 fruit & 5 veg. You can only go up from here!	Low Intake Hi Andy, it's Kate from CHAT with your junk food score. Ave serves = 1, varying from 0 - 2.5, over 4 days. Junk foods are fatty, salty or sugary foods that are usually high in calories. So try to only eat these foods sometimes and if you do, in small amounts. Looks like you're on the right track!
Medium Intake [b] Hi Matt, it's Kate from CHAT with your feedback. So how did you score? Ave fruit serves = 1, ave veg serves = 3. Your fruit serves varied from 0.5 - 1, veg from 0.5 - 4.5 over 4 days. What's the goal again? 2 fruit & 5 veg. You are over half way there!	Medium Intake Hi Naomi, it's Kate from CHAT with your junk food score. Ave serves = 5, varying from 3.5-7 over 4 days. Junk foods are fatty or sugary foods & high in calories. Try eating these foods sometimes & if you do, in small amounts. Could you try swap-ping sugary drinks for diet drinks/water?
Met Recommendation [c] Hi Alana, it's Kate from CHAT with your feedback. So how did you score? Ave fruit serves = 2, ave veg serves = 5. Your fruit serves varied from 2 – 4.5, veg from 4 - 6 over 4 days. What's the goal again? 2 fruit & 5 veg. Right on target! Keep up the good work!	High Intake Hi Sam, it's Kate from CHAT with your junk food score. Ave serves = 9, varying from 5 - 11 over 4 days. Junk foods are fatty or sugary foods that are high in calories. So try to only eat these foods sometimes and in small amounts. Could you try eating less fatty foods e.g. pies, fast food?

[a] 0 to < 3.5 servings of fruit and vegetables, [b] 3.5 to < 7 servings of fruit and vegetables, [c] at least 2 servings of fruit and 5 servings of vegetables per day.

Weekly text messages

The group receiving dietary feedback and weekly text messages, were sent text messages to their mobile telephone for six months. The motivational and informative messages focused on fruits, vegetables and junk foods and beverages. The text message content was based on formative focus group work testing the potential persuasiveness of messages for use in the intervention (Pollard et al., 2016). We used an autonomous supportive style of communication (pull vs push messages) and avoided offering direct advice consistent with motivational interviewing principles (Resnicow et al., 2008). Offering substitutes and using an empathetic tone guided message construction. For example, “Running late, no time to make lunch, so you end up eating junk? How about a soup or sandwich - it's quick and healthy too!” or “Isn't it easy to reach for unhealthy snacks when you're hungry? So maybe keep some fruit handy for when those hunger pangs hit!”. The message also included web links to recipes and nutrition information. The Go for 2&5® campaign recipes (Pollard, Nicolson, Pulker, & Binns, 2009), developed and tested against nutrition criteria to meet the AGHE, were adapted for readability and suitability for smartphone viewing. A total of 32 messages were sent once or twice a week over a 24 week period. They were delivered between four and six pm on different days of the week to minimise their predictability. Participants were able to stop receiving text messages at any point by replying “stop”.

Outcome measures

The primary outcome variables measured at baseline and post intervention, were the serves of fruits, vegetables, SSB and EDNP foods consumed each day. Height and weight were measured according to a standard protocol (Stewart, Marfell-Jones, Olds, & de Ridder, 2011). Demographic and personal characteristics (sex, age, eating behaviour, educational level, country of birth, ethnicity, living arrangements, socioeconomic status, financial status, cooking abilities, attitudes towards eating a healthy diet, perception of their body weight, intake of fruits, vegetables, junk and alcohol intake and recent dietary changes) were assessed using written questionnaires (Daly, Pollard, Kerr, Binns, & Phillips, 2015). Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ) Short Form and the results reported as MET- minutes per week according to the recommended method of scoring (Craig et al., 2003). Based on a motivational interviewing strategy, importance, confidence and motivation to change behaviour with regards to the primary outcomes were examined using a 10 point rating scale; for example, ‘How important is eating a healthy diet to you? One was “*not at all important*” and 10 was “*very important*” (Resnicow et al., 2008). The responses to these questions were categorized as low for scores 0-5 and high for scores 6-10.

Statistical analysis

The primary outcomes were changes in servings of fruit, vegetables, SSB, and EDNP foods in the three groups (dietary feedback and text messaging; dietary feedback; and control group). Changes from baseline to 6 months were assessed using the paired-sample t test. Secondary outcomes were changes in body weight and BMI. The intervention effects (dietary feedback and text message compared to control and dietary feedback only compared to control) at 6 months were assessed using linear mixed effect models for continuous variables (change in serves). Differences between treatment groups are expressed as mean change in serves and associated 95% confidence interval (CI). Logistic regression analyses were used to assess whether there were differences between groups in a change of 0.5 serves in targeted foods and odds ratio along with 95% CI. Data were analysed using Stata MP 14.0 (Texas, US) and p values < 0.05 (2 tailed) were considered as statistically significant.

4.5 Results

Table 4.1Error! Reference source not found. shows the participant characteristics at baseline according to the study group. The data shows an even distribution across age, BMI category, ethnicity, education level, alcohol and smoking status. At baseline, there were no significant differences in the intake of food groups between the three study groups. In total, 220 of the 247 participants completed the intervention, which resulted in an 89% retention rate at six months. Figure 4.1 shows the reasons for non-completion. The final sample was 219 as one participant underwent gastric surgery for obesity and was excluded from the analysis. A further 15 participants who were unable to undertake the final mFR completed on-line questionaries. Two dietary feedback and text messaging participants elected to stop receiving messages.

Forty-seven percent of the participants were employed full-time and 20% were students, 37% lived with their parents and 27% lived with a partner (with no children) and 16% lived with friends. Forty-one percent of participants shared some responsibility for the household’s food shopping, 33% were the main food shopper and 23% had little or no responsibility. The majority of participants (46%) had shared food preparation responsibility, 30% were the main food preparer and 19% had little or no food preparation responsibility. Most participants said they could cook, 69% were able to cook a wide variety of meals or almost anything, 25% reported they could prepare a ‘basic meat and three veg’ meal, whilst 5 % reported being able to boil an egg, barbecue or heat frozen meals.

Each participant used a study provided iPod. As for the study participants’ own mobile telephone ownership, there were only six participants (2.4%) whose mobile telephone did not have smartphone capabilities. Approximately 56% of participants owned an iPhone and 25% owned an Android smartphone.

The effects of the intervention within each study arm and between group differences for the outcome variables are shown in Table 4.2. No significant differences were observed in food group serves for the group receiving dietary feedback and weekly text messages or for the group receiving only dietary feedback. Compared to baseline, at the end of the 6-months study, the dietary feedback and weekly text intervention group significantly reduced EDNP food. The dietary feedback only intervention arm increased vegetable intake and reduced sugar-sweetened beverage and EDNP food, and the control group significantly increased vegetable intake (Table 4.2). Subgroup analysis by gender did appear to show a different response to the intervention. Men who received dietary feedback only, significantly reduced their EDNP foods compared with controls ($p< 0.05$). For women in the dietary feedback only group compared to the control group, there was a significant reduction in SSB serves ($p< 0.05$) compared to the control group. Compared to baseline, women in all three groups significantly increased their vegetables serves ($p< 0.05$) and reduced their EDNP foods ($p< 0.05$).

Table 4.1 Characteristics of study participants randomised at baseline (n=247) comparing dietary feedback and text messages, dietary feedback only and control group

Characteristic	Feedback + Text (n=82)	Feedback only (n=83)	Control (n=82)
Men	29	28	28
Women	53	55	54
Mean ± SD			
Age (years)	24.2 ± 3.2	23.7 ± 3.4	25.0 ± 3.5
Height (cm)	168.8 ± 10.1	168.9 ± 9.1	170.9 ± 8.8
Weight (kg)	67.9 ± 14.1	70.4 ± 17.7	71.9 ± 17.6
Body Mass Index (kg/m^2)	23.8 ± 4.1	24.7 ± 6.2	24.6 ± 5.6

BMI category (%)			
Underweight < 18.5 (kg/m^2)	11.0	12.0	4.9
Healthy weight 18 .5 – 24.9 (kg/m^2)	58.5	50.6	65.9
Overweight 25 – 29.9 (kg/m^2)	20.7	25.3	13.4
Obese ≥ 30(kg/m^2)	9.8	12.0	15.9
Ethnicity (%)			
White	76.8	77.1	78.0
Aboriginal	0.0	1.2	3.7
Asian	23.2	12.0	14.6
Pacific Islander	0.0	0.0	0.0
Black	0.0	1.2	0.0
Mixed race	0.0	7.2	3.7
Level of Education (%)			
Year 12 or lower	31.7	41.0	35.4
Trade or diploma	25.6	27.7	19.5
Bachelor degree or higher	42.7	31.3	45.1
Alcohol status (%)			
Never drink alcohol	14.8	14.5	8.5
1-4 times a month	59.3	54.2	62.2
2 or more times a week	25.9	31.3	29.3
Smoking status (%)			
Never smoked	65.4	69.9	70.7
Former smoker	28.4	26.5	23.2
Current smoker	6.2	3.6	6.1
Physical Activity mean ± SD			
Total MET minutes per week	2814 ± 2876	2926 ± 3073	3155 ± 2844
Importance of eating a healthy diet[b] mean ± SD			
Score	7.6 ± 1.6	7.3 ± 1.6	7.8 ± 1.5
Food group servings (mean daily serves ± SD)[a]			
Fruit serves (150g)	1.1 ± 1.1	1.0 ± 1.1	0.9 ± 0.8
Vegetable serves (75g)	2.0 ± 1.0	1.7 ± 0.9	1.9 ± 1.1
EDNP food serves	3.1 ± 1.5	3.3 ± 1.8	3.1 ± 1.7
EDNP (sugar-sweetened) beverages	0.5 ± 0.6	0.5 ± 0.7	0.4 ± 0.5
Alcohol serves	0.6 ± 0.8	0.7 ± 1.3	0.5 ± 0.7
Total EDNP food & beverages	4.2 ± 1.9	4.5 ± 2.7	4.0 ± 2.1

[a] Serving sizes based on Australian Guide to Health Eating (AGHE). EDNP serves ~ 600 kilojoules equivalents.

[b] Question was 'How important is eating a healthy diet to you?' used a 10 point rating from zero "*not at all important*" to 10 "*very important*".

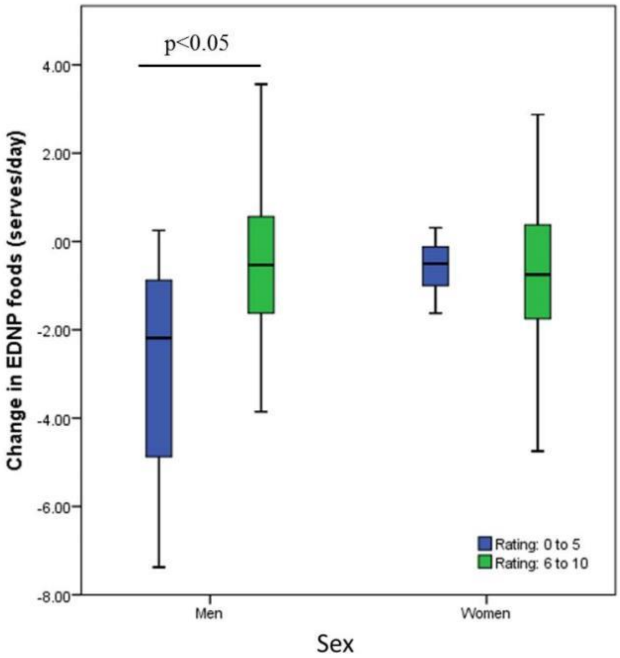
Table 4.2 The change in food groups serves per day, body weight and BMI within trial groups

	[a] Mean ± SEM (6 months – baseline)			[b] Between group difference in Mean change [95% CI]	
	Feedback + Text (n=78)	Feedback only (n=72)	Control (n=69)	Feedback + Text Control	Feedback only Control
All participants					
Vegetables serves	0.2 ± 0.1	0.4 ± 0.1*	0.4 ± 0.1*	-0.1 [-0.5,0.2]	0.1 [-0.3,0.4]
Fruit serves	-0.2 ± 0.1*	-0.1 ± 0.1	-0.2 ± 0.1	-0.1 [-0.4,0.2]	0.1 [-0.2,0.4]
Sugar-sweetened beverage serves	-0.1 ± 0.1	-0.2 ± 0.1*	-0.1 ± 0.1	0.1 [-0.2,0.3]	-0.1 [-0.3,0.1]
EDNP food serves	-0.8 ± 0.2*	-0.8 ± 0.2*	-0.5 ± 0.2	-0.3 [-0.9,0.3]	-0.4 [1.0,0.2]
Alcohol serves	-0.1 ± 0.1	-0.2 ± 0.1	0.0 ± 0.1	-0.1 [-0.4,0.2]	-0.1 [-0.4,0.2]
Body weight (kg)	0.4 ± 0.4	-0.6 ± 0.5	1.1 ± 0.7	-0.8 [-2.2,0.7]	-1.7 [-3.2,-0.3]*
BMI	0.1 ± 0.1	-0.3 ± 0.2	0.4 ± 0.2	-0.2 [-0.7,0.3]	-0.6 [-1.1,-0.1]*
Men					
Vegetables serves	-0.2 ± 0.2	0.2 ± 0.3	0.2 ± 0.2	-0.4 [-0.9,0.2]	0.0 [-0.6,0.6]
Fruit serves	-0.5 ± 0.3	-0.2 ± 0.3	-0.3 ± 0.2	-0.3 [-0.9,0.4]	0.0 [-0.7,0.7]
Sugar-sweetened beverage serves	0.0 ± 0.2	0.0 ± 0.2	-0.1 ± 0.1	0.2 [-0.3,0.6]	0.2 [-0.3,0.7]
EDNP food serves	-1.0 ± 0.4*	-1.4 ± 0.5*	-0.0 ± 0.4	-0.9 [-2.1,0.3]	-1.4 [-2.6,-0.2]*
Alcohol serves	-0.1 ± 0.1	0.0 ± 0.3	0.0 ± 0.1	-0.1 [-0.6,0.5]	-0.1 [-0.5,0.6]
Body weight (kg)	0.6 ± 0.7	0.3 ± 0.8	1.8 ± 1.9	-1.3 [-4.4,1.9]	-1.5 [-4.8,1.8]
BMI	0.2 ± 0.2	0.1 ± 0.2	0.6 ± 0.6	-0.4 [-1.4,0.6]	-0.5 [-1.5,0.5]
Women					
Vegetables serves	0.4 ± 0.2*	0.5 ± 0.1*	0.4 ± 0.2*	-0.2 [-.05,0.4]	0.1 [-0.4,0.6]
Fruit serves	-0.2 ± 0.1	0.0 ± 0.1	-0.2 ± 0.1	0.0 [-0.3,0.3]	0.1 [-0.2,0.4]
Sugar-sweetened beverage serves	-0.1 ± 0.1	-0.3 ± 0.1*	-0.1 ± 0.1	0.0 [-0.2,0.3]	-0.2 [-0.4,-0.01]*
EDNP food serves	-0.7 ± 0.2*	-0.5 ± 0.2*	-0.6 ± 0.3*	0.0 [-0.7,0.6]	0.1 [-0.5,0.8]
Alcohol serves	-0.3 ± 0.1	-0.3 ± 0.1	0.0 ± 0.1	-0.1 [-0.4,0.2]	-0.2 [-0.5,0.1]
Body weight (kg)	0.3 ± 0.5	-1.0 ± 0.6	0.8 ± 0.5	-0.5 [-2.0,0.9]	-1.8 [-3.3,-0.4]*
BMI	0.1 ± 0.2	-0.4 ± 0.2	0.3 ± 0.2	-0.2 [-0.7,0.4]	-0.7 [-1.3,-0.2]*

[a] Paired-sample t test was used to assess within group differences.
[b] Linear mixed models was used to assess between group differences.
* Statistically significant ($p < 0.05$).

There was a significant decrease in EDNP foods for men who received dietary feedback only compared to the control group ($p < 0.05$). Logistic regression analysis found men who received dietary feedback only were four times more likely to reduce their EDNP foods compared to controls (OR=4.00 95% CI [1.16 - 13.86]; $p < 0.05$). Participants were categorised into a high (6 to 10) and low (0 to 5) scores for the question 'how important is eating a healthy diet' (Figure 4.4). Men in the two intervention arms who scored low on importance of healthy eating at baseline reduced their EDNP food serves per day significantly ($p < 0.05$) compared to men whose score was high.

Figure 4.4 Interaction between sex and 'importance of healthy eating' on change in energy-dense nutrient poor (EDNP) food serves, for the two intervention arms of the study



Although not primary targets of the intervention, dietary feedback only group reduced weight and BMI significantly compared with the control group (Table 4.2**Error! Reference source not found.**, all $p < 0.05$). Further analysis of the dietary feedback only group showed the weight change from baseline was significant in those who were overweight (difference from baseline = -1.75 kg, 95% CI [-3.1, -0.4], $p = 0.01$), whereas no other BMI category (underweight, healthy weight or obese) reached statistical significance (p values ranging from 0.19 to 0.70). Control group participants who were in the healthy BMI category gained significant weight (difference from baseline =1.55 kg, 95% CI [0.57, 2.53], p=.003).

4.6 Discussion

This six-month randomized controlled trial showed using a mobile food record to inform tailored dietary feedback delivered via text messaging has promising potential for interventions targeting dietary intake and weight. Although the intervention was designed to be equally effective in both men and women this was not the case. Men who received tailored dietary feedback only showed a significant reduction of 1.4 serves of EDNP foods per day (equivalent to 840 kJ per day) compared with men in the control group. Men from both intervention groups reduced their intake of EDNP foods compared with baseline. For women, all groups increased their daily vegetable serves and reduced their EDNP food serves compared with baseline. Women in the intervention group receiving the dietary feedback only significantly reduced their daily intake of sugar-sweetened beverages, body weight and BMI compared with the control group. The participant retention was noticeably higher in the dietary feedback and text messaging (95%) compared with the other groups (dietary feedback 88% only and control 84%), suggesting greater engagement may have occurred with this arm of the intervention.

The uniqueness of this study design includes the use of the mobile food record to collect food intake data and the use of text messaging to deliver tailored dietary feedback and nutrition messages. The analysis of the 4-day mFR formed the basis of the tailored dietary feedback text message. In demonstrating the usability of the mFR for this purpose we have addressed one of the criticisms of tailoring interventions, the lack of detailed dietary data for basing the feedback on (Broekhuizen et al., 2012). Usually food frequency questionnaires or brief assessment methods are used as an outcome measurement instrument to assess fruit and vegetable intake, fibre or fat intake (Fries et al., 2005; Gans et al., 2009; Smeets, Kremers, Brug, & de Vries, 2007; Wright, Sherriff, Dhaliwal, & Mamo, 2011). More detailed measures of diet such as food records are less often used due to concerns about respondent burden and costs associated with analysis. The high adherence rates achieved in this study show the mFR is a feasible dietary assessment method in young adults with potential for upscaling to larger population-based interventions.

The observed differences in intervention effects on fruits, vegetables, EDNP foods and SSB warrants further investigation, as do the changes from baseline. The fruits and vegetables text message provided tailored feedback on participants' average daily serves intake compared with recommendations to eat two servings of fruit and five of vegetables each day. The Go for 2&5® high profile social marketing fruit and vegetable campaign has been conducted in Western Australia since 2001 and was running during the intervention period. The campaign targeted the main household food preparers (usually women) through television and other media and communications focused on increasing vegetable intake (Pollard, Daly, et al., 2009). In the current study, women in both intervention arms and the control group increased their daily serves of vegetables above baseline values but men did not. The reason for this effect on women but not men may be due to either a dietary monitoring effect or influence of the Go for 2&5® campaign. The fruit and vegetable text messages (the feedback and the weekly texts) were based on the Go for 2&5® campaign messages. Different message content may be needed to motivate men in this age group to increase their vegetable intake (Glasson, Chapman, & James, 2011).

In addition to the Go for 2&5® campaign, the LiveLighter® social marketing campaign which aims to encourage people to eat well, be physically active and maintain a healthy weight, commenced in Western Australia in June 2012 during the intervention period. Media advertisements encouraged limiting EDNP foods and beverages, particularly sugar-sweetened beverages (from July 2013). The tailored feedback on daily intake of serves of EDNP serves suggested changes they could make to their diet (see Figure 4.3 for example messages). Men in the dietary feedback only arm significantly reduced their EDNP foods whereas women in the dietary feedback only arm reduced their intake of SSB. These results may indicate the messages may have resonated with the target group and reinforced the campaign message. The focus groups that were conducted to inform the message development for this study found that messages to reduce EDNP food and SSB should incorporate both information and justification to be persuasive. There appeared to be low awareness of what constitutes EDNP foods and why they should be limited. At baseline, participants were consuming over four serves of EDNP food and beverages daily (equivalent to 2400 kJ) with EDNP making up around three serves. This is consistent with the findings of the recent Australian Health Survey which found EDNP food and beverages accounted for 35% of average daily energy intake for young adults (Australian Bureau of Statistics, 2014).

Reducing EDNP foods is an important public health intervention target and is consistent with the ‘small-change approach’ proposed by Hill (2009) for addressing obesity at a population level. The intervention group receiving tailored dietary feedback significantly reduced their body weight by an average of 1.7 kg and BMI by 0.6 kg/m^2 compared with the control group participants. Further, the weight reduction from baseline was significant in those who were overweight ($p= 0.01$). Although this intervention didn’t directly target body weight as a primary outcome, the results from this study suggest that tailored dietary feedback only appeared to have an important effect on reducing body weight in those who were overweight and that this change may have resulted from reduction in serves of EDNP foods.

Message tailoring appears to work by increasing the likelihood that people perceive the messages as personally relevant to them (Hawkins et al., 2008). The tailoring used in this RCT was static and feedback was provided only once on the baseline assessment. It has been suggested that this type of tailoring is less effective than on-going dynamic tailoring (Krebs et al., 2010). The number of intervention contacts with participants is considered important in message tailoring (Noar, Benac, & Harris, 2007). However, there is limited evidence on the most effective aspects to guide text messaging interventions (Hall, Cole-Lewis, & Bernhardt, 2015). In the current study, one intervention arm, in addition to dietary feedback only also received weekly text messages designed to support and reinforce the dietary behaviours. The message was personalised with their name and participants could respond to the message. Although we would have ideally liked to have customized the weekly messages more, this was not feasible in the current study. The weekly text messages were more targeted communications rather than individually tailored (Hawkins et al., 2008). A key finding from our focus group testing was the complexity of message development with no "one size fits all"(Pollard et al., 2016). Therefore we may not have framed the text messages in a way that was personally relevant to all participants. A priori, the hypothesis was the weekly text messages would be prompts for behaviour change. The additional intervention contacts did not appear to have any added benefit compared with dietary feedback alone. Perhaps the weekly text messaging dose was not adequate, however further research is needed to determine if this is the case.

To date there has been limited evaluation of nutrition text messaging interventions in healthy populations, with most focused on people with a chronic health condition such as diabetes or obesity (Hall et al., 2015; Siopis, Chey, & Allman-Farinelli, 2015). The weekly text messages were carefully constructed to be persuasive and increase motivation towards healthy eating behaviours (Pollard et al., 2016). However, the text messages may not have been perceived as personally relevant or more frequent and appropriate timing of messages may have had additional benefit. We were mindful of not burdening respondents or turning them off with too frequent interactions as there was little data in the literature on nutrition messages to guide the correct dose (Smith, Kerr, Fenner, & Straker, 2014). We relied on focus group advice prior to the intervention to set the weekly message dose. Only two participants in the intervention group receiving the weekly text messages opted to stop receiving them suggesting that message fatigue was not an issue. One cannot rule out that participants may have opted out by ignoring the messages or simply deleted them rather than choosing to formally stop the messages. From these results, further research is needed to identify the factors associated with text messaging acceptance, including message content for specific dietary behaviours, in healthy young adults.

A major strength of this study was the high retention level achieved which may be partly attributed to the level of engagement in technology by using the mFR App. Although the control group only had two interactions with the research team six months apart, 89 % completed the study. In our previous studies we have emphasised the importance of obtaining user feedback (Boushey et al., 2015). The request for usability feedback on the novel CHAT App at baseline and 6-month may have contributed to better engagement than is typically observed with other dietary assessment methods. A criticism of the design of technology-based behavioural interventions is the lack of behaviour change models to inform them (Mohr, Schueller, Montague, Burns, & Rashidi, 2014; Riley et al., 2011). Mohr et al. (Mohr et al., 2014) proposed a Behavioural Intervention Technology (BIT) framework for interventions using a range of technologies, including mobile telephones, the internet and sensors. Features such as usability and willingness to continue to use the App may contribute to greater engagement and motivation enhancement by participants (Mohr et al., 2014). The current intervention was designed on theoretical constructs from SDT and MI (Deci & Ryan, 2012; Patrick & Williams, 2012; Vansteenkiste & Sheldon, 2006) but future technology-based interventions may need to consider other novel constructs that take these features into account. The text message content was developed to support autonomous decision making and the ‘tone of voice’ and language used in all communications was consistent with SDT. The intervention also drew on the researchers formative focus group findings which found that providing practical solutions to barriers to healthy eating important, as well as including access to healthy, cheap, quick and easy to prepare recipes adapted to a mobile phone platform (Pollard et al., 2016).

Limitations

Although we attempted to recruit a population-based sample by using the electoral role the responders may not have been representative of the population. The response rate from women was higher than men. This is consistent with other population studies in Western Australia that have found it is more difficult to recruit men into studies than women (Pollard et al., 2013). However, the participants recruited were from a diverse background for socio-economic status and ethnicity.

We selected young adults as these are a group in transition from adolescents to adulthood and where improving dietary habits and preventing weight gain is important for the prevention of chronic diseases. Text messaging interventions in health have wide appeal to public health researchers as there is direct delivery of the message to participants. The mobile telephone is increasingly used to send reminders to people about appointments. Therefore people may 'turn off' to text messages not perceived as directly relevant to them. In the current study, intervention group participants received two personalised dietary feedback messages delivered as text messages, related to their fruit and vegetable and junk food intake. Although positive effects were observed, it is possible that with a higher dose (more frequent dietary feedback), additional changes may have been observed. Long periods of dietary monitoring may also improve outcomes. The current mFR has been designed more as an assessment tool rather than a self-monitoring tool. However, in the future, the mFR could be modified for the dual purpose of assessment and self-monitoring of diet.

The lack of effect observed with the weekly messages also requires further exploration. Our hypothesis was that the more intensive intervention with greater contact points would be more effective but this was not the case. The weekly text messages, designed to support behaviour change, were personalised with the name of the person but it is possible the content of the message may not have been relevant or sent at an appropriate time. The content of the weekly messages had been constructed from focus group work prior to the intervention (Pollard et al., 2016). As found in other research in overweight and obese adolescents (Smith et al., 2014; Woolford et al., 2011), what people say they want in a text message versus their actual experience in receiving the text message may not be the same. Process evaluation of the text messages may assist in exploring these issues to inform future interventions. A further limitation was that there was no follow up after the 6-month intervention period to evaluate if the observed changes were maintained over time.

Misreporting of dietary intake is common to most dietary assessment methods and cannot be ruled out in the current study (Subar et al., 2015). Misreporting of intake may have occurred due to participants either not recording all food and beverages consumed or modifying their usual intake during the record period. Reactivity bias may have occurred with the mobile food record; however the control group also undertook the mFR recording (same time points and length of recording) but did not receive feedback. We would expect the reactivity bias to be similar across the groups. The findings presented here are based on food group servings of fruit, vegetables and EDNP foods and beverages, rather than grams and nutrients. A possible limitation of the study was that the manual assessment of food group serves by a trained analyst may not be sensitive enough to detect small but meaningful changes in dietary habits, for example 0.25 serve increase in fruit or vegetables. Food recording whether by paper, digital entry or image-based requires an estimation of portion size by either the participant or the researcher. For the mFR the participant was not required to record the portion size consumed. The trained analyst, used the fiducial marker (a scaling device) in the image to assist with portion size estimation. Future planned improvements to automate the image analysis for the mobile food record may improve the accuracy of the dietary assessment (Zhu et al., 2015). In addition, further analysis of post-intervention feedback on the text messages may guide future improvements in the methodology.

4.7 Conclusions

This 6-month RCT has demonstrated the potential of the image-based mobile food record as a feasible method for collecting dietary data in young adults. In addition, we have been able to show the importance of dietary feedback in promoting behaviour change. The effect of the dietary feedback intervention on reduction in body weight was an unexpected finding and requires further investigation to confirm these results. This innovative approach making best use of technology for the collection of dietary data and delivering tailored feedback direct to the individual may provide an efficient delivery method for health promotion programs that target this hard to reach population group.

4.8 List of abbreviations

CHAT	Connecting Health and Technology
EDNP	energy-dense nutrient poor
mFR	mobile food record
SSB	sugar-sweetened beverages
RCT	randomized controlled trial
TADA	Technology Assisted Dietary Assessment

4.9 Competing interests

The authors do not have any competing interests. The study was funded by Healthway who did not have any role in the study design; collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication.

4.10 Author contributions

DK conceived and designed the study, participated in data collection and drafted the manuscript. AH and KK coordinated the study and undertook the data collection and analysis. ED, CB, ZA and DK conceived and designed the mobile food record. CB, ED, CP, PH, SD, JW and SP contributed to the design of the study. SD and XM performed the statistical analysis. All authors read and approved the final manuscript.

4.11 Acknowledgements

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4.12 Summary

The dietary changes seen during the CHAT study were consistent with a healthy and sustainable diet, namely the reduction in EDNP food and SSB intake. The findings in this manuscript indicate the mFR is an accepted method of collecting dietary intake data from young people in Australia, which had not been tested previously. In addition, this study found providing feedback on current dietary behaviours via a mobile device can result in behaviour change. Both of these findings are relevant to using the mFR to collect data on healthy and sustainable dietary behaviours. The candidate believes providing feedback on how one’s diet adheres to a sustainable diet and whether this motivates behaviour change is a worthwhile avenue for future research.

Chapter 5 Perception of dietary intake versus actual intake of foods related to a healthy and sustainable diet

5.1 Introduction

This chapter provides the final manuscript, after addressing the reviewers' comments, of the published manuscript on the perception versus actual intake of foods related to a healthy and sustainable diet. This chapter helps address objective two of this research - *evaluate the perception of young adults toward their energy-dense nutrient-poor food and beverage intake, compared to actual food intake data collected using a 4-day image-based mFR.*

The candidate was involved in; the screening and recruitment of participants in the CHAT study; collection of all data; analysis of all food images; formulating the research question; sorting and analysing the data; drafting the manuscript and; coordinating co-author feedback. This manuscript has been reproduced with permission (Appendix B, Section B.2).

This manuscript relates to the topic of H&S diets in a number of ways including: the intake of EDNP foods and SSBs are behaviours inconsistent with a healthy or a sustainable diet, while the intake of fruits and vegetables is consistent with a H&S diet. The results indicate people have an inaccurate perception of the volume of EDNP food and SSBs they consume, of which they consume excessive amounts.

Reference:

Harray, A. J., Boushey, C. J., Pollard, C. M., Panizza, C. E., Delp, E. J., Dhaliwal, S. S., & Kerr, D. A. (2017). Perception v. actual intakes of junk food and sugar-sweetened beverages in Australian young adults: assessed using the mobile food record. *Public Health Nutrition*, *20*(13), 2300-2307.

ARTICLE: Perception versus actual intake of junk food and sugar-sweetened beverages in Australian young adults: Assessed using the mobile food record.

5.2 Abstract

Objective: To determine perception versus actual intake of energy-dense nutrient-poor 'junk food' (JF) and sugar-sweetened beverage (SSB) intake in young adults, using the mobile food record (mFR).

Design: Before- and after eating images using a 4-day mFR were assessed for standardised 600kJ (143kcal) serves of JF and SSB (excludes diet drinks). Participants reported their concern about the health aspects of diet, perceptions and intentions regarding JF and SSB.

Setting: Perth, Western Australia.

Subjects: 246 adults (18-30 years).

Results: The mean daily intake of JF+SSB was 3.7 (SD 2.0) servings. Women thinking about drinking less SSB consumed more SSB servings/day (1.5, SD 1.2) than men (0.7, SD 0.5) ($p<0.05$) who were thinking about drinking less. Men not thinking about cutting down JF consumed more servings/day (4.6, SD 2.4) than women (2.5, SD 0.7) ($p<0.01$) who were not thinking about cutting down. Those who paid a lot of attention to the health aspects of their diet consumed less JF+SSB than those who only took a bit of notice ($p<0.001$), were not really thinking much about it ($p< 0.001$), or who didn't think at all about the health aspects of food ($p<0.01$).

Conclusion: Perceptions and attitudes regarding JF and SSB were associated with level of consumption. Those not thinking about cutting down their intake of these foods represent an important target group as they consume more than their peers. Further research is needed to identify how amenable young adults are to changing their intake, particularly given the lack of attention paid to the health aspects of their diet.

5.3 Background

Worldwide overweight and obesity rates are increasing and are related to significant health consequences (World Health Organization, 2015). Over half of young adults aged 18 to 24 years and 59% of 25 to 34 year olds in Western Australia are classified as overweight or obese (Australian Bureau of Statistics, 2013b). In Australia, 25 to 34 year olds have the greatest yearly increment in waist circumference and weight compared to any other age group and are gaining weight at a faster rate than in previous generations (Tanamas et al., 2014). To slow the trajectory of weight gain, this age group is an important target population for nutrition interventions that improve dietary habits. The excessive energy intake from the frequent consumption of 'energy-dense nutrient-poor' (EDNP) foods and sugar-sweetened beverages (SSB) and physical inactivity are modifiable risk factors associated with weight gain (Australian Institute of Health and Welfare, 2004). EDNP, commonly referred to as 'junk food' (JF) by the general public, are those foods and beverages high in energy (kilojoules), saturated fat, added sugar, salt or alcohol, and low in nutrients (NHMRC, 2013).

The availability and affordability of EDNP food and SSBs worldwide has led to higher consumption of these foods and increased likelihood of excessive kilojoule consumption (Drewnowski, 2004). Regularly consuming an energy intake above energy requirements is associated with overweight, obesity, cardiovascular disease, Type 2 Diabetes and some cancers (Martin-Calvo et al., 2014; Vartanian, Schwartz, & Brownell, 2007). Hence, the Australian Dietary Guidelines (ADGs) recommend limiting the frequency of consumption of these unnecessary EDNP foods and beverages (referred to as *discretionary choices* in the ADGs) to "occasionally" and in small amounts" (NHMRC, 2013). Adherence to the ADGs in young adults is poor. In 2011/12, the Australian National Health Survey found that adults consumed approximately 35% of their total energy intake from EDNP food and beverages, with young adults more likely to choose highly processed convenient options, such as hot chips, meat pies, chocolate, SSB, commercial burgers and pizzas (Australian Bureau of Statistics, 2012; Rangan et al., 2009). Previous research highlights that consuming excess amounts of EDNP foods and SSBs may be key factors in the rapid increase in the body weight (Bes-Rastrollo et al., 2006; Rangan et al., 2009).

Consumption of SSB has been identified as a key public health issue due to the frequency of consumption, low satiety, high added sugar content, and associations with excess weight gain (Malik et al., 2010). Over half (53%) of men and 39% of women, aged 19 to 30 years consume SSB on any given day in Australia (Australian Bureau of Statistics, 2012). A Western Australian study found that men with obesity and those ages 18 to 44 years were most likely to consume SSB (Pollard, Meng, et al., 2015). Reducing EDNP food and SSB are important targets for population-based interventions, therefore, exploring perceptions and attitudes towards these foods may lead to better outcomes. A recent study found a disconnect between perceived diet quality and whether dietary recommendations were being met, indicating the need to assess both dietary intake and perceptions (Powell-Wiley et al., 2014). Accurate assessment of dietary intake however, is difficult.

While all dietary assessment methods are accompanied by a level of participant and researcher burden, collecting accurate dietary intake data from young adults is particularly challenging. As young adults are high users of mobile devices, technology-based dietary assessment methods incorporating digital or image-based recording may be more appealing (Boushey et al., 2015; Boushey et al., 2009). An image-based method known as the mobile food record (mFR) App appears to have high acceptance amongst young people and shows potential for upscaling to population-wide nutrition monitoring(Kerr et al., 2016; Zhu et al., 2008).

Several studies have identified the unrealistic perception of dietary fat, fruit and vegetable intake as barriers for improving dietary intake (Bogers et al., 2004; Brug et al., 1994; Lechner et al., 1997; Pollard, Daly, et al., 2009), highlighting a potential disconnect between what people think they are eating and what they are actually eating. Future interventions assessing both perceived intake (using questionnaires) and actual intake (using the mFR) could segment questions which more accurately represent actual intake. This cross-sectional study aimed to assess whether young adults' perception of their current diet is associated with their intake of EDNP 'junk food' and SSB, collected using a 4-day mFR.

5.4 Methods

Study Design

This study was a cross-sectional analysis of the baseline data collected during a six-month randomised controlled trial (RCT), the Connecting Health and Technology (CHAT) study (Harray et al., 2015; Kerr et al., 2016; Kerr et al., 2012). Participants were asked to attend Curtin University on two separate occasions, one week apart. During the initial visit, height and weight were recorded and participants were asked to complete a paper-based questionnaire to collect information on demographics and on their knowledge and attitudes relating to food, nutrition and health. Participants were lent a mobile device (Apple iPod Touch) and trained how to use the specifically designed dietary assessment tool, the CHAT App, pre-uploaded onto the device. Participants were asked to collect an mFR for four days. Approval for this study was granted by the Curtin Human Ethics Research Committee and the trial was registered (Australian Clinical Trials Registry Registration number ACTRN12612000250831).

Subjects

Adults living in the Perth Metropolitan Area were recruited via the Federal Electoral Roll. Screening occurred either online using a survey website, or on the telephone to ensure the inclusion criteria were satisfied (18 to 30 years old and owned a mobile telephone). Potential participants were excluded if they were (a) unable to attend on four occasions to complete the six-month RCT; (b) studied nutrition; (c) took part in extreme forms of exercise; (d) followed a restrictive diet; or were (e) pregnant or breastfeeding.

Data Collection

Participants completed a 4-day mFR using an App running on an Apple iPod Touch. Details of the mFR CHAT App, also known as Technology Assisted Dietary Assessment system (TADA), and its use in dietary assessment have been previously described (Zhu et al., 2015; Zhu et al., 2010; Zhu et al., 2008). Participants were asked to take before- and after eating images of all meals, snacks and beverages consumed over four consecutive days (Wednesday to Saturday). Participants were instructed to record any forgotten food or beverages in the notes section of the iPod Touch or in the small paper booklet provided. On completion of the mFR, the research dietitian clarified the contents of each image with participants in an open-ended approach, avoiding the use of leading questions. Where the contents of the images were unclear (for example, food was covered up or lighting issues with image quality), the dietitian verified and recorded the image contents.

Dietary analysis

Post confirmation of the image contents, all food records were assessed by the research assistants for servings of JF and SSB, classified according to the Australian Guide to Healthy Eating standard definition of discretionary choices (NHMRC, 2013). Two research assistants trained in dietary assessment entered the food and beverages items into an electronic database independently. These data were checked by a third researcher (AH) who confirmed the content of the images and the portion size entered and corrected any discrepancies. One standard serve of ‘discretionary food’ including SSB was equivalent to 600kJ (143kcal) , for example, 12 hot chips, one slice commercial pizza, 25 grams chocolate or 375mL SSB (includes cordials, soft drinks and flavoured mineral waters, energy and electrolyte drinks, and fruit drinks). Artificially sweetened beverages were reported separately and not included in the serves of SSB. Beverages already poured into glasses were classified by type (i.e. SSB) and the volume was estimated based on the size of the drinking vessel. Where the volume could not be confirmed by the participant, the research dietitian used the fiducial marker to estimate volume. Pure (100%) fruit juices were classified according to the Australian Guide to Healthy Eating. The first 125mL (1/2 cup) of 100% juice consumed was capped as one serve of fruit, then intake above this was counted as a SSB serves. Although alcohol is also considered a discretionary food (due to it being energy-dense and nutrient-poor) and a contributor to overall kilojoule intake, it was not included in the calculation of JF or SSB serves for this study.

Attitudes toward current dietary behaviours

Written questionnaires collected demographics (age, ethnicity, employment status, income, living arrangements, education level, cooking abilities) and three questions measured attitudes regarding health aspects of diet, and self-perception of current SSB and EDNP ‘junk food’ consumption. These questions were previously used in the Western Australian Nutrition Monitoring Survey Series (Pollard, Harray, et al., 2015) and were self-completed by study participants on visit one, prior to completing the mFR. The three outcome measures were:

1. Attention paid to the health aspects of diet were measured by asking “*Which statement best describes how you feel about your diet?”* with response options of:
    1) I pay a lot of attention to the health aspects of the food I eat to make sure my diet is as healthy as possible;
    2) I take a bit of notice of the health aspects of the food I eat to make sure I have a fairly good diet;
    3) I don’t really think much about the health aspects of the food I eat;
    4) I don’t think at all about the health aspects of the food I eat.

2. Perception of current JF and SSB intake were measured by the question, "*Junk food or unhealthy food has been defined as food high in fat, sugar and/or salt with little nutritional value, such as fast food, crisps, sweetened breakfast cereals, confectionary or fizzy drinks. Which of the following best describes you?*", response options:

   1) I already eat a diet low in junk food;
   2) I am currently trying to eat less junk food;
   3) I am thinking about cutting down the amount of junk food I eat;
   4) I am not thinking about cutting down on the amount of junk food I eat.

   The term junk food was used as this is a commonly used contemporary term among Australians.

3. Intention toward changing current SSB intake was measured by asking *"Which of the following best describes you?"* and the response options were:

   1) I am currently trying to drink less sugary drinks (e.g. soft drinks, cordial, energy drinks or sports drinks);
   2) I am thinking about trying to drink less sugary drinks;
   3) I am not thinking about cutting down on the amount of sugary drinks I have;
   4) I already drink very little sugary drinks;
   5) I don't drink sugary drinks.

Statistical analysis

Descriptive statistics were used to assess the participants' physical characteristics and their mean intake of JF and SSB serves (treated as a continuous variable). The comparison between the mean daily intakes of two groups (men versus women) were compared using 2-sample t-test, and the comparison between the four groups of participants were conducted using Analysis of Variance. The perception of diet was compared to actual mean daily intake of food group serves. ANOVA and t-tests were selected as we are comparing the group means for the daily intake of JF and SSB serves collected over a 4-day mFR. One-way ANOVA analyses was used to measure the differences between mean daily intake of JF or SSB serves using the mFR and how participants felt about their diet. Age was not significantly different between all groups compared ($p>0.05$). The dependent variable for the analyses was the intake of JF only, SSB only and JF and SSB combined (JF+SSB).

5.5 Results

Demographics

The study sample consisted of 247 participants (85 men and 162 women), with a mean age of 24.3 years ($_{SD}$ 3.4) and a mean body mass index (BMI, kg/m^2) of 24.3 ($_{SD}$ 5.4) (Table 5.1). One participant was excluded due to an incomplete mFR (*n* 246). Self-reported highest education level found 36% of participants had completed school years '10, 11 or 12', 24% had a trade or diploma and 40% had a University degree or higher (Table 5.1).

Dietary intake of junk foods and sugar-sweetened beverages.

The mean intake of JF+SSB was 3.7 serves per day ($_{SD}$ 2.0). Men consumed a mean of 3.3 serves ($_{SD}$ 2.0) of JF and 0.55 serves ($_{SD}$ 0.65) of SSB each day (Table 5.1). The mean intake for women was 3.1 serves ($_{SD}$ 1.4) of JF and 0.46 serves ($_{SD}$ 0.59) of SSB per day. There were no statistically significant difference between men and women for the intake of JF, SSB, or JF+SSB. Age and a BMI (< or ≥ 25 kg/m^2) were not associated with intake of JF, SSB or JF+SSB.

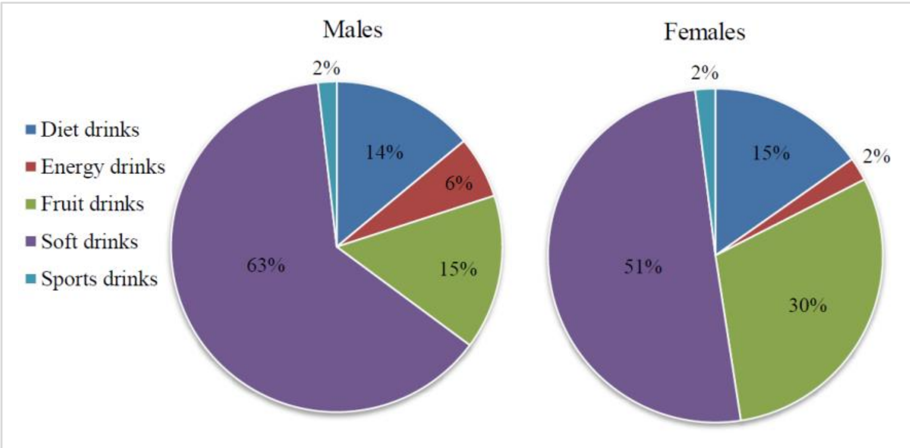
Table 5.1 Characteristics of participants and actual mean serves of junk food and sugar-sweetened beverages over the 4-day mFR

Characteristic	Men (n = 85)		Women (n = 161)		Persons (n = 246)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	24.6	3.3	24.2	3.4	24.3	3.4
Height (m)	1.78	0.1	1.65	0.1	1.7	0.1
Weight (kg)	78.7	15.1	65.6	15.6	70.1	16.6
BMI (kg/m^2)	24.7	4.4	24.1	5.8	24.3	5.4
Sugar-sweetened beverage serves*	0.5	0.6	0.5	0.6	0.5	0.6
Junk food serves*	3.3	2.0	3.1	1.4	3.2	1.7
Junk food plus SSB serves	3.8	2.3	3.6	1.8	3.7	2.0
Education level	*n*	%	*n*	%	*n*	%
Year 10, 11 or 12	32	38	56	35	88	36
Trade or diploma	29	34	31	19	60	24
University Degree or higher	24	28	74	46	98	40

*One serve of junk food or SSB is equivalent to 600kJ (e.g. 1 serve= 375mL SSB, 1 serve= 25g chocolate). Australians are encouraged to consume these foods 'occasionally and in small amounts' (NHMRC, 2013).

Of those who consumed SSB or artificially sweetened (diet) beverages, the most commonly consumed beverage was soft drink (e.g. cola, lemonade) (55%), followed by fruit drink (25%), diet drinks (15%) and energy drinks (3%). Although fruit drinks occupied a greater proportion of SSB consumed by women compared with men (Figure 5.1), there were no significant differences in the types of SSB consumed by sex.

Figure 5.1 Types of sugar-sweetened beverages and artificially sweetened beverages consumed, by sex



Perception of junk food intake compared to intake recorded using the mFR

Perception of junk food intake using the questionnaire and dietary intake, assessed using the mFR, are presented in Table 5.2. Participants who believed they were already eating a diet low in junk food consumed 2.5 (SD 1.4) serves of JF each day, less than those who reported currently trying to eat less JF 3.3 (SD 1.5) serves ($p < 0.001$), thinking about cutting down 3.5 (SD 1.7) serves ($p < 0.001$) or not thinking about cutting down 3.8 (SD 2.2) serves ($p < 0.001$). Men who were not thinking about eating less junk food consumed more JF per day than women who were also not thinking about eating less junk food, 4.6 serves (SD 2.4) and 2.5 serves (SD 0.7), respectively ($p < 0.01$) (Table 5.2).

Perception of sugary drink intake compared to intake recorded using the mFR

Over 53% of participants reported drinking very little or no sugary drinks, 36% were either trying to drink less sugary drinks (27%) or thinking about drinking less sugary drinks (9%), and 11% were not thinking about cutting down on the amount of sugary drinks they consume (Table 5.2). Amongst those thinking about drinking less sugary drinks, women consumed significantly more SSBs than the men (1.5 (SD 1.2) serves and

0.7 (SD 0.5) serves respectively (p<0.05)). However, in those not thinking about drinking less sugary drinks, men consumed significantly more SSBs (1.2 serves, SD 0.9), than women (0.5 serves, SD 0.4) (p<0.05).

One Way ANOVA analyses revealed that participants who said they don't drink sugary drinks consumed less SSB than those who were trying to drink less sugary drinks (0.2 serves vs 0.6 serves per day, respectively p<0.05), thinking about drinking less sugary drinks (1.0 serves, p< 0.001) and those not thinking about drinking less (0.8 serves, p<0.001) (Table 5.2). Participants who said they already drink very little sugary drinks consumed less SSB than those who were trying to drink less (p<0.001), thinking about drinking less (p< 0.001) or were not thinking about drinking less (p<0.001). Participants trying to drink less sugary drinks consumed less SSB than those who were thinking about drinking less sugary drinks (p< 0.001) and those not thinking about drinking less (p< 0.05).

Attention paid to the health aspects of food eaten

The level of attention participants paid to the health aspects of the food they ate was associated with their intake of JF, SSB, and JF+SSB assessed using the mFR (Figure 5.2Figure 5.2). Those who paid a lot of attention consumed less JF+SSB than those who were taking a bit of notice (p< 0.001), not thinking much about it (p< 0.001) or not thinking at all about it (p< 0.01). Those who paid a lot of attention to the health aspects of the food they ate consumed 0.25 serves (SD 0.4) of SSB compared with those who don't really think much (0.6 serves, SD 0.8; p< 0.05) and those who don't think at all (1.4 serves, SD 0.8; p< 0.001). There was no significant difference in SSB intake between participants who paid a lot of attention and those who only take a bit of notice. Age, sex and BMI were not associated with attention participants paid to the health aspects of the food they ate.

Table 5.2 Perception of diet compared to actual mean daily intake of junk foods and SSBs collected over 4-day mFR, by sex

Perception of junk food intake	Actual mean daily serves of junk food over 4-day mFR								
	Men (n=84)			Women (n=158)			Persons (n=242)		
	n (%)	Mean	SD	*n* (%)	Mean	SD	*n* (%)	Mean	SD
I already eat a diet low in junk food	20 (24)	2.3	1.5	44 (28)	2.6	1.3	64 (26)	2.5	1.4
I am currently trying to eat less junk food	30 (36)	3.1	1.6	68 (43)	3.4	1.5	98 (41)	3.3	1.5
I am thinking about cutting down the amount of junk food I eat	19 (22)	3.6	2.3	38 (24)	3.5	1.4	57 (23)	3.5	1.7
I am not thinking about cutting down on the amount of junk food I eat	15 (18)	4.6**	2.4	8 (5)	2.5	0. 7	23 (10)	3.8	2.2

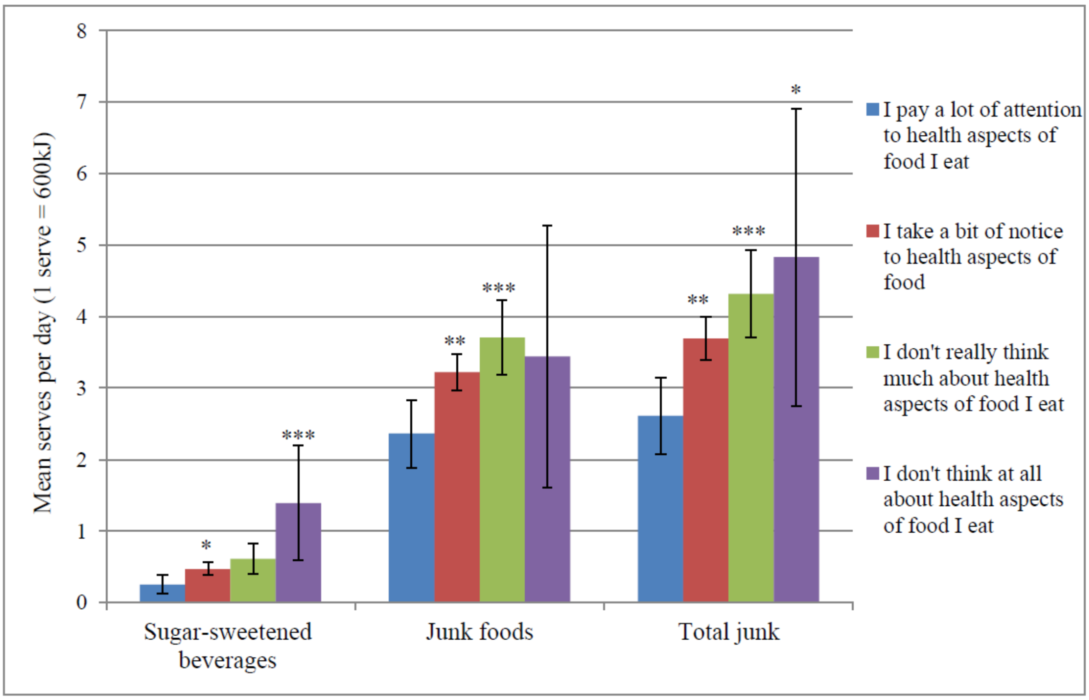
Perception of sugary drink intake	Actual mean daily serves of SSBs over 4-day mFR								
	Men (n=84)			Women (n=158)			Persons (n=242)		
	n (%)	Mean	SD	*n* (%)	Mean	SD	*n* (%)	Mean	SD
I don’t drink sugary drinks	4 (5)	0.1	0.1	13 (8)	0.3	0.6	17 (7)	0.2	0.5
I already drink very little sugary drinks	31 (36)	0.2	0.3	82 (51)	0.3	0.4	113 (46)	0.3	0.4
I am currently trying to drink less sugary drinks (soft drinks, cordial, energy drinks or sports drinks)	24 (28)	0.6	0.7	42 (26)	0.6	0.5	66 (27)	0.6	0.6
I am thinking about trying to drink less sugary drinks	13 (15)	0.7*	0.5	9 (6)	1.5	1.2	22 (9)	1.0	0.9
I am not thinking about cutting down on the amount of sugary drinks I have	13 (15)	1.2*	0.9	14 (9)	0.5	0.4	27 (11)	0.8	0.7

|Attention paid to health aspects of diet	Actual mean daily serves of junk foods plus SSBs over 4-day mFR								
	Men (n=85)			Women (n=159)			Persons (n=244)		
	***n* (%)**	**Mean**	**SD**	***n* (%)**	**Mean**	**SD**	***n* (%)**	**Mean**	**SD**
I pay a lot of attention to the health aspects of the food I eat to make sure my diet is as healthy as possible	11 (13)	2.2	1.9	29 (18)	2.8	1.6	40 (16)	2.6	1.7
I take a bit of notice of the health aspects of the food I eat to make sure I have a fairly good diet	50 (59)	3.9	2.0	97 (60)	3.6	1.7	147 (60)	3.7	1.8
I don’t really think much about the health aspects of the food I eat	22 (26)	4.4	2.7	29 (18)	4.2	1.8	51 (21)	4.3	2.2
I don’t think at all about the health aspects of the food I eat	2 (2)	6.1	0.3	4 (3)	4.2	2.2	6 (3)	4.8	2.0

Significant differences between men and women (dependant variable: junk food or SSB intake) *$p< 0.05$, ** $p< 0.005$

One serve of junk food or SSB is equivalent to 600kJ (e.g. 1 serve= 375mL SSB, 1 serve= 25g chocolate). Australians are encouraged to consume these foods ‘occasionally and in small amounts’ (NHMRC, 2013).

Figure 5.2 **How the level of attention participants paid to the health aspects of their diet was associated with their actual mean daily intake of junk foods and sugar-sweetened beverages serves**



Level of statistical significance using One-way ANOVA, against 'I pay a lot of attention to the health aspects of the food I eat' *$P < 0.05$, ** $P < 0.005$, *** $P < 0.0001$

5.6 Discussion

Participants perceptions of their current junk food and sugary drink intake were associated with their intake of these foods assessed using the mFR. There were significant associations between perceived and actual intake of junk foods (JF, SSB, JF+SSB) found in our study, highlighting the need to incorporate assessment methods to strengthen knowledge regarding these dietary behaviours. Young adults who reported they were not thinking much or at all about the health aspects of the food they ate consumed significantly more JF+SSB than those who said they paid a lot of attention (4.8 and 4.2 serves, respectively). Based on their consumption, they represent a priority target population. The challenge however is that they may be less amenable to changing their dietary behaviour as health is not a salient issue.

Young adults who perceived their diet to be low in JF consumed significantly less than those who felt their diets were high in JF; although they still consumed about 2.8 serves of JF+SSB each day; equivalent to approximately 1700kJ (406kcal). The findings indicate that compared to their peers young adults who believed they were already consuming a diet low in JF had a semi-accurate perception of their intake compared to the intake of their peers.

The majority of participants in this study reported they were currently trying to eat less junk food (40%) or already eating a diet low in junk food (26%), indicating either a particularly motivated group or a strong influence of social desirability. Social desirability is evident when positive responses are given in the hope to impress the research investigators, either intentionally or unintentionally (Cadmus-Bertram & Patterson, 2013) and can be a result of a person's knowledge of dietary recommendations or what they believe to be healthy or unhealthy dietary choices. A participant's modification of their dietary intake, for reasons of social desirability, is a potential influencing factor in all forms of self-reported dietary assessment, with junk food more likely to be underreported than more nutritious foods (Bingham et al., 1995; Krebs-Smith et al., 2000; Subar et al., 2015). In the current study, the mean intake of SSB was 0.5 serves per day (equivalent to 187 mL). These findings are consistent with another study in young Australian adults (Rangan et al., 2016). The dietary intake was collected using a 5-day electronic dietary record and found a median intake of 172 g of SSB per day. However, we cannot rule out that although participants in the current study could not review or edit the mFR images, they may have altered their intake of junk foods and SSB prior to capturing their intake. The recording process itself may have also raised the participant's awareness of their intake leading to changes in food and beverage intake. In addition, the Western Australian state Government funded *LiveLighter®* public health social marketing campaign (LiveLighter, 2015; Morley et al., 2016), which used mass media to discourage the consumption of junk foods and SSB was being conducted around the time of data collection and therefore may have influenced participants perceptions and dietary intake.

The highest consumers of junk food were men who reported they were not thinking about cutting down their junk food intake. Almost one in five young men (18%) consumed an average of 5.3 serves of junk foods and SSB per day, equivalent to approximately 3180kJ (760kcal) and higher than all other groups. This is despite the Australian Guide to Healthy Eating recommendations that these foods should only be consumed "occasionally and in small amounts for good health" (NHMRC, 2003).

These findings indicate nutrition interventions may need to specifically target young men to increase awareness of their food and SSB intake. As with other behaviours, these findings also suggest nutrition messages regarding JF and SSB need to be targeted to participant’s knowledge, attitudes, perceptions and behaviour, while acknowledging the availability of healthier options within their food environment (Fishbein & Ajzen, 1975; Powell-Wiley et al., 2014).

These findings reinforce the need to better understand the relationship between perceived diet and actual dietary intake as potential barriers to dietary change as this may lead to more appropriate targeting of nutrition messages and public health interventions. Powell-Wiley et al. (2014) investigated the association between perceived and objective diet quality, using the Dietary Approaches to Stop Hypertension (DASH) index score finding that among most ethnic groups those who perceived their diet quality to be higher received a higher objective diet quality index score. However, consistent with the findings of the current study, measured diet quality was not consistent with dietary recommendations.

The notable strengths of our study include the use of a population-based sample of young adults and the collection of dietary intake data over four consecutive days using the mFR App, including weekdays and a weekend day. Asking participants to report on how they perceived their diet prior to informing them of which elements of diet were being assessed strengthens these findings. Using the mFR to measure dietary intake provides a more objective method compared to short screening questions due to the level of systematic error inherent in methods whereby people are expected to estimate usual dietary intake (Kirkpatrick et al., 2014).

There are some limitations that need to be considered when interpreting the results of our study. Firstly, a definition of the term ‘junk food’ was provided to participants with examples when completing the questionnaire, however, this was not a complete list. The foods classified as *discretionary choices* in the Australian Guide to Healthy Eating for the analyses may not have been perceived as ‘junk food or SSB’ by some participants when answering the question, for example butter, mayonnaise, or fruit juice drink. An understanding and sound knowledge of food, nutrition and dietary recommendations would be required to provide an accurate assessment of discretionary intake. Secondly, misreporting of junk foods and SSB may have occurred as a result of participants either modifying their usual dietary intake during the 4-day mFR or being selective in the foods and beverages they took images of. Participants were asked to take images of all foods and beverages consumed over four days but only junk foods and SSB were considered in these analyses. Whilst a longer recording period may better capture the intake of JF and SSB, it tends to lead to less compliance. We elected to use four days as this is the typical recording period with paper-based food records and were mindful of participant burden but this may not have fully captured usual intake. Lastly, although we attempted to recruit a population-based sample by recruiting through the Federal Electoral Roll (a compulsory register of voters in Australia) it is possible however, that the findings are not representative of the population of young adults.

Previous research has highlighted a need to explore determinants of food behaviours in young adults as they transition from adolescence to adulthood (Thorpe et al., 2014). Although there is a strong evidence base supporting the relationship between JF and SSB intake and negative health outcomes, there is limited evidence on how young adults perceive their intake, their intention to change and whether this is a determinant of food choice.

5.7 Conclusions

Young adults who pay more attention to the health aspects of the food consume less junk foods and sugar-sweetened beverages, regardless of age, sex or BMI. Compared to their peers young adults who believed they were already consuming a diet low in junk food had a semi-accurate perception of their intake compared to the intake of their peers. However, even this group consumed unhealthy foods in excess of dietary recommendations for good health. The findings from this cross-sectional analysis indicate the importance of assessing attitudes when developing nutrition interventions. Specific strategies are required for those who are not currently thinking about cutting down their intake of junk foods and sugar-sweetened beverage intake and those who pay little or no attention to the health aspects of the food they eat.

5.8 Acknowledgments

The Connecting Health and Technology Study was funded by a three-year Heathway Project Grant with funding from the Department of Health, Western Australia. The authors are grateful to the Purdue University TADA project team, Marc Bosch, Ziad Ahmad, Maggie Zhu, Yu Wang and Brendon Wade and Andrew Buttsworth from Curtin University IT Services, for their ongoing technical support for the mobile food record application. We wish to thank the study participants.

5.9 Conflicts of interest

The authors of this manuscript have no conflicts of interest to declare.

5.10 Summary

The foods measured in this study, EDNP foods and SSBs, are inconsistent with a healthy and sustainable diet and Australian young adults consume well above recommended limits for good health. The findings help address the gap in the literature around between how people perceive their current dietary intake compared to their actual intake, assessed using the mobile food record. This study found that people who pay attention to the health aspects of their diet consume significantly less of these foods than those who do not think much about health. This raises the question, are nutrition messages encouraging people to pay more attention to food choice for good health enough of a motivation to eat foods more supportive of the environment? The findings suggest that people may believe their current dietary intake is more closely aligned with a healthy and sustainable diet than what is actually is.

Chapter 6 Eating frequency and intake of foods related to a healthy and sustainable diet

6.1 Introduction

This chapter involved a cross-sectional analysis of 4-day mFRs collected from 247 participants collected at baseline as part of an RCT in young adults (the CHAT study). The findings address objective three of this thesis - *Determine the association between daily eating occasions and the intake of foods relating to a healthy and sustainable diet, as defined by the consumption of fruit, vegetables, EDNP foods and beverages.*

The candidate contributed to this study by: formulating the research question; designing a Microsoft Access Database to categorise eating occasions; collecting all data; analysing all eating images from 247 4-day mFRs for types and number of eating occasions; assessing food group intake; analysing data and; writing the chapter. This chapter is formatted as a draft manuscript as the candidate aims to submit these findings to a scholarly journal for publication.

There are multiple influences on food intake so it is important to assess eating patterns and context when assessing diet. For example, the types of foods, combinations of foods, eating times and locations. Doing so helps gain understanding of what behaviours encourage healthier eating and potential areas for change. It can also help dietary recommendations and public health messages be more relevant to the eating behaviours of populations. In the assessment of healthy and sustainable diets, the candidate aimed to assess whether the number of daily eating occasions (eating frequency) were associated with these dietary behaviours. A healthy and sustainable diet is characterised by a diet high in plant-based foods, moderate amounts of animal-based foods, low in highly processed EDNP foods and SSBs and adequate energy to meet individual energy requirements, but not beyond (Friel et al., 2013). The mFR had not previously been used to assess eating frequency or a sustainable diet.

MANUSCRIPT: The mobile food record: A novel way to assess the association between eating frequency, food intake and body mass index using automated time and date stamps.

Amelia J Harray, Carol J Boushey, Edward J Delp, Satvinder S Dhaliwal, Christina M Pollard and Deborah A Kerr.

6.2 Abstract

Objective: Young adults are gaining weight at a faster rate than any other age group. Poor diet and the number of daily eating occasions (EOs) are possible contributing factors. However, assessing the number of daily EOs, referred to as eating frequency (EF), often relies on self-reported eating times and EO types. The objective of this study was to use a novel dietary assessment method to assess eating occasions to determine whether eating frequency is associated with food intake and body mass index.

Design: Participants used a purpose built App to collect a 4-day image-based mobile food record (mFR). Each ‘before’ and ‘after eating’ image contained an automated time and date stamp thus eliminating the need for participants to record EO data. Types of EOs were categorised and serving sizes of food groups estimated by the research team.

Setting: Perth, Western Australia.

Subjects: Adults aged 18 to 30 years (n= 240).

Results: The mean body mass index (BMI) of the 82 men and 158 women was 24.7 ± 4.4 and 24.0 ± 5.8 kg/m^2, respectively. Men recorded a mean of 4.7 ± 2.4 EOs and women 5.1 ± 2.1. After adjusting for sex and BMI, significant positive associations were found between EF and fruit (r= 0.309, p< 0.001), vegetable (r= 0.320, p< 0.001), energy-dense nutrient-poor food (EDNP) (r= 0.228, p< 0.001) and alcohol intakes (r= 0.751, p< 0.000). There was no association with sugar-sweetened beverage intake. An inverse association between BMI and EF was found (r= -0.190, p< 0.01).

Conclusion: Greater EF was associated with a lower BMI and improved fruit and vegetable intake. Of concern was the association with EDNP food and alcohol intake because of related poor health outcomes. These findings suggest EF may be important when considering targeted nutrition messages, and the mFR is an objective method to

assess dietary behaviours without the need for participants to record the types and times of foods consumed.

Keywords: mobile food record; eating frequency; eating occasions; dietary intake; body mass index.

6.3 Background

There has been a global shift from nutrient to food based dietary recommendations, with a greater focus on dietary patterns (Cespedes & Hu, 2015). As eating behaviours in Australia change it is important to consider more than just food intake when assessing diet. Obesity rates in Australia are increasing with more people moving from being classified as overweight (BMI 25 - 29.9 kg/m^2) to obese (BMI $\geq$30 kg/m^2) (Australian Bureau of Statistics, 2012), with young adults gaining weight faster than any other age group (Allman-Farinelli, Chey, Bauman, Gill, & James, 2007). Increasing portion sizes and the excessive intake of energy-dense nutrient-poor (EDNP) foods and beverages have been linked with overweight and obesity (NHMRC, 2013; World Health Organization, 2003). However, eating frequency (EF) may be a contributing factor with some studies finding dietary habits that include more ‘snacking’ or ‘grazing’ are associated with overweight (Duffey & Popkin, 2011; Leech et al., 2017). A researcher in this area, Richard Mattes, proposed that environmental and metabolic signals may play a greater influence on how often people eat compared to feelings of hunger and suggested more research on the health effects of EF was required to challenge the emphasis put on portion size and weight gain (Mattes, 2014b).

There are a lack of consistent findings in studies examining eating occasions (EOs). An increased number of EOs has been associated with higher BMI (Duffey & Popkin, 2011; Howarth et al., 2007), lower BMI (Aljuraiban et al., 2015; Drummond et al., 1998), lower overall energy intake or higher nutrient density of the diet (Aljuraiban et al., 2015; Ritchie, 2012).

There are inconsistencies in terminology and perceptions of what constitutes a ‘meal’ or ‘snack’ which adds additional complexity with regard to partitioning EOs (Hess et al., 2016; Hess et al., 2017). Calls for a neutral definition to assist further research have been suggested by researchers, including terms such as ‘feeding frequency’ or ‘ingestive frequency’ which encompass both food and beverage intake (Leech et al., 2015a; Mattes, 2014a; Mattes, 2014b). Previous studies investigating EOs have classified them by the reported or recorded time in which the food was consumed as specific time intervals, e.g., within a 15 minute period (Aljuraiban et al., 2015; Drummond et al., 1998; Duffey &

Popkin, 2011; Popkin & Duffey, 2010) or a one hour period (Howarth et al., 2007)); the type of food consumed (Drummond et al., 1998); the kilojoule density of the food or beverage (Leech et al., 2015a); a participant classification system whereby the respondent states whether the EO was a 'snack' or 'meal' (Duffey & Popkin, 2011; Popkin & Duffey, 2010) or specifically reported as 'breakfast', 'lunch' or 'dinner' (Fayet-Moore et al., 2017; Howarth et al., 2007). Some studies excluded all beverages from the analysis of EOs (Aljuraiban et al., 2015) while others counted EOs where beverages were consumed if more than half a pint of milk was consumed (Drummond et al., 1998).

There are limited dietary assessment methods to objectively assess EF without placing additional burden on participants. The assessment of EOs often heavily relies on memory or self-reported eating times (Leech et al., 2015b; Leech et al., 2017). Collecting such dietary information can create extra burden for people on top of estimating or recording the types and volumes foods and beverages consumed, and cannot be verified. Self-reported methods used to assess EF previously, such as the 24HR method (Aljuraiban et al., 2015; Evans et al., 2015; Fayet-Moore et al., 2017; Leech et al., 2015a; Smith et al., 2012a; Smith et al., 2012b; Zizza & Xu, 2012), rely on the recall ability of the participant. Another method which has been used to assess EF is the weighed food record (Drummond et al., 1998; Ritchie, 2012), which involves participants electronically or manually recording what, when and how much they eat or drink. Although it is assumed people will complete this is real time, this is often not the case (Boushey et al., 2009).

Use of the mobile food record (mFR) allows for a more objective assessment of eating frequency. The purpose built mFR App can objectively assess EF by using automatically recorded time and date stamps from each eating image, thus eliminating the need for participants to record these data points. This embedded feature in the mFR may improve accuracy when assessing eating times by reducing burden on participants. Therefore, providing unique data which may identify associations between eating occasions, eating behaviours and BMI. The objective of this study was to use a novel dietary assessment method, the mFR, to determine whether EF is associated with key dietary intake indicators and BMI.

6.4 Methods

Study design

This study was a cross-sectional analysis using the baseline data collected during a 6-month randomised controlled trial, the Connecting Health and Technology (CHAT) study.

Participants were asked to attend Curtin University on two separate occasions, one week apart. During the initial visit, anthropometric data were collected and participants were provided with a mobile device (iPod Touch). Participants were taught how to use the specifically designed dietary assessment tool, the CHAT App (also known as the mFR or as part of the TADA system), uploaded onto a device to collect an image-based mFR. On completion of the mFR, participants returned the devices, completed paper usability questionnaires and confirmed their images with the Research Dietitian. This involved the Dietitian accessing the external server to collect the respective participant's eating images, and confirming any ambiguous or occluded foods and beverages using open ended questions (for example, "Can you please tell me what was in this glass?"). Details of the study have been previously described (Kerr et al., 2012). Ethics approval was obtained from Curtin University. Australian Clinical Trials Registry Registration number: ACTRN12612000250831.

Study participants

Community dwelling individuals living in the Perth Metropolitan Area were recruited via the Federal Electoral Roll. Participants were screened either online, using a survey website, or on the telephone to ensure the inclusion criteria were satisfied (18 to 30 years old and owned a mobile phone). Potential participants were excluded if they were (a) unable to attend on four occasions to complete the 6-month randomised controlled trial; (b) studied nutrition; (c) took part in extreme forms of exercise; (d) followed a restrictive diet; or (e) pregnant or breastfeeding. A total of 247 participants completed the baseline mFR, however, seven participants were excluded from the analysis of EF due to incomplete mFRs or an average of less than one EO per day.

Data collection

Participants completed a 4-day mFR running on an iPod Touch. Details of the mFR CHAT App have been previously described (Kerr et al., 2012). Participants were asked to take 'before' and 'after' eating images of all foods and beverages consumed over four consecutive days, from Wednesday to Saturday. Images were automatically sent to an external server, therefore could not be reviewed or edited by the user. All devices used in this study were set in the same time zone and connected to Wi-Fi.

Assessment of eating occasions

In this study the term ‘eating occasion’ applies to times in which foods and/or beverages (excluding water only occasions) appeared in the before eating image captured by individuals using the mFR accompanied with a date and time stamp. The number of EOs is referred to as ‘eating frequency’.

Each ‘before’ and ‘after eating’ image contained an automated time and date stamp, allowing for identification of the time at which food and/or beverages were consumed (Figure 6.1). The Research Dietitian classified EOs according to whether the image contained: food only; food and beverage; beverage only (excluding water); single item; or water only. Each image was classified as a unique eating occasion. To assist in the accuracy of portion size estimation, participants were asked to place a small fiducial marker in the bottom left hand corner of every image.

Figure 6.1 Example of before and after-eating image from a cloud based server housing the images captured using the mFR with date and time stamp

Assessment of healthy eating

All images were assessed and serve sizes were classified according to the Australian Guide to Healthy Eating (NHMRC, 2003; NHMRC, 2013). The following food groups were included in these analyses: fruits; vegetables, EDNP foods, SSBs and alcohol. EDNP refers to foods and beverages high in energy and low in nutrients, hence are not required to meet the nutrient requirements of individuals. The ADGs recommend limiting foods from this food group to only occasionally and in small amounts (NHMRC, 2013). One serve of EDNP foods, SSBs or alcohol is equivalent to 600kJ (143kcal).

Statistical analysis

Descriptive statistics were used to assess age, BMI, number of EOs and food group servings averaged over the 4-day mFR (treated as continuous variables). Due to the skewed nature of dietary intake data, food group servings were displayed as median and 95% confidence intervals (95%CI). Non-parametric tests, including Spearman's correlation and the Mann-Whitney Test, were used to assess the relationship between eating frequency and individual variables, including fruit, vegetable, EDNP food, SSBs and alcohol servings per day. Levene's test for equality of variances was used to assess whether there were significant differences in the number of eating occasions between men and women. Logistic regression analyses were used to assess whether there were associations between the intake of foods servings (as above), sex, BMI (above and within the healthy weight range) and eating frequency. These findings were presented as odds ratio (OR) along with 95%CI. Sex and BMI were adjusted for in the logistic regression analyses, therefore the participants' height and weight were considered. Data were analysed using SPSS Version 22 and p values < 0.05 (2-tailed) were considered as statistically significant.

6.5 Results

Descriptive statistics of study sample

The sample consisted of 82 men and 158 women, with average ages of 24.7 ± 3.4 years and 24.2 ± 3.4 years, respectively. The mean BMI for men was 24.7 ± 4.4 kg/m^2 and for women, 24.0 ± 5.8 kg/m^2.

Food group intake over 4-day mFR

The mean daily intake of fruits and vegetables for all participants (n=240) was 0.98 and 1.9 servings, respectively. Mean daily EDNP food, SSBs and alcohol servings were 3.2, 0.49 and 0.58, respectively, equivalent to 2560 kJ from EDNP foods and beverages per day. Table 6.1 outlines the median and 95% confidence interval (CI) for each food group by sex.

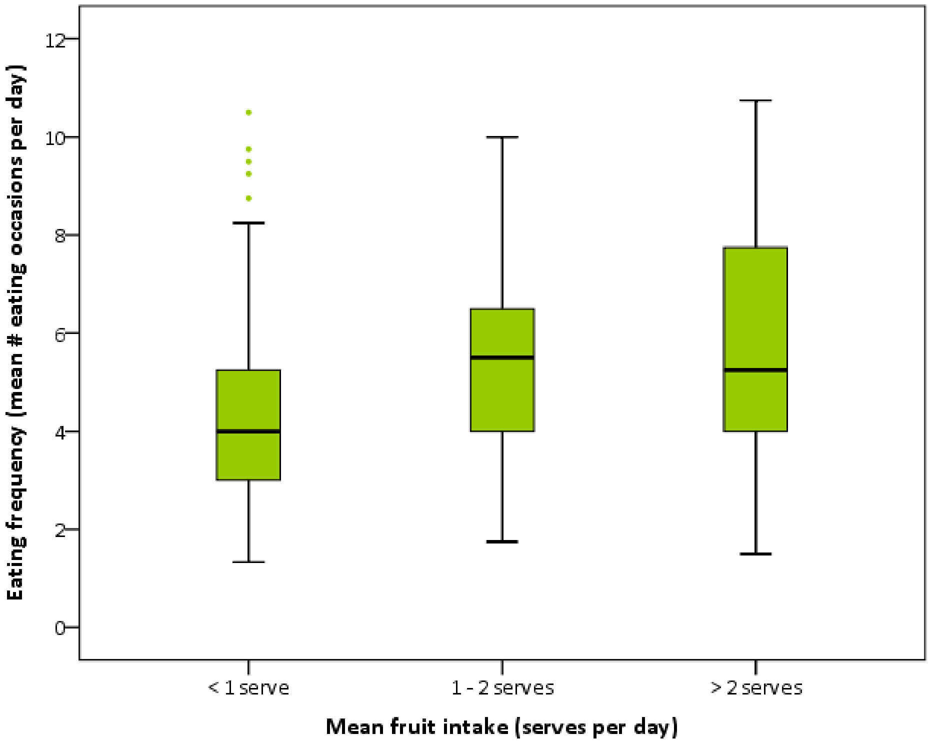
Mean number of eating occasions over 4-day mFR

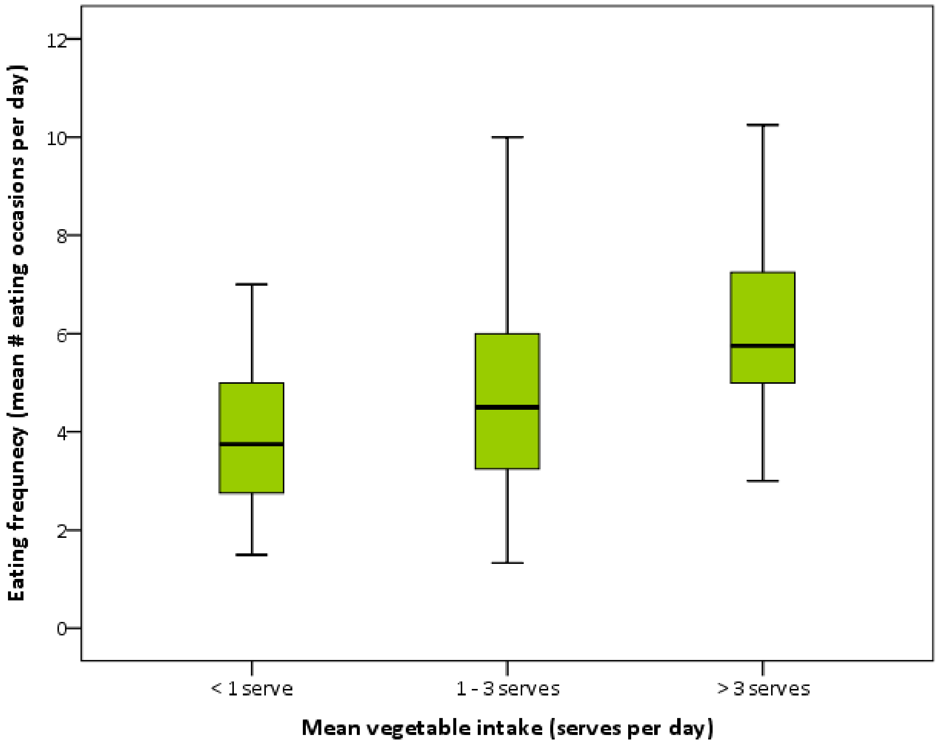
Men recorded a daily average of 4.7 ± 2.4 EOs and women 5.1 ± 2.1 EOs (see Table 6.2 for a breakdown of types of EOs). Levene's test for equality of variances found no significant difference in EF between men and women (p = 0.133).

Associations between fruits and vegetable intake and eating frequency

There was a positive association between EF and fruit (r = 0.391, p<0.001) and vegetable intake (r = 0.344, p< 0.001), using Spearman's correlation. The association between fruit and vegetable intake and EF was then assessed using the Mann-Whitney Test. Average daily fruit intake was categorised into <1 vs. 1-2 serves (p = < 0.001), 1-2 vs. ≥2 serves (p = 0.645) and <1 vs. ≥2 serves (p< 0.001). Average daily vegetable intake was categorised into <1 vs. 1-3 serves (p = 0.017), 1-3 vs. ≥3 serves (p< 0.001) and <1 vs. ≥3 serves (p< 0.001) (Figure 6.2).

Figure 6.2 Fruit and vegetable intake
Assessed using Mann-Whitney Test (n=240)





*Serving sizes based on Australian Guide to Health Eating (NHMRC, 2013) (Appendix D)

Table 6.1 Daily intake of food group servings, by sex (n=240)

	Men (n=82)		Women (n=158)		Total (n=240)	
Food Group	**Median (95%CI)**	**Range**	**Median (95%CI)**	**Range**	**Median (95%CI)**	**Range**
Fruit serves*	0.8 (0.8, 1.4)	0.0 - 7.2	0.8 (0.8, 1.0)	0.0 - 3.2	0.8 (0.8, 1.1)	0.0 - 7.5
Vegetable serves*	1.8 (1.7, 2.1)	0.3 - 5.3	1.8 (1.7, 2.0)	0.0 - 5.3	1.8 (1.8, 2.0)	0.5 - 5.5
EDNP food serves*	3.0 (2.8, 3.7)	0.2 - 8.1	2.9 (2.9, 3.4)	0.0 - 7.4	3.0 (2.9, 3.4)	0.0 - 8.1
Sugar-sweetened beverage serves*	0.2 (0.4, 0.7)	0.0 - 3.0	0.2 (0.4, 0.6)	0.0 - 4.0	0.2 (0.4, 0.6)	0.0 - 4.0
Alcohol serves*	0.0 (0.4, 1.0)	0.0 - 6.2	0.1 (0.4, 0.7)	0.0 - 4.0	0.0 (0.5, 0.7)	0.0 - 6.2
EDNP food & SSB serves*	3.3 (3.3, 4.3)	0.2 - 9.0	3.2 (3.3, 3.8)	0.0 - 9.4	3.2 (3.4, 3.9)	0.0 - 9.4
Total EDNP (foods, SSBs & alcohol) serves*	4.0 (3.9, 5.1)	0.4 - 13.0	3.8 (3.8, 4.4)	0.0 - 10.6	3.8 (3.9, 4.5)	0.0 - 13.0

*Serving sizes based on Australian Guide to Health Eating (NHMRC, 2013) (Appendix D)

Table 6.2 Number of daily eating occasions, by type (n=240)

Eating occasion	Mean ± SD	Median (95%CI)	Range
Food only	2.1±1.0	2.0 (2.0, 2.2)	0.3 - 5.5
Food and beverage	0.9±0.8	0.8 (0.8, 1.0)	0.0 - 3.8
Beverage only[1]	1.0±1.0	0.8 (0.8, 1.1)	0.0 - 5.0
Single item[2]	0.9±0.8	0.8 (0.8, 1.0	0.0 - 4.3
All EOs	4.9±2.1	4.5 (4.6, 5.2)	1.3 - 10.8

[1] Excluding water only EOs. [2]Single item includes foods, such as one piece of fruit or one chocolate bar.

Associations between EDNP food andbeverage intake and eating frequency

Using Spearman's correlation, there were positive associations between EF and EDNP food intake (r=0.242, p<0.0001), alcohol intake (r=0.335, p<0.0001) and total EDNP foods and beverages (r=0.194, p< 0.005). However, no association was found between EF and SSB intake (r=-0.17, p = 0.789). The association between EDNP food and SSB intake and EF was then assessed separately using the Mann-Whitney Test. Average daily EDNP food intake was categorised into <2 vs. 2-4 serves (p< 0.05), 2–4 vs. ≥4 serves (p = 0.055) and <2 vs. ≥4 serves (p< 0.005). Average daily SSB intake was categorised into < 0.5 vs. 0.5-1 serve (p = 0.817), < 0.5 vs. ≥1 serve (p = 0.756) and 0.5-1 vs. ≥1 serve (p = 0.946) (Figure 6.3).

Association between eating frequency and BMI

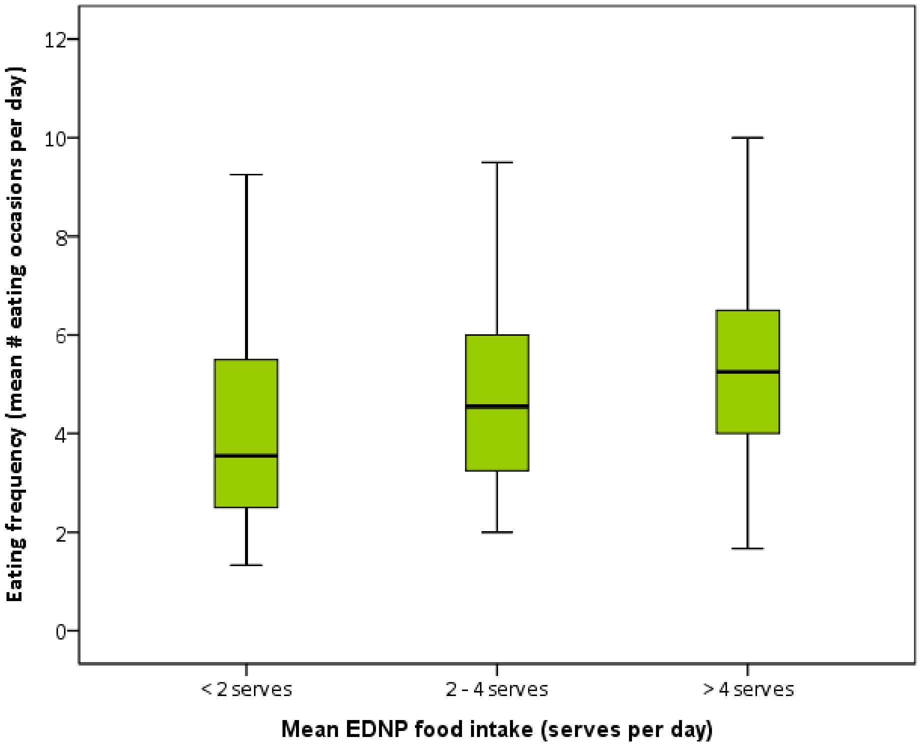
Pearson correlation's showed an inverse association between BMI and EF (r = -0.190, p< 0.005). Analysis of Covariance showed a significant association between eating occasions and BMI (p< 0.01) and education level (p< 0.05).

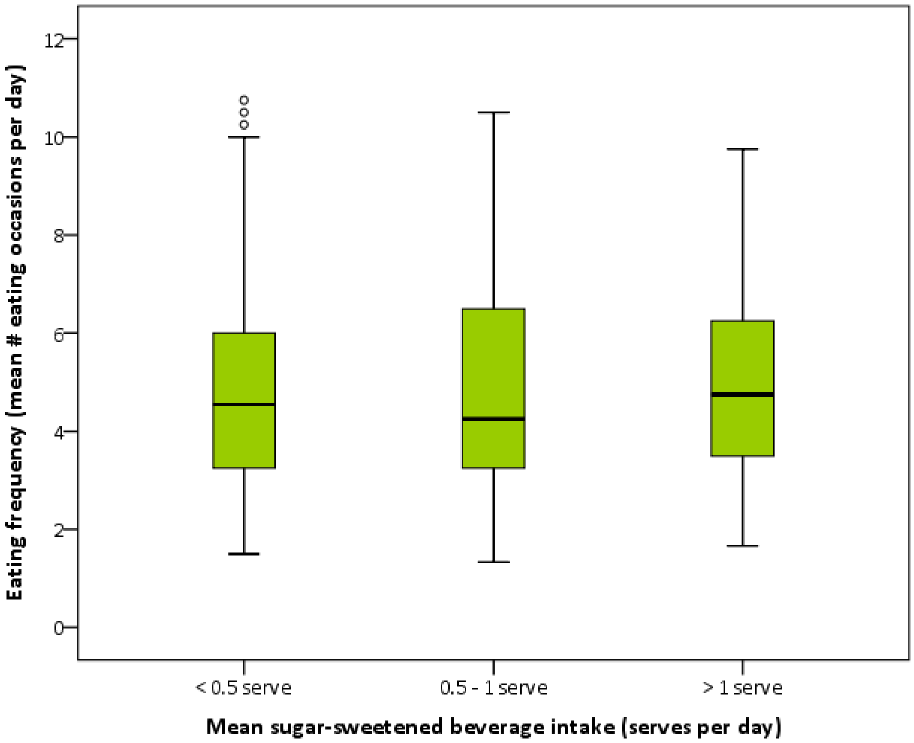
Logistic regression analyses

The logistic regression analyses (adjusted for sex and BMI) found that the average daily eating occasions were positively associated with the likelihood of eating two or more serves of fruit (OR=1.257, 95%CI [1.066, 1.484] p< 0.05), 3 or more serves of vegetables (OR=1.335, 95%CI [1.125, 1.581] p< 0.005), 3 or more serves of EDNP foods (OR=0.808, 95%CI [0.710, 0.920] p< 0.005) and, more than half a serve of alcohol (OR=0.751, 95%CI [0.657, 0.859] p< 0.001). Eating frequency was not associated with one's likelihood of consuming SSBs. All food and beverage serve sizes were classified according to the Australian Guide to Healthy Eating servings (NHMRC, 2013). Results can been seen inTable 6.3.

Figure 6.3 EDNP food and SSB intake

Assessed using Mann-Whitney Test (n=240)





*Serving sizes based on Australian Guide to Health Eating (NHMRC, 2013) (Appendix D) EDNP and SSB serves ~ 600 kilojoules equivalents.

Table 6.3 Logistic regression analysis using mean food intake over 4-day mFR (n=240)

		Sex Women vs men		BMI < 25 vs ≥ 25 kg/m2		Eating Frequency (average daily EOs)	
Outcome Variable	**Description**	**OR *p* value**	**95%CI**	**OR *p* value**	**95%CI**	**OR *p* value**	**95%CI**
Fruit	< 2 vs ≥ 2 serves*	0.656 p = 0.294	0.299, 1.441	1.475 p = 0.385	0.614, 3.546	1.257 p< 0.05	1.066, 1.484
Vegetables	< 3 vs ≥ 3 serves*	0.839 p =0.675	0.370, 1.905	2.155 p =0.119	0.820, 5.663	1.335 p< 0.005	1.128, 1.581
EDNP food	< 3 vs ≥ 3 serves*	1.136 p = 0.653	0.651, 1.982	1.371 p = 0.280	0.774, 2.429	0.808 p< 0.005	0.710, 0.920
SSBs	< 0.5 vs ≥ 0.5 serves*	0.992 p = 0.978	0.567, 1.737	1.612 p = 0.099	0.915, 2.841	0.960 p =0.520	0.848, 1.087
Alcohol	< 0.5 vs ≥ 0.5 serves*	1.427 p = 0.237	0.791, 2.572	0.811 p = 0.504	0.439, 1.499	0.751 p< 0.001	0.657, 0.859
EDNP foods and SSBs	< 3 vs ≥ 3 serves*	0.998 p = 0.994	0.574, 1.735	1.261 p = 0.427	0.712, 2.231	0.861 p< 0.05	0.757, 0.979
Total EDNP (foods, SSBs and alcohol)	< 3 vs ≥ 3 serves*	0.919 p = 0.776	0.514, 1.643	0.930 p = 0.812	0.513, 1.687	0.795 p< 0.005	0.688, 0.918

*Serving sizes based on Australian Guide to Health Eating (NHMRC, 2013) (Appendix D)

6.6 Discussion

A key finding from this study was that greater eating frequency was positively associated with higher fruit and vegetable intake and a lower BMI in young adults. These findings are consistent with a cross-sectional Australian study of 2775 young adults which found the proportion of men meeting dietary recommendations was associated with a higher number of daily eating occasions (Smith et al., 2012a). In this same study, there was no association between eating occasions and BMI amongst women.

A finding of concern in the present study was the association between greater eating frequency and the intake of EDNP food and alcohol serves, due to the related poor health outcomes. These findings suggest eating frequency may be important when considering targeted nutrition messages, and the mFR is an objective method to assess dietary behaviours without the need for participants to record the types and times of foods consumed. Due to the cross-sectional nature of this analysis, causal relationships cannot be drawn upon and eating frequency cannot be considered in isolation of other influences on food intake. However, using a representative sample of Western Australian young adults this study found a positive association between eating frequency and fruit, vegetable, EDNP food and alcohol intakes, but no association with SSB intake. There was an inverse association between eating occasions and BMI, suggesting that the more frequently someone eats is associated with lower BMI. When considering BMI, excluding water only eating occasions was important as these eating occasions do not contribute to overall energy intake and may occur multiple times over the day.

The objective of this study was to use a novel dietary assessment method to assess eating occasions to determine whether eating frequency is associated with key dietary intake indicators and BMI. Previous challenges highlighted in the literature include inconsistent terminology used to define eating occasions and limitations associated with the self-reported methods used to assess when eating and drinking occasions occur. This study presented findings on what and how often WA young adults are eating using a novel and accepted dietary assessment method, the mFR. This method shows potential to assess dietary behaviours beyond food intake (Harray et al., 2015) and the present study demonstrates how the mFR can objectively capture a variety of eating occasions using automated time and date stamps. This automated feature reduces risk of human error in regard to recording the correct eating start time and does not place additional burden on participants.

Further research focusing on what people are eating at each eating occasion and the time in which they are eating specific foods using the mFR will provide further detail regarding dietary patterns. In addition to collecting information on factors influencing eating frequency, such as physiological hunger, behavioural habits, or environmental triggers, would also positively add to the understanding of eating frequency.

A limitation of this study was that the types of foods and portion sizes of specific eating occasions were not considered, so the authors were unable to determine whether particular foods are consumed at a certain time of day or more EDNP foods, for example, are consumed as single items. Another limitation of this study was the inability to adjust for overall energy intake due to select key dietary indicators being the focus, not overall dietary intake. This is not a limitation of the dietary assessment method itself. The findings relating to a lower BMI and a high fruit and vegetable intake should be considered in the context of the other results. The more often one eats or drinks in a 24 hour period (their eating frequency) the higher their chances of also eating more EDNP food and drinking more alcohol. These results were found after adjusting for sex and body weight (above and within the healthy weight range), therefore those who consistently consume above their individual energy requirements would be adjusted for in their BMI category.

6.7 Conclusions

The mFR is an effective way to capture eating occasions and measure eating frequency due to the automated time and date stamps assigned to each eating image. This feature may help eliminate recall bias as users do not need to record or remember the times at which they ate. Previous research in this area has relied on self-reported methods to determine the times and types of eating occasions. The findings of these analyses show that the mFR can objectively record the times at which a person commences their intake of food or beverages and the association with intake of foods that support or hinder H&S eating. The results indicate eating frequency is positively associated with the intake of fruits, vegetables, EDNP foods and alcohol, although inversely associated with BMI. This indicates that looking at eating frequency alone does not tell enough of the story and further research into factors influencing the intake of the these foods should be conducted.

6.8 Acknowledgments

The Connecting Healthy and Technology Study was funded by a three-year Heathway Project Grant with funding from the Department of Health, Western Australia. The authors are grateful to the Purdue University TADA project team, Marc Bosch, Ziad Ahmad, Maggie Zhu, Yu Wang and Brendon Wade and Andrew Butts worth from Curtin University IT Services, for their ongoing technical support for the mFR App. The authors are grateful to Curtin University Masters of Dietetic students Madison Sanford, Danielle Sacht and Mary Phan for their assistance with image analysis. Amelia Harray completed this research as part of her Doctor of Philosophy and would like to acknowledge the Australian Government Research Training Program Scholarship in supporting this research.

6.9 Author contributions

A.J.H. formulated the research question, designed the study, conducted data collection, analysed all diets, conducted data analysis, drafted and reviewed the manuscript. C.J.B. assisted in formulating the research question and interpretation of results, reviewed the manuscript. E.D. led the mFR and image database technology development, reviewed the manuscript. S.S.D. assisted in data analysis. D.A.K. assisted in formulating the research question, took part in data collection, assisted in data analysis and interpretation, and reviewed the manuscript. All authors read and contributed to the final manuscript.

6.10 Conflicts of interest

The authors declare no conflict of interest.

6.11 Summary

This study aimed to use a novel dietary assessment method to assess eating occasions to determine whether eating frequency was associated with food intake and body weight. The findings suggest that the mFR can objectively record the times at which a person commences their food or beverage intake and the association with foods related to a healthy and sustainable diet. The results highlight that the more often one eats or drinks during the day, the higher their chances of consuming greater amounts of fruits, vegetables, EDNP foods and alcohol. The consumption of both EDNP foods and alcohol places unnecessary burden on the environment due to their high energy density and lack of nutrients for good health. Conversely, the more often one eats or drinks is associated with a lower BMI. In many cases, BMI is a reflection of excessive kilojoule intake above one's energy requirements, therefore it was assumed that a high BMI was a reflection of less sustainable dietary behaviours. Further research into the relationship between EF and other sustainable dietary behaviours, such as animal-food intake, food waste and use of individual food packaging would build on these findings. Such evidence would help inform what dietary patterns and behaviours support or hinder one's adherence to a healthy and sustainable diet.

Chapter 7 Protocol used to assess healthy and sustainable diets using the mobile food record

7.1 Introduction

This chapter provides the final manuscript, after addressing the reviewers' comments, of the published paper on the protocol used to assess a healthy and sustainable diet using the mobile food record in this research. The methodology outlined in this paper relates to objective four of this thesis - *Develop a Healthy and Sustainable Diet Index to measure key components of a H&S diet using images, including:*

- *Animal-based foods (ruminant meat, pigs, poultry, fish, dairy foods and eggs)*
- *Fruits and vegetables (including seasonality)*
- *Ultra-processed energy-dense nutrient-poor foods and beverages*
- *Individually packaged foods and beverages*
- *Food (plate) waste*

The candidate was responsible for conceiving the concept of using images captured with the mFR, developed the methodology, wrote the first draft, contributed to and approved the final draft, submitted the manuscript to the publisher, addressed reviewer comments, made amendments as required and resubmitted revised manuscript for final publication. This manuscript was reproduced with permission from the publisher and a declaration of author contribution has been signed by all co-authors (Appendix B, Section B.4).

Reference:

Harray, A. J., Boushey, C. J., Pollard, C. M., Delp, E. J., Ahmad, Z., Dhaliwal, S. S., Mukhtar, S. A., & Kerr, D. A. (2015). A novel dietary assessment method to measure a healthy and sustainable diet using the mobile food record: Protocol and methodology. *Nutrients,* 7(7), 5375-5395.

ARTICLE: A novel dietary assessment method to measure healthy and sustainable diets using the mobile food record: Protocol and methodology.

Amelia J Harray, Carol J Boushey, Christina M Pollard, Edward J Delp, Ziad Ahmad, Satvinder S Dhaliwal, Syed Aqif Mukhtar and Deborah A Kerr.

7.2 Abstract

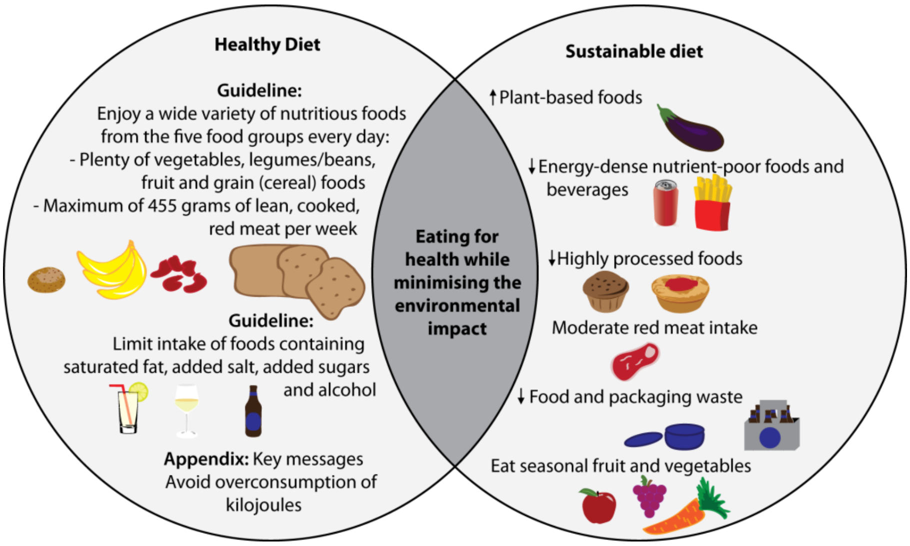
The world-wide rise in obesity parallels growing concerns of global warming and depleting natural resources. These issues are often considered separately but there may be considerable benefit to raising awareness of the impact of dietary behaviours and practices on the food supply. Australians have diets inconsistent with recommendations, typically low in fruit and vegetables and high in energy-dense nutrient-poor foods and beverages (EDNP). These EDNP foods are often highly processed and packaged, negatively influencing both health and the environment. This paper describes a proposed dietary assessment method to measure healthy and sustainable dietary behaviours using 4-days of food and beverage images from the mobile food record (mFR) application. The mFR images will be assessed for serves of fruit and vegetables (including seasonality), dairy, eggs and red meat, poultry and fish, ultra-processed EDNP foods, individually packaged foods, and plate waste. A prediction model for the Healthy and Sustainable Diet Index will be developed and tested for validity and reliability. The use of the mFR to assess adherence to a healthy and sustainable diet is a novel and innovative approach to dietary assessment and will have application in population monitoring, guiding intervention development, educating consumers, health professionals and policy makers, and influencing dietary recommendations.

7.3 Background

Recent evidence would suggest that eating a diet that increases environmental sustainability has the potential to also benefit health (Burlingame & Dernini, 2012; Macdiarmid, 2013a; Macdiarmid et al., 2012; Reynolds, Buckley, et al., 2014). Worldwide overweight and obesity rates are rising, posing significant costs at an individual and societal level (Swinburn et al., 2011). In Australia, the direct cost spent annually on overweight and obesity is estimated to be at least $21 billion (Colagiuri et al., 2010). The overconsumption of kilojoules above an individual’s energy requirements (resulting in weight gain) is environmentally unsustainable and places burden on the future food supply (NHMRC, 2013). Hence, there may be considerable health and environmental benefits in assessing the impact of dietary behaviours and practices on the food supply (Lowe, 2014; Riley & Buttriss, 2011). Research on the effects of diet on the environment is rapidly emerging, particularly the area of life cycle assessment- a method for measuring the carbon footprint (amount of greenhouse gas emissions) of food products throughout production (Drewnowski et al., 2015; Roy et al., 2009). However, identifying a healthy and sustainable diet that meets the nutrient requirements of all populations groups and cultures is complex and challenging (Garnett, 2014; Macdiarmid, 2013a; Riley & Buttriss, 2011; Tilman & Clark, 2014). Researchers have identified the need to identify dietary patterns that provide adequate nutrition at a low environmental cost (Drewnowski, 2014), but methods to do so have focused on the assessment of typical diets and food choices at a population level (Macdiarmid et al., 2012; Tilman & Clark, 2014) rather than individual dietary behaviours. Therefore, there is limited evidence on whether current individual dietary patterns align with a sustainable diet.

The Australian Dietary Guidelines, which provide the evidence-base for dietary recommendations and directions for nutrition policy in Australia, have highlighted the issue of food, nutrition and environmental sustainability over the last decade. The 2013 review of the Guidelines sought to assess the evidence to make dietary recommendations that were protective of health as well as the environment. However, no specific guidelines to address a sustainable diet were made as a result of inadequate evidence in the area, rather an appendix containing key messages regarding food, nutrition and environmental sustainability. These recommendations include advice to: try to eat seasonal produce; reduce food and packaging waste; and avoid overconsuming kilojoules (NHMRC, 2013). Several of the Australian Dietary Guidelines form indirect synergies between eating a diet for good health and a sustainable diet to reduce burden on the environment (represented graphically in Figure 7.1). For example, the overconsumption of kilojoules is associated with overweight and obesity, but is also creating an avoidable environmental burden due to the resources used in the production, storage and preparation of food (Bradbear & Friel, 2011; Friel et al., 2013; NHMRC, 2013). While attempts to create awareness of the impact of dietary choices on the environment exist, the absence of set guidelines relating to sustainable diets in Australia is the probable result of limited evidence in this area of nutrition and no dietary assessment method to accurately measure an individual's healthy and sustainable dietary behaviours.

Figure 7.1 Graphic representation of the direct synergies between the 2013 Australian Dietary Guidelines and sustainable dietary behaviours outlined in the Australian Dietary Guidelines
(NHMRC, 2013)



There is no agreed definition for what constitutes a "healthy and sustainable diet". Separately, healthy diets conform to the Australian Dietary Guidelines (NHMRC, 2013), while sustainable diets have been defined by the Food and Agriculture Organization of the United Nations as "those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources." (Burlingame & Dernini, 2012). Several European countries have developed guidelines for a healthy and sustainable diet (Clonan & Holdsworth, 2012; Dixon & Isaacs, 2013) and research examining associations between other dietary recommendations and dietary patterns and their associations with environmental sustainability is becoming available (Reynolds, Buckley, et al., 2014; Tilman & Clark, 2014). Even with strengthening evidence on the health benefits of diets with lower environmental impact, the revised Australian Dietary Guidelines failed to include specific sustainable eating dietary recommendations (Reynolds, Buckley, et al., 2014; Selvey & Carey, 2013).

There is a plethora of evidence suggesting climate change and poor health are two major public health concerns, both of which would benefit from government policy promoting more sustainable dietary behaviours (Bradbear & Friel, 2013; Lowe, 2014;

Macdiarmid et al., 2012; Morgan, 2009). However, dietary recommendations and policies cannot be developed without an evidence base. In order to collect evidence on how current dietary patterns adhere to a sustainable diet, surveillance and monitoring of individual dietary behaviours using a comprehensive dietary assessment method is required.

To the authors' knowledge there is no feasible dietary assessment method to accurately measure an individual's healthy and sustainable dietary behaviours and the need for such a method has been highlighted in a recent review by Johnston *et al.* (Johnston et al., 2014). To date methods of dietary assessment have focused mostly on nutrients and food groups and not considered the assessment of sustainable dietary practices, such as reducing food packaging and waste. Brief assessment instruments, commonly used in population surveillance, have been used to reliably estimate the quality of diets in Australia (Collins et al., 2015). These methods typically use a short questionnaire or several questions to assess knowledge and specific diet and nutrition behaviours (Kirkpatrick et al., 2014; Thompson & Subar, 2013). Other frequently used dietary assessment methods, such as written food records, provide more objective data on what individuals are eating and in some cases individuals may be asked to record food waste. However, a limitation of written food records is there is no way to verify the recording and researchers must rely on good literacy levels, the ability of people to accurately estimate portion sizes and remember to write down all meals, snacks and beverages, creating burden on participants. The use of technology in dietary assessment, and more specifically image-based food records, is a new and rapidly emerging area that will reduce the burden for participants through the elimination of detailed writing and portion size estimation. Image-based dietary assessment methods, including the mobile food record (mFR) application, enable people to capture their intake by taking a momentary image and do not allow users to review, edit or alter earlier images (Ahmad et al., 2014; Daugherty et al., 2012; Xu, He, Khanna, Boushey, & Delp, 2013; Zhu et al., 2015; Zhu et al., 2010). This feature may reduce the chances of people reflecting on their prior consumption and consequently underreporting further intake. In addition, before and after eating images taken using the mFR application allow for the assessment of plate waste and packaging use, as well as the estimation of serving and portion sizes. For such reasons the existing mFR application shows great potential as a feasible method for individual and population-wide nutrition monitoring of sustainable dietary behaviours. Food image data previously collected from a population-based sample of adults using the mFR will enable the validation of a *HSDI.*

Diet quality indices assist in translating intake data collected using dietary assessment methods to values or scores that are more easily interpretable and allow for consistent comparisons between groups of interest. Such indices are developed to measure dietary patterns, behaviours and adherence to particular eating recommendations in populations (McNaughton et al., 2008). Diet quality indices consider multiple components of a diet and apply weighting factors to each component to calculate a final diet quality score (Sofi, Macchi, Abbate, Gensini, & Casini, 2014). Developing and validating indices for use in dietary assessment can assist in guiding nutrition interventions, population monitoring, informing policy makers, monitoring the effectiveness of programs and research (Guenther, Reedy, & Krebs-Smith, 2008). Examples of validated diet quality indices include the Healthy Eating Index (Guenther, Reedy, & Krebs-Smith, 2008), Mediterranean Diet Score (Trichopoulou et al., 2003), Diet Quality Index (Patterson et al., 1994), Dietary Guideline Index (McNaughton et al., 2008), Dietary Quality Score (Toft, Kristoffersen, Lau, Borch-Johnsen, & Jorgensen, 2007), Australian Recommended Food Score (Collins et al., 2015) and DASH Diet Score (Harrington et al., 2013).

Traditionally, dietary indices have been developed to monitor specific or general nutrient intake and predict the effect of dietary behaviours on health outcomes. But, there is increasing need to measure impacts of dietary behaviours on external factors due to the potential negative impact on the future of the food supply (e.g., the environment) (Johnston et al., 2014). A recent review by Johnston and colleagues highlighted the urgent need to develop innovative approaches to measuring and promoting sustainable diets so consumers and policymakers can become aware of the benefits on individual and population health and the environment (Johnston et al., 2014). In doing so, the authors emphasised the need for culturally acceptable and locally appropriate indices to accurately assess sustainable diets, suggesting the development of such indices would enable the measurement of a suite of indicators relating to the impact of dietary behaviours on health and the food system to inform policy makers (Johnston et al., 2014). This paper addresses the gap in the literature by proposing a feasible method to assess multiple elements of a healthy and sustainable diet.

This paper describes the protocol and methodology for a proposed novel dietary assessment method to measure indicators of an individual's healthy and sustainable diet not typically measured in traditional methods. Due to a lack of consensus of what constitutes a healthy and sustainable diet, the five dietary behaviours selected for assessment were chosen based on the evidence documented in the Australian Dietary

Guidelines, and Appendix G of ADGs on Environmental Sustainability (NHMRC, 2013). The five characteristics of a healthy and sustainable diet selected relate to nutritional status and/or future food supplies to maintain good health. As the proposed dietary assessment method uses images to assess healthy and sustainable dietary behaviours, the selection has been confined to those that can be objectively assessed from food and beverage images using a mFR. The five indicators to be assessed using the mFR application include the intake of ultra-processed EDNP foods and beverages, individually packaged foods and beverages, fruit and vegetables (including seasonality), dairy, eggs and meat, and plate waste.

Food intake data, collected using the image-based mFR during the Connecting Health and Technology study, will provide evidence to assist the development of this method and the Healthy and Sustainable Diet Index, which will provide evidence for policy makers, health professionals, and others interested in promoting environmental sustainability through dietary recommendations (e.g., the agricultural sector). A validated index to accurately assess healthy and sustainable dietary behaviours, and ultimately gather evidence on individual eating behaviours, is timely and urgent. It is yet to be determined but the mFR may have the potential to be a cost effective method to gather valuable data on healthy and sustainable dietary behaviours, an area of nutrition in need of evidence. The dietary assessment method described in this paper when implemented will provide evidence on current adherence to a healthy and sustainable diet, addressing a gap in the literature both in Australia and globally. This protocol paper outlines the methods used to assess healthy and sustainable dietary behaviours using an mFR, providing detail to assist with further advancements in this field of dietary assessment and allowing for future reproducibility. Importantly, the methods proposed in this paper may address the lack of dietary assessment methods to assess sustainable dietary behaviours, as highlighted in the review by Johnston *et al.* (2014).

7.4 Experimental section

7.4.1 Study participants

The study sample to be used for developing the proposed methods will consist of 247 adults aged between 18 to 30 years, comprising of 162 (66%) women and 85 (34%) men previously recruited for another study, the Connecting Healthy and Technology study, referred to as CHAT (Zhu et al., 2010). Recruitment involved sending letters of invitation to 15,000 residents from 57 suburbs (using the Socio-Economic Indexes for Areas) in the Perth Metropolitan Area from the Federal Electoral Roll, a compulsory enrolment system for Australians aged over 18 years. Participants were screened either online, using a survey website, or on the telephone to ensure the inclusion criteria were satisfied (aged between 18 and 30 years and owned a mobile phone). For the original study, potential participants were excluded if they were: (a) unable to attend on four occasions to complete the 6-month randomised controlled trial; (b) studied nutrition; (c) took part in extreme forms of exercise; (d) followed a restrictive diet; or (e) pregnant or breastfeeding. The CHAT study was conducted between July 2012 and June 2013.

The Connecting Health and Technology Study was registered on the Australian and New Zealand Clinical Trials Registry (ACTRN12612000250831) and approved by the Curtin University Human Resources Ethics Committee (HR181/2011) and the Western Australian Department of Human Research Ethics Committee (#2011/90).

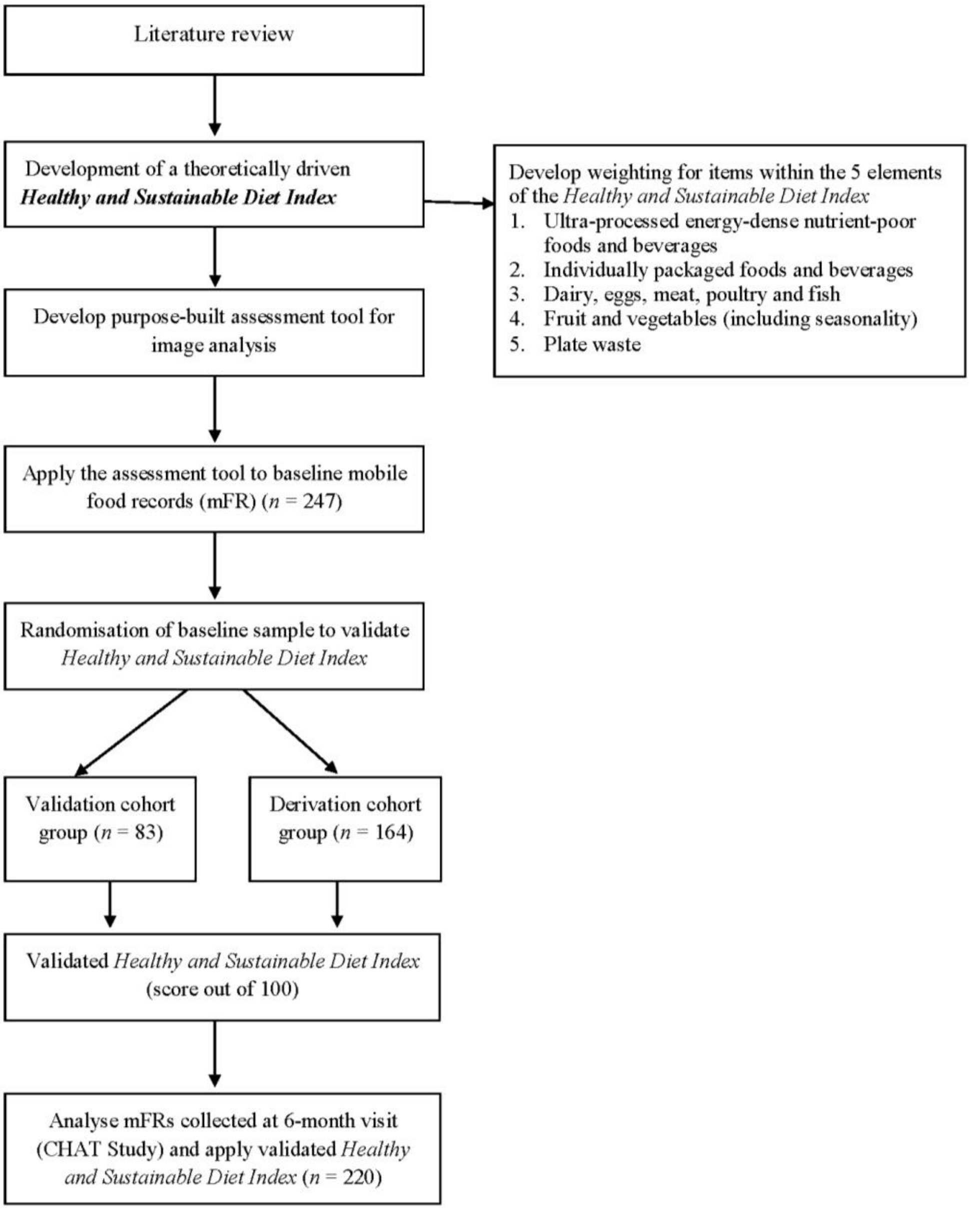
7.4.2 Study Design

During the Connecting Health and Technology study, participants completed four day mFRs using the CHAT application at baseline and at the end of the 6-month randomised controlled trial. During both visits height and weight data were collected. Participants were asked to capture before and after images of all eating occasions using a mobile device (iPod Touch) provided by the research team. On the initial visit participants were taught how to use the specifically designed dietary assessment method, the CHAT application, uploaded onto the iPod Touch (iOS6). Participants were asked to place a small fiducial marker in the bottom left hand corner of every image to assist in portion size and colour estimation(Xu, Zhu, Khanna, Boushey, & Delp, 2012). Details of the mFR CHAT application have been previously described by Kerr *et al. (2012)*.

Participants were asked to take images over four consecutive days, from Wednesday to Saturday. On completion of the food record, participant’s clarified the contents of images with an Accredited Practising Dietitian, and verified plate waste or if the leftover food or beverage was consumed at a later stage. Each image obtained during the CHAT study contains metadata on the time, date and location it was taken, allowing for the assessment of whether fresh produce were in season at time of consumption. The food images collected during the CHAT study will be used to validate and test the Healthy and Sustainable Diet Index.

For the development of the proposed methodology, participants completed an mFR at baseline (n = 247) and repeated this six months later (n = 220). A secondary analysis by the Accredited Practising Dietitian who was involved in the original analysis of all food images collected during the CHAT study will take place. A purpose built Microsoft Access database will be developed to assess the contents of images, and the review of each image pair (including a before and after eating image). A minimum of one image pair per day will be required to be considered a valid day. Five indicators of a healthy and sustainable diet will be assessed using the images captured using the mFR. An objective of this study is to determine whether the five selected dietary behaviours can be assessed from image-based food records without interaction with participants. This is therefore a “proof of concept” approach to developing the Index before replication in possible future interventions. A flowchart outlining the design of the proposed study can be seen in Figure 7.2.

Figure 7.2 Flow chart of study design



7.4.3 Assessment of healthy and sustainable dietary behaviours

For the development of the Healthy and Sustainable Diet Index, dietary behaviours were identified from evidence of their supportive or unsupportive role within a healthy and/or a sustainable diet and the inclusion of details that can be assessed using images. Descriptions of each component's role within the context of a healthy and sustainable diet are outlined below. The five indicators to be assessed using the mFR application include: the intake of ultra-processed EDNP foods and beverages, individually packaged foods and beverages, fruit and vegetables (including seasonality), dairy, eggs and meat portions, and plate waste. These dietary behaviours will be assessed using the following proposed methodologies.

Ultra-processed EDNP foods and beverages

Processed foods form a large component of modern diets and have been linked to the growing rates of overweight and obesity (Monteiro et al., 2010; NHMRC, 2013; Rangan et al., 2009; Tavares et al., 2012). A definition of food processing is "all methods and techniques used by industry to turn whole fresh foods into food products" (Moubarac et al., 2013). Food processing is important to ensure an adequate and safe food supply (Monteiro, 2010), however, high levels of food processing often increases the energy density of food due to "ultra-processing" with the addition of added fat and sugar. In general, foods that have been highly or ultra-processed are more likely to contain high levels of saturated fats, added sugars and/or sodium and minimal levels of micronutrients therefore are often categorised as "energy-dense nutrient-poor" choices (Monteiro et al., 2010; World Health Organization, 2003). Energy-dense nutrient-poor foods and beverages are associated with poor diet quality, overweight, obesity and chronic disease (Smith et al., 2012a; World Health Organization, 2003), as well as being some of the most emissions-intensive food products due to the processing, packaging and landfill necessary to produce these foods in certain locations (Lowe, 2014). Although all EDNP foods may not negatively affect the environment more than other food items, these foods are generally low in nutrients (NHMRC, 2013). In addition, the excessive intake of kilojoules above an individual's energy requirements, from these EDNP foods and beverages, is a dietary behaviour unsupportive of health whilst creating unnecessarily burden on natural resources (Bradbear & Friel, 2011; NHMRC, 2013). Highly processed takeaway foods and poor diet quality are associated with abdominal obesity in young adults (Rangan et al., 2009; Smith et al., 2009) and compared to older age groups, young adults are more likely to consume EDNP that are convenient, highly processed and packaged, such as meat pies, fried potatoes, pizzas, crisps, confectionary, savoury pastries, chocolate and sugar-sweetened beverages (Drewnowski & Specter, 2004; Rangan et al., 2009). Hence, processed food is not the issue in a healthy and sustainable diet, the issue is EDNP ultra-processed foods.

Ultra-processed foods are defined as those that require minimal, if not any, culinary preparation (Monteiro et al., 2010). Previous studies have relied on household expenditure surveys and semi-quantitative food frequency questionnaires to assess the intake of ultra-processed foods (Monteiro et al., 2010; Moubarac et al., 2013; Tavares et al., 2012), yet no studies have investigated the consumption of ultra-processed foods in Australia. A unique aspect of the methods to be used is that EDNP ultra-processed foods will be assessed using image-based mFRs. For inclusion in this component only ultra-processed foods and beverages categorised as energy-dense and nutrient-poor, such as cakes, crisps, commercial burgers and sugar-sweetened beverages will be used (NHMRC, 2013). Ultra-processed EDNP foods and beverages will be assessed according to the Australian Dietary Guidelines serve sizes-one serve of EDNP food or beverage being equivalent to 600 kJ (143 kcal) (NHMRC, 2013). Nutrient dense foods that are highly processed, such as bread, will be excluded due to associated health benefits.

An example image of ultra-processed EDNP foods collected using the mFR application can be seen in Figure 7.3. Using the proposed assessment protocol, this eating occasion would be recorded as 14 serves of ultra-processed EDNP foods. The two pieces of fried chicken appearing in the after eating image would not be counted as ultra-processed EDNP serves but rather non-compostable food waste. We can appreciate all EDNP foods may not necessarily be worse for the environment than other food items, however, in regard to health consequences, these food items offer minimal, if any, nutritional benefit. In addition, the excessive intake of kilojoules above an individual's energy requirements, from these EDNP foods and beverages, is a dietary behaviour unsupportive of health whilst creating unnecessarily burden on natural resources.

Figure 7.3 Example of using an mobile food record (mFR) to assess ultra-processed energy-dense nutrient-poor foods

(a) Before eating image; (b) After eating image shows the food waste

(a) (b)

The number of energy-dense nutrient-poor food and beverage (EDNP) serves consumed were: 1 sausage roll (commercial, 175 g) = 2100 kJ, fried sausage (large) 1300 kJ × 2 = 2600 kJ, crumbed fried sausage (large) 1800 kJ × 2 = 3600 kJ → Total: 8300 kJ/600 kJ = 14 serves of EDNP foods.

Individually packaged foods and beverages

Food packaging plays a crucial role in maintaining a safe food supply and has the ability to reduce waste by retaining the effect of food processing to extend shelf life (Marsh & Bugusu, 2007). However, food packaging negatively impacts the environment at a number of stages including during production, transport and land fill (Bradbear & Friel, 2011). Individually packaged foods are convenient and are becoming more common in Australian supermarkets. An Australian study assessed attitudes towards environmentally friendly eating behaviours and found people believe food packaging has a greater impact on the environment compared to the consumption of meat (Lea & Worsley, 2008).

Key messages in Appendix G of the Australian Dietary Guidelines encourage people to select foods with appropriate packaging and recycle due to the impact on natural resources (NHMRC, 2013). Food packaging is not assessed by traditional dietary assessment methods. Images from mFRs show great potential for the accurate assessment of the intake of individually packaged products as they are easily identifiable from the before eating images. Due to the negative impact of packaging on the environment, all individually packaged items will be recorded regardless of the nutrient composition of the food it originally contained. However, individually packaged foods, classified as either EDNP or healthy, will be counted separately to allow for further assessment of adherence to a healthy and sustainable diet. Foods and beverages served from larger packages (so not individually packaged) such as a glass of milk poured from a two litre bottle will not be recorded due to the unavoidable use of larger packages to ensure a safe food supply. A limitation of this method is that some food or beverages may be removed from individual packaging prior to the before eating image being taken. This challenge could be avoided by requesting participants do not remove individual packaging prior to taking images using the mFR.

An example of an image containing individually packaged items collected using the mFR application can be seen in Figure 7.4. Using the proposed protocol, this eating occasion would likely be assessed as containing two individually packaged EDNP food items and one individually packaged EDNP beverage item.

Figure 7.4 Example of using the mobile food record (mFR) to assess individually packaged food
(a) Before eating image; (b) After eating image

(a) (b)

Fruit and vegetables

A diet consistent with the Australian Dietary Guidelines can help maintain a healthy weight and assist in the prevention of chronic diseases, such as cardiovascular disease, Type 2 Diabetes and some cancers (Martínez-González et al., 2011; Morgan, 2009; NHMRC, 2013; Riley & Buttriss, 2011). Previous studies have found Australian adults eat less than the recommended daily serves of fruit and vegetables (Pollard et al., 2008), supported by the most recent Australian Health Survey which found only three per cent of young adults meet the recommended two 150 gram serves of fruit and five 75 gram serves of vegetables per day, compared to 9.6% of older adults (Australian Bureau of Statistics, 2014). The reasons why people are not eating enough fruit and vegetables are complex but household income and the expense of fruit and vegetables have been shown to be significant factors (Kamphuis et al., 2006; Pollard, Miller, Woodman, Meng, & Binns, 2009). In recent years, changes in climate have influenced the availability and affordability of some fresh fruits and vegetables in Australia (Barosh et al., 2014; Johnston et al., 2014). The cost of fresh fruit and vegetables in Australia appears to be increasing at a higher rate than other food categories, evidenced by an 18.8% increase in the cost of fresh fruit and 10.7% increase in fresh vegetables in Western Australia since 2010 (Australian Bureau of Statistics, 2013a).

Diets high in fruit and vegetables have a lesser impact on the environment than those high in processed foods or animal-based foods (Bradbear & Friel, 2011; Reynolds, Buckley, et al., 2014). Although the consumption of a diet that consists of mostly fresh fruits and vegetables is encouraged (NHMRC, 2013), it has been suggested that additional considerations need to be included, for example, produce grown locally and in season. This is because fruits and vegetables grown locally or in season are less likely to require a climate controlled environment and typically undergo less processing, packaging, transportation and storage (Lake et al., 2012; Larsen et al., 2008). However, other studies have suggested the benefits of consuming locally grown seasonal produce is not the determining factor of environmental impact because food production has more impact on the environment than transportation (Avetisyan, Hertel, & Sampson, 2014; Garnett, 2014; Macdiarmid, 2013b).

A recent study by Drewnowski *et al.* (Drewnowski et al., 2015) assessed the relationship between nutrient and energy density and carbon footprint, and found that processed and frozen fruit and vegetables had a low carbon footprint when considered as per 100 g in comparison to meat and dairy products. But when looking at energy density per 100 kcal, the carbon footprint of frozen and processed fruit and vegetables increased dramatically (Drewnowski et al., 2015). This study pointed out that carbon footprint is only one of many metrics to assess the environmental impact of food. Overall, it is widely accepted that some fruits and vegetables are more emissions-intensive than others depending on several factors, including the country of origin, the need for protected conditions, storage and cooking.

Choosing seasonal local fruits and vegetables requires specific knowledge of where food was grown. This information is not always evident or available to consumers (NHMRC, 2013) particularly when meals are prepared or purchased by others (e.g., meals eaten at a restaurant). Studies have shown people are prepared to buy local produce, although factors such as convenience, price, accessibility and perceived quality also determine purchasing habits (Lea & Worsley, 2008; Vermeir & Verbeke, 2008).

Using the protocol outlined in this paper, the intake of fruit and vegetables will be analysed from each eating image pair and classified according to the Australian Dietary Guidelines serve sizes (1 serve of vegetables = 75 g, ½ cup cooked vegetables or 1 cup of salad vegetables, and 1 serve of fruit = 150 g, 1 medium piece or 2 small pieces of fruit). A Microsoft Access database tool will be created to record the estimated serve size and type of fruit and vegetable consumed separately. This feature will allow for further assessment of the environmental impact of different varieties. As the time and date stamp is available from images collected with the mFR, the date fruits and vegetables were consumed can be recorded and merged within the database containing information on when each fruit and vegetable is in season. For example, in Western Australia bananas are in season in summer and autumn, meaning if someone consumed a banana between 1st December and the 30th May then the banana will be recorded as "eaten in season". For this study, seasonal fruits and vegetables will be classified according to the WA Seasonal Fruit and Vegetable Calendar (Department of Agriculture and Food, 2013).

Dietary assessment of seasonal and local fruit and vegetable intake poses significant challenges including: the additional burden of recording "place of origin" at time of purchase; prepared food not carrying this information (e.g., buying a salad at a café): and the sale of fruits and vegetables all year around, regardless of seasonality. A limitation of assessing the intake of seasonal fruit and vegetable intake is that there is no way of determining the origin of fresh produce, for example a banana from Queensland could be eaten in Western Australia, 4341 kilometres away by road (the main transportation method used). However, consuming seasonally available produce, regardless of origin, is likely to reflect an aspect of a healthy and sustainable diet. There is currently limited data on the intake of seasonal fruits and vegetables by adults in Australia. As less than 7% of Australians consume the recommended daily serves of vegetables and less than half consume the recommended two serves of fruit (Australian Bureau of Statistics, 2012), increasing intake alone, regardless of seasonality, would result in health benefits. An example of fruit to be consumed can be seen in the mFR image (as it appears using the web application hosted on a secure server) in Figure 7.5. Using this example containing the date of the image, one serve of fruit (e.g., one medium banana) would be entered in the database and because this eating occasion took place in September in Western Australia, this piece of fruit would be considered eaten "out of season".

Figure 7.5 Example of using the mobile food record to assess seasonal fruit and vegetable intake

Dairy, eggs and meat products

There is substantial evidence supporting the additional environmental impact of meat and dairy foods, compared to plant-based foods (Friel et al., 2013; Macdiarmid et al., 2012; Masset, Soler, Vieux, & Darmon, 2014). Along with a growing population and urbanisation, there is a global transition from largely plant-based diets to diets higher in EDNP foods and animal-based foods (World Health Organization, 2003), increasing burden on the food system. While the consumption of dairy foods in Australia is generally below dietary recommended levels, Australians traditionally consume large volumes of meat, with the consumption of beef constituting the highest amount (Bradbear & Friel, 2011). Meat and dairy products from ruminant cattle and sheep are some of the greatest greenhouse gas contributors in modern diets (Lowe, 2014; Riley & Buttriss, 2011).

Previous research in the area of sustainable diets has highlighted a healthy and sustainable diet can be followed without the complete exclusion of dairy and meat (Macdiarmid, 2013a; Macdiarmid et al., 2012; Masset et al., 2014; Riley & Buttriss, 2011), however, excessive red meat and processed meat consumption has been linked to an increased risk of colorectal cancer (NHMRC, 2013; World Cancer Research Fund, 2007). To accommodate this, the latest review of the Australian Dietary Guidelines reduced the standard serving size of lean red meat to a set 65 g from the previous range of 65 to 100 g of cooked meat, with a maximum of seven serves, or 455 g, of red meat per week (NHMRC, 2013). In Australia, only 2.1% of people avoid red meat (Australian Bureau of Statistics, 2014). Therefore, comparing meat intake between small, moderate and large meat consumers is relevant in assessing a healthy and sustainable diet when only a small percentage of the population are vegetarians (de Boer, Hoogland, & Boersema, 2007).

When applying the proposed method to this component, food images will be used to estimate average daily intake of milk, cheese and yoghurt, eggs and meat products (including red meat, poultry and fish). The volume of specific types of dairy, eggs and meat products (e.g., beef mince) will be recorded as an approximate gram or millilitre weight and compared to the Australian Dietary Guidelines recommendations (NHMRC, 2013). Meat consumed in other food products assessed using this method, such as a beef patty in a commercial burger, will be counted as ultra-processed EDNP food serves and also meat serves.

Food waste

Australians throw away $5.3 billion Australian dollars (AUD) worth of food each year. This includes fresh food (AUD $2.9 billion), frozen food (AUD $241 million), take-away food (AUD $630 million), unfinished beverages (AUD $596 million) and leftover food (AUD $876 million) (Hamilton et al., 2005). Young adults waste more food than older adults with 38% of 18–24 year olds wasting more than AUD $30 on fresh produce per fortnight, compared to only seven percent of older adults (Hamilton et al., 2005). Reducing food waste from production to consumption will decrease burden on the food system, in turn benefiting the environment (Mason et al., 2011). Discrepancies were detected in an Australian study comparing reported household fresh food waste (AUD $4.6 million) and actual fresh food waste (AUD $8 billion), collected during a household garbage bin audit (Hamilton et al., 2005). The methods proposed here will accurately capture an important element of food waste, consumer plate waste, through the use of before and after eating food images, to support an area of research with a lack of sufficient data (Mason et al., 2011).

Image pairs allow for the accurate assessment of plate waste due to the presence of before eating and after eating images. Plate waste will be estimated as a percentage of food or beverage not consumed in the after eating image. Food waste in each image will also be classified as compostable (e.g., fruit, vegetables, egg shells), not compostable (e.g., meat and dairy) or unable to determine.

An example of red meat intake and food waste can be seen in Figure 7.6. Using the described protocol, this eating occasion will be assessed as four serves of roast beef, and having 30% edible plate waste. Note, one serve of cooked beef is 65 g (NHMRC, 2013).

Figure 7.6 Example of using the mobile food record (mFR) to assess food waste and meat intake
(a) Before eating image; (b) After eating image

(a) (b)

7.4.4 Outcome variables

The outcome variables measured using the proposed dietary assessment method include:number of serves and types of fruit and vegetables and whether they were in season at the time and location of consumption,intake of ultra-processed energy-dense nutrient-poor foods and beverages, separated by type and number of serves, intake of foods and beverages that are individually packaged, separated into “healthy” or “EDNP” foods or beverages,portion sizes and total amount of dairy, eggs and meat products percentage of plate waste and whether the food wasted was compostable.

7.4.5 Development of the Healthy and Sustainable Diet Index

Existing diet quality indices will be reviewed to investigate the processes undertaken in development, validation, and evaluation and will guide the development of the Healthy and Sustainable Diet Index. This will be a theoretically driven Index, which will be evaluated using food images collected during the CHAT study. Each indicator incorporated in the Index will be categorised into one or more of the following elements; impact on human health and/or impact on the environment. For example, ultra-processed EDNP foods and beverages impact health (contributing excess kilojoules and contributing to chronic disease risk) and the environment (use of water, electricity, transport and packaging). Another example is food waste, which has a direct negative impact on the environment (landfill) and a potential influence on health as fresh fruit and vegetables are perishable and often thrown away, creating a barrier for purchase and consumption.

The influence of dietary behaviours on human health will be given the highest weighting, followed by impact on the environment, for example plate waste. Weighting of different food items will involve a thorough assessment of available evidence, including evidence on the life cycle assessment of particular foods (which takes into account greenhouse gas emissions), and additional effects on ecosystems and biodiversity. The final Index may need to be modified when applied in other countries to take into account differences in the environmental impact of foods produced in various areas and climates, including climate conditions, farming, agricultural and production methods. For example the environmental impact of fruit that requires a climate controlled environment, *versus* seasonal fruit grown outside. A maximum number of total points will be allocated to each component of the Healthy and Sustainable Diet Index. A high weighting will not be given to components of the Index that cannot be measured accurately using image-based food records, for example whether fruits and vegetables consumed were locally grown and in season, due to the amount of error.

Each component incorporated into the Healthy and Sustainable Diet Index, will be given a weighting used to calculate a final score measuring adherence to a healthy and sustainable diet. For example, typically indices have a maximum score of 100, with a higher score indicating greater adherence to the preferred dietary pattern (Collins et al., 2015). Individual components will be given a weighting to reflect consistency with the recommended dietary and sustainable eating outcomes, for example, fruit and vegetable intake may be given a higher weighting as it contributes to both healthy and sustainable eating.

The theoretically driven Healthy and Sustainable Diet Index will be internally validated for reliability, content validity and construct validity using 4-days image-based food records collected during a 6-month randomised controlled trial. The baseline data collected during the CHAT study (n = 247) will be randomised into thirds using age- and sex-stratified random sample techniques. Two-thirds of the sample will be randomly selected as the derivation cohort and the image-based mFRs of those selected will be used to develop the Healthy and Sustainable Diet Index using regression techniques. The remaining one-third of the sample will be used as the validation cohort for the Healthy and Sustainable Diet Index. This Index will also be used in the assessment of food images from the 6-month follow up (n = 220), and the results compared with baseline.

To assess content validity, components of the *Healthy and Sustainable Diet Index* will be assessed against the Australian Dietary Guidelines (NHMRC, 2013). Construct validity will quantitatively assess how well the Index measures conformance to a healthy and sustainable diet.

To determine a total score using the Healthy and Sustainable Diet Index, density scores for each component will be calculated. Internal consistency, one form of reliability, will be assessed using Cronbach's coefficient α. This test has previously been used in the evaluation of the Healthy Eating Index (Guenther, Reedy, Krebs-Smith, et al., 2008) to examine the degree of association between components, to determine if a diet only has one dimension. The relationship between the components of the Healthy and Sustainable Diet Index will be assessed using Pearson correlations coefficient. Principle component analysis will be used to assess if there are independent components of the Index. This will measure if there are any significant independent predictors of an overall score.

7.5 Discussion

The proposed methodologies described in this paper aim to determine if the mobile food record can be used to accurately measure five key indicators of a healthy and sustainable diet. The availability of dietary intake data collected from 4-day mFRs during the CHAT study enables the refinement of the assessment tool and internal validation of a theoretically driven Healthy and Sustainable Diet Index. This Index will be tested on a duplicate sample and a longitudinal sample of adults' 4-day image-based food records to measure content validity, construct validity and reliability.

The Healthy and Sustainable Diet Index will be unique in two ways; firstly it will combine the assessment of eating behaviours that influence health outcomes (e.g., EDNP foods and beverages) and dietary behaviours that significantly burden the environment (e.g., ultra-processed foods, food waste). Secondly, it will require the use of image-based food records, which will enable the accurate assessment of dietary behaviours not assessed in traditional forms of dietary assessment (e.g., individually packaged foods).

Using an mFR application to assess the five healthy and sustainable dietary behaviours described in this paper has the potential for further enhancement of the mFR applications capability as a new dietary assessment method. For example, a current fiducial marker probe exists to alert users when the fiducial marker is not located in the image, as described by Ahmad *et al. (2014)*. A similar mechanism to ask the user whether food waste detected in the after image was thrown in the rubbish bin, composted, saved for consumption at a later time or other could be incorporated into the mFR application.

Currently there is limited evidence on whether Australian adults have dietary habits consistent with a sustainable diet. Without adequate evidence in this area, appropriate changes to dietary recommendations and nutrition policy are challenging. Results from the Australian Health Survey indicate most Australian's have eating habits inconsistent with the Dietary Guidelines, contributing to the burden of diet-related diseases in this country (Department of Agriculture and Food, 2013). However, to the authors' knowledge, there is currently no dietary assessment tool or indexing system to assess and monitor whether individuals have dietary behaviours inconsistent with a sustainable diet, such as the use of individual food packaging and plate waste.

Similar to other dietary assessment methods, using the mobile food record to assess dietary behaviours does not come without limitations. The primary limitation being if a participant forgets to take an image of an eating occasion. This can be minimized by the ability to set alerts on the mobile device to remind participants to take images of all foods and beverages consumed.

Although this method of dietary assessment was tested on a population-based sample of young adults during the CHAT study, the mFR has also been tested in other ages groups (Six et al., 2010). A unique aspect of this proposed work is that images collected using the mFR application have not previously been used to measure these important and topical dietary behaviours, and hold potential for accurate dietary assessment. In addition to the development and validation of a novel dietary assessment method, findings from the work proposed will provide evidence on the current healthy and sustainable dietary habits of young Australian adults.

7.6 Conclusions

The strengths of the protocol and methodology proposed include the development of a dietary assessment method to accurately assess key indicators of a healthy and sustainable diet that are not measured during traditional dietary assessment methods. This innovative method will enable the development of a Healthy and Sustainable Diet Index to assess an individual's adherence to these dietary behaviours. The use of the mFR to assess adherence to a healthy and sustainable diet is a novel and innovative approach to dietary assessment. The steps outlined in this paper only capitalise on the images captured with the mFR, however other features in mobile devices, such as activity measures, could also be considered. Future applications of this method may strengthen this area of research, influence behaviour and raise the awareness of the potential benefits on individual and population health and the environment.

7.7 Acknowledgments and funding

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7.8 Author contributions

Amelia J Harray, Deborah A Kerr, Carol J Boushey and Christina M Pollard designed the protocol. Amelia J Harray and Deborah A Kerr took part in data collection and image analysis . Edward J Delp, Carol J Boushey and Deborah A Kerr developed the mobile CHAT Application and backend server. Deborah A Kerr, Carol J Boushey, Christina M Pollard, Edward J Delp and Ziad Ahmad designed the CHAT study. Amelia J Harray, Deborah A Kerr, Carol J Boushey drafted the manuscript. Satvinder S Dhaliwal and Syed Aqif Mukhtar advised on statistical analysis and database development. All authors read and contributed to the final manuscript.

7.9 Conflicts of Interest

The authors declare no conflict of interest.

7.10 Summary

This chapter outlined the methodology used to assess key components of a healthy and sustainable diet is a novel contribution to the field as images have not previously been used to assess sustainable dietary behaviours. Developing a novel method to assess healthy and sustainable diets in free-living will provide evidence on an area of nutrition with limited data in an Australian context. This study has proposed a new method to be used in future studies to assess healthy and sustainable diets in wider population groups and various settings.

Chapter 8 Development, application and evaluation of the Healthy and Sustainable Diet Index

8.1 Introduction

The literature review and contents of food images captured using the mobile food record (mFR) informed the development of the Healthy and Sustainable Diet Index (HSDI) and its components. This study aimed to assign weighting to individual components of the theoretically derived HSDI and then apply and evaluate the novel method on food images. This involved a secondary analysis of all mFRs collected at baseline and at the six-month return visit of the CHAT study. The HSDI aimed to measure adherence to the ADGs and key messages outlined in Appendix G (of the ADGs) relating to diet and environmental sustainability and; sustainable dietary behaviours that are evidenced in the scientific literature but not included in the ADGs (NHMRC, 2013). For example, the consumption of animal-based foods is well evidenced in the academic literature as a dietary behaviour that has more of a negative impact on the environment than the intake of plant-based foods (Section 2.5.1) but this is not reflected in the current Dietary Guidelines in Australia.

The present chapter details the methods used for weighting each component of the HSDI (to determine a density score), and to calculate a final score (measuring adherence to a healthy and sustainable diet). Individual components of the HSDI, ranging from most ideal to least ideal healthy and sustainable dietary behaviours can be seen in Appendix I. The results of applying this scoring system to a populations-based sample of young adults' mFRs collected during the Connecting Health and Technology study, referred to as the CHAT study, helps address objectives four and five of this research - *Objective 4) Develop a Healthy and Sustainable Diet Index to measure key components of a H&S diet using images. Objective 5) Apply and evaluate the Healthy and Sustainable Diet Index using 4-day image-based food records.*

The candidate conceived the concept of using the mFR to assess healthy and sustainable diets; developed a method to so do; analysed all mFRs collected during the CHAT study at baseline and 6-months (n=247); developed the HSDI and assigned weighting to twelve individual components; entered all data; coordinated and undertook statistical data analysis and; wrote this chapter.

8.2 Abstract

Background: The issues of environmental sustainability and health are often considered in isolation from one another, but would both benefit from policies supporting and encouraging more sustainable dietary behaviours. Such policies are unlikely to occur without a solid evidence base, and current methods to assess how dietary patterns adhere to a healthy and sustainable (H&S) diet have significant limitations. This study aimed to assign weighting to individual components of a theoretically derived Healthy and Sustainable Diet Index (HSDI) to determine a density score, and then apply and evaluate the index on images captured using the mobile food record (mFR).

Methods: Four day image-based mFRs, anthropometric data and demographic questionnaires were collected from 247 adults, aged between 18 to 30 years (162 women and 85 men) in Perth, Western Australia. A HSDI was developed, containing twelve individual components related to a H&S diet, including the intake of animal-based foods, fruits and vegetables (including seasonality); the intake of ultra-processed energy-dense nutrient-poor foods and beverages; the use of individually packaged foods and beverages and; food (plate) waste behaviours. The influence of dietary behaviours on human health were given the highest weighting, followed by impact on the environment. The HSDI used a continuous scale with a maximum score of 90 points.

Results: The mean overall HSDI score was 42.7 (SD 9.3) points. Participants who ate ruminant meat and pigs were less likely to eat vegetables (p<0.001), and those who ate non-animal protein foods, such as legumes, tofu, nuts and seeds, were more likely to eat more fruit (p< 0.001), vegetables (p< 0.05) and dairy foods (p< 0.05). Participants who reported taking vitamin supplements were significantly more likely to have a higher HSDI score than those who reported not taking supplements (p< 0.005). After adjusting for age, sex and body mass index, multivariate regression found the strongest predictor of the likelihood of being in the lowest tertile for total HSDI scores was dietary health consciousness (how much attention people paid to the health aspects of their diet).

Conclusion: This study provides a contribution to the field as a new reference standard has been proposed in the HSDI. This prediction model can be applied to other population groups and datasets, along with refinements to the mFR App, to further evaluate its ability to measure adherence to a healthy and sustainable diet.

8.3 Methods used in the evaluation of the Healthy and Sustainable Diet Index

8.3.1 Study sample

The study sample consists of 247 adults aged between 18 to 30 years, comprising of 162 (66%) women and 85 (34%) men previously recruited during the CHAT study, referred to as the CHAT study (Kerr et al., 2016). Recruitment involved sending letters of invitation to 15,000 residents from 57 suburbs (using the Socio-Economic Indexes for Areas) in the Perth Metropolitan Area from the Federal Electoral Roll, a compulsory enrolment system for Australians aged over 18 years. Participants were screened either online, using a survey website, or on the telephone to ensure the inclusion criteria were satisfied (aged between 18 and 30 years and owned a mobile phone). Participants were excluded if they were: (a) unable to attend on four occasions to complete the six-month randomised controlled trial; (b) studied nutrition; (c) took part in extreme forms of exercise; (d) followed a restrictive diet; or (e) were pregnant or breastfeeding.

The CHAT study was conducted between July 2012 and June 2013 and was registered on the Australian and New Zealand Clinical Trials Registry (ACTRN12612000250831) and approved by the Curtin University Human Resources Ethics Committee (HR181/2011) and the Western Australian Department of Human Research Ethics Committee (#2011/90).

8.3.2 Assessment of healthy and sustainable dietary behaviours

The protocol outlining the methods used to assess individual healthy and sustainable (H&S) dietary behaviours were published by the candidate in Nutrients (Harray et al., 2015) (Chapter 7). The healthy and sustainable dietary behaviours assessed using images captured with the mobile food record were:

- Intake of animal-based foods, including ruminant meat, pigs, poultry, fish, seafood, dairy foods and eggs

- Intake of fruits and vegetables (including legumes and beans) and other plant-based foods high in protein (including nuts, seeds, tofu). This assessment also involved determining whether fresh fruits and vegetables were in season at time of consumption.

- Intake of ultra-processed energy-dense nutrient-poor (EDNP) foods and beverages, including sugar-sweetened beverages (SSBs) and alcohol

- Use of individually packaged foods and beverages (regardless of nutrient composition)

- Food (plate) waste behaviours

8.3.3 Assigning weighting to individual components

Diet quality indices typically have a maximum score, with a higher score indicating greater adherence to the preferred dietary pattern. The Healthy Eating Index, one of the primary indices in the US has a maximum score of 100, indicating a diet fully achieving the US Dietary Guidelines, with a range of 0 (lowest adherence) to 100 (highest adherence) (Guenther et al., 2014). Other diet quality indices use alternative scoring systems, such as the Alternative Healthy Eating Index 2010 (AHEI-2010) - 0 (lowest adherence) to 110 (highest adherence); alternate Mediterranean Diet (aMED) score - 0 (lowest adherence) to 9 (highest adherence); Dietary Approaches to Stop Hypertension (DASH) score - 8 (lowest adherence) to 40 (highest adherence) (Liese et al., 2015). Documentation of the rationale behind why previous studies have assigned particular weighting to components of a DQI often lacks detail to allow repetition and is accompanied by varying levels of subjectivity (Waijers et al., 2007). The following methodology was applied to the HSDI scoring system and has been outlined previously in Chapter 7 (Harray et al., 2015).

The theoretically driven HSDI contains twelve individual components related to a H&S diet. These items and their respective weightings can be seen in Table 8.1. The influence of dietary behaviours on human health were given the highest weighting, followed by impact on the environment. This was due to stronger evidence in this area of dietary intake and health outcomes. A maximum score was allocated to each component of the HSDI. To determine the weighting, each component in the HSDI was categorised into one or more of the following elements; impact on human health and/or impact on the environment. For example, ultra-processed EDNP foods and beverages affect health (contributing excess kilojoules and contributing to chronic disease risk) and the environment (use of water, electricity, transport, packaging and disposal). Therefore, these foods and beverages were given a maximum weighting of ten points each. Another example is food waste, which has a direct negative impact on the environment (resources used to dispose of waste and landfill) and a potential influence on health as fresh fruit and vegetables are perishable and often thrown away, creating a barrier for purchase and consumption. However, due to limited evidence on the latter, food waste was assigned a maximum of five points (for an average of ≤10% of edible plate waste over the 4-day mFR). Ten points were allocated to behaviours that positively or negatively align with both a healthy *and* sustainable diet (such as vegetables) and a maximum of five points were allocated to other dietary behaviours.

The HSDI used a continuous weighting system based on increments of food group serves, or proportions of total intake for behaviours without set recommendations, such as seasonality of fruits and vegetables and plate waste. This method (of using continuous scales opposed to simple cut offs or binary scales), has previously been identified, in a review of diet quality indices, as a superior method, because more foods have a ‘U shaped’ effect when considering intake (Waijers et al., 2007) and continuous scales allow for more variability and provide more sensitivity within the index. For example, one serve of red meat provides nutrients for good health but the consumption of five serves of red meat per day would pose significant negative health and environmental impacts over time. Determining the categories for the continuous scale involved developing a maximum score for each component (as described above), then dividing it into five categories, each with different scores assigned. In circumstances where these dietary behaviours were reflected in the ADGs (such as fruit, veg and milk, yoghurt and cheese) the maximum weighting assigned to the item was determined by the ADGs recommended daily number of serves (NHMRC, 2013). In circumstances where the behaviour was not reflected in the ADGs, such as seasonality, food waste or individual food packaging, categories were created from the academic literature, as outlined in Chapter 2.

Some food groups in the ADGs were separated into several items in the HSDI due to notable differences on the impact of these foods on the environment. For example, the ‘lean meat, poultry, fish and alternatives’ food group was separated into ‘ruminant meat and pigs’, ‘poultry and fish’, ‘non-animal protein alternatives’. To minimise foods being picked up in two or more components of the index, legumes and beans, which appear in both the ‘vegetable’ and ‘lean meat and alternatives’ food group, were assigned to the ‘non-animal protein foods’ group. Some foods, such as EDNP foods may have been counted in both the categories of ‘individually packaged foods’ and ‘ultra-processed EDNP foods’. However, to minimise repetition foods such as ice-cream were only counted as ultra-processed EDNP foods, and not also ‘milk, yoghurt and cheese’.

8.3.4 Statistical analysis used to evaluate the index

A Microsoft Access Database was purpose built to capture the components of a H&S diet. A secondary analysis of 4-day food records collected from a population based sample of 18 to 30 year olds at baseline (n=247) and six months (n=220) were used in these analyses. Appendix H contains screenshots of this Microsoft Access Database. Once the secondary analysis of all mFRs (approximately 12,000 food images) was complete, the dietary data was exported to SPSS Version 22 and merged with the participants' anthropometric and demographic characteristics collected during the CHAT study. SPSS Version 22 was used for all data analyses and p-values of less than 0.05 were considered statistically significant.

To evaluate the HSDI five stages of analysis were conducted to assess the following:

1. Descriptive statistics about the sample including demographic, anthropometric and dietary variables (Table 8.2).
2. The relationship between the components of the index to assess if H&S dietary behaviours are related. This was conducted using the non-parametric test, Spearman's correlation coefficient (Table 8.3.
3. The differences between participants with the lowest, middle and highest total HSDI scores. This was conducted by separating the participants' total HSDI scores into tertiles using the SPSS rank function. One-way ANOVA was used for continuous variables (age and BMI) and Chi-Squared test for all remaining categorical variables (Table 8.4).
4. Regression analyses were conducted to assess which variables help determine those who are in the lowest tertile for total HSDI score and whether any individual variables were predictors of overall HSDI score. Univariate regression analysis was conducted to identify which individual variables predict those most at risk of being in the lowest tertile (HSDI score of 20-38 out of 90). Univariate regression analyses was then conducted after adjusting for age, sex and BMI. Multivariate regression analysis was conducted to see which variables continued to determine those most at risk of being in the lowest tertile when including all variables in the model (Table 8.5).
5. The test re-test reliability of the index was assessed by comparing individual components and the overall HSDI score of participants who completed the CHAT study (mFRs collected at baseline and at the six-month visit (n=220)) (Table 8.6).

8.4 Results of the Healthy and Sustainable Diet Index

Descriptive statistics from the 247 participants at baseline are outlined in Table 8.2. One participant was excluded from the analysis due to an incomplete food record (only one image was captured with the mFR over four days). These results include information collected from participants during the baseline visit including; height, weight, demographics (obtained using a written questionnaire - see Appendix K) and data on dietary behaviours obtained from images captured using the mFR. Individual components of the HSDI were analysed as the mean HSDI score (out of 5 or 10) and also the mean number of serves (according to the Australian Guide to Healthy Eating (AGTHE)) or number of items/percentages (for dietary behaviours not reflected in the AGTHE).

Results in Table 8.2 indicate the majority of the participants were white (77.2%) and had a BMI in the healthy weight range (18.5-24.9 kg/m^2) (58.5%). Nearly one third of participants were classified as either overweight or obese (32.1%) and over one third of participants reported taking vitamin supplements at the time of data collection (37.4%). The mean intake of fruit was 0.9 (±0.7) serves per day and vegetables 1.8 (±1.0) serves per day, less than the recommended two and five serves per day, respectively. Just over half (51.4%) of the fruits and vegetables consumed were in season in WA at the time of consumption and one-fifth (20%) of edible food prepared and served was assessed as edible plate waste.

The intake of individual components of the HSDI are shown in Table 8.2. The mean intake of ultra-processed EDNP foods and beverages over 4 days was 2.7 (±1.4) and 1.0 (±1.0) serves per day, respectively. One serve of EDNP foods and beverages is equivalent to about 600kJ. Approximately 1.9 (±1.4) individually packaged EDNP items (such as a chocolate bar or can of SSB) and 1.6 (±1.2) individually packaged healthy items (such as a bottle of water or small tub of yoghurt) were consumed per day.

Results from the Spearman's correlation tests (Table 8.3) indicate participants who ate ruminant meat and pigs were significantly less likely to eat vegetables. Those who consumed milk, yoghurt and cheese were significantly more likely to eat vegetables. In addition, those who ate non-animal protein foods, such as legumes, tofu, nuts and seeds, were significantly more likely to eat more fruit ($p< 0.001$), vegetables ($p< 0.05$) and dairy foods ($p< 0.05$). The strongest association found was between the intake of individually packaged EDNP foods and ultra-processed EDNP foods ($p< 0.001$) and EDNP beverages ($p< 0.001$) (Table 8.3).

People who reported taking vitamin supplements were significantly more likely to have a higher HSDI score than those who reported not taking supplements ($p < 0.005$). Those who reported paying a lot of attention to the health aspects of their diet were more likely to have a higher total HSDI score than those who reported not thinking much or at all about the health aspects of food ($p < 0.0005$). There were statistically significantly differences in participants in each tertile and scores for individual components of the index (Table 8.4), which is expected as the tertiles were ranked on total HSDI score taking into account all components. However, the intake of seasonal fruits and vegetables, ruminant animal meat and pigs, and milk, yoghurt and cheese were exceptions to this. There were no significant differences detected between the tertiles. See Table 8.4 for the differences between the HSDI scores for each tertile.

The univariate analyses showed that those who do not take a vitamin supplement are more likely to have a HSDI score in the lowest tertile (OR=1.855, 95%CI [1.059, 3.250], $p < 0.05$) (Table 8.5). This relationship was still significant after adjusting for age, sex and BMI, however, was ruled out as a predictor for being in the lowest tertile of HSDI scores once all variables were taken into account in the multivariate regression. Participants who reported currently smoking were significantly more likely to be in the lowest tertile (OR=3.407, 95%CI [1.065, 10.904], $p < 0.05$), however, after adjusting for age, sex and BMI no significant association was observed. The strongest predictor of the likelihood of being in the lowest tertile for total HSDI scores was dietary health consciousness (how much attention people paid to the health aspects of their diet). After adjusting for all other variables in the multivariate regression model, those who reported only taking a bit of notice (OR=5.276, 95%CI [1.765, 15.619], $p < 0.005$) or not thinking much or at all about the health aspects of their diet (OR=8.308, 95%CI [2.572, 26.836], $p < 0.0001$) were more likely to be in the lowest tertile. See Table 8.5 for the results from the univariate and multivariate regression analyses.

The test re-test reliability of the HSDI was assessed using data collected from the same sample on two different occasions, six months apart (participants who completed the study) (n=220) (Table 8.6). The results indicated significant differences between the baseline and six month visit for all components of the index, with the exception of non-animal protein foods and poultry, fish and eggs. The difference between the total HSDI scores for participants from baseline to the six-month visit was 4.1 points ($p < 0.0005$), with the six-month visit having improved HSDI scores (closer adherence to a healthy and sustainable diet).

Table 8.1 Components of the Healthy and Sustainable Diet Index, in ascending order of alignment with a H&S diet (maximum score of 90)*

Item	Item description	Lowest HSDI score	→	→	→	Highest HSDI score	Maximum item score
1	Fruit[a]	0 serves *(0 points)*	0.01-0.5 serves *(2 points)*	0.51-1.25 serves *(5 points)*	1.26-1.99 serves *(8 points)*	≥2 serves *(10 points)*	10
2	Vegetables[a]	< 0.5 serve *(1 point)*	0.5-1.5 serves *(2 points)*	1.51-3 serves *(5 points)*	3.01-4.99 serves *(8 points)*	≥5 serves *(10 points)*	10
3	Seasonality of fruits and vegetables[b]	0-20% *(1 point)*	20.1-40% *(2 points)*	40.1-60% *(3 points)*	60.1-80% *(4 points)*	>80% *(5 points)*	5
4	Ruminant animal meat and pigs[a]	>3 serves *(0 points)*	2.01-3 serves *(1 points)*	1.01-2 serves *(2 points)*	< 0.25 serve *(4 point)*	0.25-1 serve *(5 points)*	5
5	Poultry, fish and eggs[a]	>3 serves *(0 points)*	2.01-3 serves *(2 points)*	< 0.25 serve *(3 point)*	1.01-2 serves *(4 points)*	0.25-1 serve *(5 points)*	5
6	Milk, yoghurt and cheese[a]	< 0.5 serve *(1 points)*	0.5-1 serve *(2 points)*	1.01-2 serves *(3 points)*	>2.5 serves *(4 points)*	2.01-2.5 serves *(5 points)*	5
7	Non-animal protein foods (legumes, tofu, nuts, seeds)[a]	0 serves *(0 points)*	0.01-0.75 serves *(2 points)*	0.76-1.75 serves *(6 points)*	1.76-2.5 serves *(8 points)*	>2.5 serves *(10 points)*	10
8	Ultra-processed EDNP foods[a]	>2.75 serves *(0 points)*	1.76-2.75 serves *(2 points)*	0.76-1.75 serves *(4 points)*	0.01-0.75 serves *(8 points)*	0 serves *(10 points)*	10
9	Ultra-processed beverages (SSBs and alcohol) [a]	>2 serves *(0 points)*	1.26-2 serves *(2 points)*	0.51-1.25 serves *(4 points)*	0.01-0.50 serves *(8 points)*	0 serves *(10 points)*	10
10	Individually packaged EDNP foods and beverages	>2.25 items *(0 points)*	1.51-2.25 items *(2 points)*	0.76-1.5 items *(3 points)*	0.01-0.75 items *(4 points)*	0 items *(5 points)*	5
11	Individually packaged healthy foods and beverages	>2.25 items *(2 points)*	1.51-2.25 items *(4 points)*	0.76-1.5 items *(6 points)*	0.01-0.75 items *(8 points)*	0 items *(10 points)*	10
12	Edible plate waste	>40% *(1 point)*	30.1-40% *(2 points)*	20.1-30% *(3 points)*	10.1-20% *(4 points)*	≤10% *(5 points)*	5
	Total maximum score for each category	**6 points**	**25 points**	**47 points**	**72 points**	**90 points**	

*A higher HSDI score indicates closer alignment to a healthy and sustainable diet
[a]Serve sizes according to the Australian Guide to Healthy Eating (NHMRC, 2013) (Appendix D for food group serve sizes)
[b]Percentage of fruits and vegetables in season at time of consumption, calculated from automated time and date stamp against WA seasonality chart (Appendix G).

Table 8.2 Descriptive statistics of the study population and HSDI index scores* at baseline (n=246)

Variable	Description	Men (n=85)	Women (n=161)	Total (n=246)
		Total score	***Total score***	***Total score***
Age	Years	24.6 ± 3.3	24.2 ± 3.4	24.3 ±3.4
Body Mass Index	kg/m^2	24.7 ± 4.4	24.1 ± 5.8	24.3 ±5.3
		n (%)	***n (%)***	***n (%)***
Ethnicity	White	68 (80.0)	122 (75.8)	190 (77.2)
	Asian	9 (10.6)	32 (19.9)	41 (16.7)
	Other	8 (9.4)	7 (4.3)	15 (6.1)
Body Mass Index	Underweight (<18.5kg/m^2)	7 (8.2)	16 (9.9)	23 (9.3)
	Healthy weight (18.5-24.9kg/m^2)	43 (50.6)	101 (62.7)	144 (58.5)
	Overweight (25-29.9kg/m^2)	37 (31.8)	22 (13.7)	49 (19.9)
	Obese (≥30kg/m^2)	8 (9.4)	22 (13.7)	30 (12.2)
Body Mass Index	Healthy weight and below (<25 kg/m^2)	50 (58.8)	117 (72.7)	167 (67.9)
	Overweight (25-29.9kg/m^2)	27 (31.8)	22 (13.7)	49 (19.9)
	Obese (≥30kg/m^2)	8 (9.4)	22 (13.7)	30 (12.2)
Vitamin supplement use	Yes	25 (29.4)	67 (41.6)	92 (37.4)
	No	60 (70.6)	94 (58.4)	154 (62.6)
Smoking status	Never smoked	53 (62.4)	116 (72.0)	169 (68.7)
	Previous smoker	25 (29.4)	39 (24.2)	64 (26.0)
	Current smoker	7 (8.2)	6 (3.7)	13 (5.3)
IPAQ category[a]	Low activity (<600 MET mins/week)	7 (8.6)	25 (16.8)	32 (13.9)
	Moderate activity (minimum 600 MET mins/week)	39 (48.1)	86 (57.7)	125 (54.3)
	High activity (>3000 MET mins/week)	35 (43.2)	38 (25.5)	73 (31.7)

Variable	Description	Men (n=85)	Women (n=161)	Total (n=246)
Education	Year 10, 11 or 12	32 (37.6)	56 (34.8)	88 (35.8)
	Trade or diploma	29 (34.1)	31 (19.3)	60 (24.4)
	University degree or higher	24 (28.2)	74 (46)	98 (39.8)
SEIFA[b]	1-2	5 (5.9)	2 (1.2)	7 (2.8)
	3-4	2 (2.4)	12 (7.5)	14 (5.7)
	5-6	22 (25.9)	38 (23.6)	60 (24.4)
	7-8	9 (10.6)	41 (25.5)	50 (20.3)
	9-10	47 (55.3)	68 (42.2)	115 (46.7)
Dietary health consciousness[c]	Pay a lot of attention to the health aspects of food	11 (12.9)	29 (18)	40 (16.3)
	Take a bit of notice to the health aspects of food	50 (58.8)	97 (60.2)	147 (59.8)
	Don't think much or don't think at all	24 (28.2)	33 (20.5)	57 (23.2)
Individual HSDI item scores		***Mean ±SD***	***Mean ±SD***	***Mean ±SD***
HSDI items with score 0-10 points	Fruit	4.4 ± 3.6	4.7 ± 3.1	4.6 ± 3.3
	Vegetables	4.0 ± 2.2	3.9 ± 2.1	3.9 ± 2.1
	Non-animal protein foods (legumes, nuts, seeds, tofu)	1.6 ± 1.9	1.8 ± 2.1	1.7 ± 2.0
	Ultra-processed EDNP foods	2.2 ± 2.7	2.0 ± 2.3	2.1 ± 2.4
	Ultra-processed beverages (SSBs and alcohol)	4.8 ± 3.6	5.4 ± 3.5	5.2 ± 3.6
	Individually packaged *healthy* foods and beverages	5.5 ± 2.8	5.3 ± 2.7	5.4 ± 2.7
HSDI items with score 0-5 points	Seasonal fruits and vegetables	3.1 ± 1.0	3.0 ± 1.1	3.0 ± 1.0
	Ruminant animal meat and pigs	3.4 ± 1.7	3.9 ± 1.5	3.7 ± 1.6
	Poultry, fish, eggs	4.0 ± 1.2	4.1 ± 1.1	4.1 ± 1.1
	Milk, yoghurt and cheese)	3.2 ± 1.1	2.9 ± 1.1	3.0 ± 1.1
	Individually packaged *EDNP* foods and beverages	2.2 ± 1.9	2.1 ± 1.7	2.1 ± 1.8
	Food (plate) waste	4.3 ± 1.2	3.6 ± 1.3	3.9 ± 1.3

Variable	Description	Men (n=85)	Women (n=161)	Total (n=246)
Overall HSDI score	Out of 90 points	42.7 ± 9.7	42.7 ± 9.3	42.7 ± 9.3
HSDI items presented as serves per day[d], number of items or % of total	Fruit (serves/day)	1.1 ± 1.3	0.9 ± 0.7	0.9 ± 0.7
	Vegetables (serves/day)	1.8 ± 1.0	1.8 ± 1.0	1.8 ± 1.0
	Seasonal fruits and vegetables (% of total fruits and vegetables)	52.9 ± 20.4	51.4 ± 20.2	51.4 ± 20.2
	Ruminant animal meat (serves/day)	1.2 ± 0.9	0.8 ± 0.7	0.8 ± 0.7
	Poultry, fish, eggs (serves/day)	1.1 ± 0.8	1.0 ± 0.7	1.0 ± 0.7
	Milk, yoghurt and cheese (serves/day)	1.8 ± 1.1	1.4 ± 0.9	1.4 ± 0.9
	Non-animal protein foods (legumes, nuts, tofu) (serves/day)	0.3 ± 0.4	0.3 ± 0.5	0.3 ± 0.5
	UP EDNP foods (serves/day)	2.8 ± 1.8	2.7 ± 1.4	2.7 ± 1.4
	UP beverages (SSBs and alcohol) (serves/day)	1.3 ± 1.4	1.0 ± 1.0	1.0 ± 1.0
	Individually packaged *EDNP* foods and beverages (# of items)	2.1 ± 2.0	1.9 ± 1.4	1.9 ± 1.4
	Individually packaged *healthy* foods and beverages (# of items)	1.5 ± 1.2	1.6 ± 1.2	1.6 ± 1.2
	Food (plate) waste (% of total food)	11.1 ± 15.3	20 ± 15.1	20 ± 15.1

*A higher HSDI score indicates closer alignment to a healthy and sustainable diet
(Australian Bureau of Statistics, 2018)[a]International Physical Activity Questionnaire
[b]Socio-Economic Indexes for Areas (Australian Bureau of Statistics, 2018)
[c]Dietary health consciousness was determined by asking, “Which of the following best describes how you feel about your diet?”
[d]Serve size according to the Australian Guide to Healthy Eating (NHMRC, 2013) (Appendix D).

Table 8.3 Relationship between components of the HSDI at baseline, assessed using Spearman's correlation coefficient (n=246)

Spearman's rho	Fruit	Vegetables	Seasonal fruits & vegetables	Ruminant meat & pigs	Poultry, fish & eggs	Milk, yoghurt & cheese	Non animal protein foods	Ultra-processed EDNP foods	Ultra-processed EDNP drinks	Individually packaged EDNP items	Individually packaged healthy items
Vegetables	0.307 **(p<0.001)**										
Seasonal fruits & vegetables	-0.09 (p=0.162)	-0.061 (p=0.342)									
Ruminant meat & pigs	-0.093 (p=0.146)	-0.225 **(p<0.001)**	-0.044 (p=0.488)								
Poultry, fish & eggs	-0.014 (p=0.832)	0.027 (p=0.673)	-0.023 (p=0.722)	0.045 (p=0.481)							
Milk, yoghurt & cheese	0.132 **(p<0.05)**	0.136 **(p<0.05)**	-0.108 (p=0.090)	-0.062 (p=0.332)	-0.011 (p=0.868)						
Non animal protein foods	0.258 **(p<0.001)**	0.242 **(p<0.001)**	-0.125 **(p<0.05)**	-0.118 (p=0.064)	-0.063 (p=0.328)	0.138 **(p<0.05)**					
Ultra-processed EDNP foods	0.082 (p=0.200)	0.140 **(p<0.05)**	0.04 (p=0.536)	0.038 (p=0.551)	0.076 (p=0.234)	-0.086 (p=0.180)	0.066 (p=0.304)				
Ultra-processed EDNP drinks	0.111 (p=0.083)	0.017 (p=0.796)	-0.04 (p=0.529)	-0.026 (p=0.689)	0.083 (p=0.193)	-0.106 (p=0.098)	0.121 (p=0.058)	0.231 **(p<0.001)**			
Individually packaged EDNP items	0.080 (p=0.209)	0.217 **(p<0.001)**	-0.004 (p=0.956)	0.044 (p=0.494)	0.068 (p=0.292)	-0.116 (p=0.070)	0.07 (p=0.277)	0.322 **(p<0.001)**	0.432 **(p<0.001)**		
Individually packaged healthy items	-0.086 (p=0.178)	-0.037 (p=0.563)	0.116 (p=0.070)	0.024 (p=0.714)	0.147* **(p<0.05)**	-0.233 **(p<0.001)**	-0.071 (p=0.268)	0.107 (p=0.094)	0.065 (p=0.310)	0.132 **(p<0.05)**	
Food (plate) waste	0.05 (p=0.431)	0.099 (p=0.120)	0.016 (p=0.808)	-0.147 **(p<0.05)**	0.026 (p=0.682)	0.141 **(p<0.05)**	-0.08 (p=0.212)	0.038 (p=0.555)	0.034 (p=0.599)	0.097 (p=0.128)	0.019 (p=0.765)

Table 8.4 Differences between total HSDI score* tertiles at baseline, using One-way ANOVA (continuous variables) and Chi-Squared test (categorical variables) (n=246)

Variable	Description	Lowest tertile (HSDI score 20-38) n=88	Middle tertile (HSDI score 39-46) n=77	Highest tertile (HSDI score 47-69) n=81	
		Mean ±SD	***Mean ±SD***	***Mean ±SD***	**p-*value***
Age	Years	24.4 ± 3	24.1 ± 3.6	24.4 ± 3.6	0.830
Body Mass Index	kg/m^2	25.1 ± 5.9	23.6 ± 4.1	24.1 ± 5.8	0.162
		n (%)	***n (%)***	***n (%)***	**p-*value***
Sex	Men	29 (33.0)	27 (35.1)	29 (35.8)	0.921
	Women	59 (67.0)	50 (64.9)	52 (64.2)	
Body Mass Index	Underweight (<18.5 kg/m^2)	8 (8.0)	7 (9.1)	9 (11.1)	0.634
	Healthy weight (18.5-24.9 kg/m^2)	47 (53.4)	50 (64.9)	47 (58.0)	
	Overweight (25-29.9 kg/m^2)	21 (23.9)	14 (18.2)	14 (17.3)	
	Obese (≥30 kg/m^2)	13 (14.8)	6 (7.8)	11 (13.6)	
Body Mass Index	Healthy weight and below (<25 kg/m^2)	54 (61.4)	57 (74.0)	56 (69.1)	0.418
	Overweight (25-29.9 kg/m^2)	21 (23.9)	14 (18.2)	14 (17.3)	
	Obese (≥30 kg/m^2)	13 (14.8)	6 (7.8)	11 (13.6)	
Vitamin supplement use	Yes	25 (28.4)	25 (32.5)	42 (51.9)	**<0.005**
	No	63 (71.6)	52 (67.5)	39 (48.1)	
Smoking status	Never smoked	54 (61.4)	55 (71.4)	60 (74.1)	0.212
	Previous smoker	26 (29.5)	20 (26.0)	18 (22.2)	
	Current smoker	8 (9.1)	2 (2.6)	3 (3.7)	

Variable	Description	Lowest tertile (HSDI score 20-38) n=88	Middle tertile (HSDI score 39-46) n=77	Highest tertile (HSDI score 47-69) n=81	
IPAQ category[a]	Low activity (<600 MET mins/week)	11 (13.6)	9 (12.7)	12 (15.4)	
	Moderate activity (minimum 600 MET mins/week)	44 (54.3)	40 (56.3)	41 (52.6)	0.988
	High activity (>3000 MET mins/week)	26 (32.1)	22 (31.0)	25 (32.1)	
Ethnicity	White	74 (84.1)	56 (72.7)	60 (74.1)	
	Asian	12 (13.6)	15 (19.5)	14 (17.3)	0.283
	Other	2 (2.3)	6 (7.8)	15 (6.1)	
Education	Year 10, 11 or 12	33 (37.5)	27 (35.1)	28 (34.6)	
	Trade or diploma	22 (25.0)	20 (26.0)	18 (22.2)	0.947
	University degree or higher	33 (37.5)	30 (39.0)	35 (43.2)	
SEIFA[b]	1-2	2 (2.3)	3 (3.9)	2 (2.5)	
	3-4	2 (2.3)	5 (6.5)	7 (8.6)	
	5-6	27 (30.7)	18 (23.4)	15 (18.5)	0.487
	7-8	15 (17.0)	15 (19.5)	20 (24.7)	
	9-10	42 (47.7)	36 (46.8)	37 (45.7)	
Dietary health consciousness[c]	Pay a lot of attention to the health aspects of food	4 (4.7)	8 (10.4)	28 (34.6)	
	Take a bit of notice to the health aspects of food	55 (64.0)	48 (62.3)	44 (54.3)	**< 0.0005**
	Don’t think much or don’t think at all	27 (31.4)	21 (27.3)	9 (11.1)	

Variable	Description	Lowest tertile (HSDI score 20-38) n=88	Middle tertile (HSDI score 39-46) n=77	Highest tertile (HSDI score 47-69) n=81	
Individual HSDI item scores		**Mean ±SD**	**Mean ±SD**	**Mean ±SD**	***p*-value**
HSDI item scores of 0-10	Fruit	2.8 ± 2.6	4.7 ± 3.0	6.4 ± 3.1	**< 0.0005**
	Vegetables	3.1 ± 1.7	3.8 ± 2.0	5.1 ± 2.2	**< 0.0005**
	Non-animal protein foods (legumes, nuts, seeds, tofu)	1.1 ± 1.4	1.5 ± 1.5	2.6 ± 2.6	**< 0.0005**
	Ultra-processed EDNP foods	0.8 ± 1.5	1.9 ± 2.2	3.6 ± 2.5	**< 0.0005**
	Ultra-processed EDNP beverages (SSBs and alcohol)	2.8 ± 2.7	5.4 ± 3.5	7.8 ± 2.5	**< 0.0005**
	Individually packaged healthy foods and beverages	4.5 ± 2.3	5.3 ± 2.8	6.4 ± 2.7	**< 0.0005**
HSDI item scores of 0-5	Seasonal fruits and vegetables	3.0 ± 1.1	3.0 ± 1.1	3.1 ± 0.9	0.699
	Ruminant meat and pigs	3.6 ± 1.6	3.8 ± 1.6	3.8 ± 1.6	0.550
	Poultry, fish and eggs	3.9 ± 1.3	4.0 ± 1.2	4.4 ± 0.8	**< 0.05**
	Milk, yoghurt and cheese	2.9 ± 1.1	2.9 ± 1.1	3.1 ± 1.1	0.644
	Individually packaged EDNP foods and beverages	1.0 ± 1.4	2.1 ± 1.7	3.4 ± 1.5	**< 0.0005**
	Food (plate) waste	3.6 ± 1.4	3.9 ± 1.2	4.2 ± 1.2	**< 0.05**

*A higher HSDI score indicates closer alignment to a healthy and sustainable diet

[a]International Physical Activity Questionnaire

[b]Socio-Economic Indexes for Areas (Australian Bureau of Statistics, 2018)

[c]Dietary health consciousness was determined by asking, "Which of the following best describes how you feel about your diet?"

Table 8.5 Association between variables and the likelihood of being in the lowest tertile of HSDI scores* at baseline: Univariate; after adjusting for Age, Sex, BMI, and; Multivariable (n=246)

Variable	Description	**Univariate** Odds-ratio (95% CI) *p*-value	**After adjusting for Age, Sex, BMI** Odds-ratio (95% CI) *p*-value	**Multivariable** Odds-ratio (95% CI) *p*-value
Age	Years	1.017 (0.941, 1.098) $p = 0.673$		-
Sex	Women	1		-
	Men	0.895 (0.516, 1.554) $p = 0.694$		-
BMI	kg/m^2	1.045 (0.995, 1.097) $p = 0.076$		-
Vitamin Supplements	Yes	1	1	-
	No	1.855 (1.059, 3.250) **$p < 0.05$**	1.810 (1.021, 3.209) **$p < 0.05$**	-
Smoking	Never smoked	1	1	-
	Previous smoker	1.457 (0.804, 2.640) $p = 0.215$	1.395 (0.757, 2.571) $p = 0.286$	-
	Current smoker	3.407 (1.065, 10.904) **$p < 0.05$**	3.284 (0.983, 10.964) $p = 0.053$	-

Variable	Description	**Univariate** Odds-ratio (95% CI) *p*-value	**After adjusting for Age, Sex, BMI** Odds-ratio (95% CI) *p*-value	**Multivariable** Odds-ratio (95% CI) *p*-value
Ethnicity	White	1	1	-
	Asian	0.649 (0.312, 1.350) $p = 0.247$	0.743 (0.348, 1.585) $p = 0.442$	-
	Other	0.241 (0.053, 1.099) $p = 0.066$	0.201 (0.042, 0.971) **$p < 0.05$**	-
Education	Year 10,11 or 12	1.182 (0.648, 2.157) $p = 0.586$	1.330 (0.660, 2.678) $p = 0.425$	-
	Trade or diploma	1.140 (0.583, 2.232) $p = 0.702$	1.073 (0.529, 2.176) $p = 0.846$	-
	University degree or higher	1	1	-
SEIFA[a]	1-2	0.695 (0.129, 3.742) $p = 0.672$	0.736 (0.135, 4.018) $p = 0.723$	-
	3-4	0.290 (0.062, 1.357) $p = 0.116$	0.256 (0.054, 1.225) $p = 0.088$	-
	5-6	1.422 (0.754, 2.683) $p = 0.277$	1.327 (0.695, 2.537) $p = 0.391$	-
	7-8	0.745 (0.365, 1.521) $p = 0.419$	0.695 (0.333, 1.447) $p = 0.330$	-
	9-10	1	1	-

Variable	Description	**Univariate** Odds-ratio (95% CI) *p*-value	**After adjusting for Age, Sex, BMI** Odds-ratio (95% CI) *p*-value	**Multivariable** Odds-ratio (95% CI) *p*-value
IPAQ category[b]	Low activity (<600 MET mins/week)	0.947 (0.396, 2.266) $p = 0.902$	0.906 (0.370, 2.220) $p = 0.829$	-
	Moderate activity (minimum 600 MET mins/week)	0.982 (0.537, 1.796) $p = 0.953$	1.011 (0.545, 1.876) $p = 0.972$	-
	High activity (>3000 MET mins/week)	1	1	-
Dietary health consciousness[c]	Pay a lot of attention to the health aspects of food	1	1	1
	Take a bit of notice to the health aspects of food	5.380 (1.817, 15.934) **$p < 0.005$**	5.250 (1.765, 15.619) **$p < 0.005$**	5.276 (1.775, 15.681) **$p < 0.005$**
	Don't think much or don't think at all	8.100 (2.548, 25.747) **$p < 0.0001$**	8.152 (2.530, 26.272) **$p < 0.0001$**	8.308 (2.572, 26.836) **$p < 0.0001$**

*A higher HSDI score indicates closer alignment to a healthy and sustainable diet

[a]Socio-Economic Indexes for Areas (Australian Bureau of Statistics, 2018)

[b]International Physical Activity Questionnaire

[c]Dietary health consciousness was determined by asking, "Which of the following best describes how you feel about your diet?"

Table 8.6 Paired-sample t-test to assess the test re-test reliability of the HSDI between data collected baseline and six months, presented as HSDI scores* on participants who completed the study (n=220)

	Description of individual HSDI item scores	**Baseline visit Mean score ±SD**	**6-month visit Mean score ±SD**	**Mean difference**	***p*-value**
Items with score 0-10 points	Fruit	4.7 ± 3.3	4.1 ± 3.3	-0.6	**< 0.05**
	Vegetables	3.9 ± 2.2	4.5 ± 2.4	0.5	**< 0.001**
	Non-animal protein foods (legumes, nuts, seeds, tofu)	1.8 ± 2.1	1.8 ± 2.1	-0.0	0.821
	Ultra-processed EDNP foods	2.1 ± 2.4	3.0 ± 2.9	0.9	**< 0.0005**
	Ultra-processed EDNP beverages (SSBs and alcohol)	5.2 ± 3.5	6.0 ± 3.5	0.8	**< 0.005**
	Individually packaged healthy foods and beverages	5.4 ± 2.7	6.0 ± 2.8	0.6	**< 0.005**
Items with score 0-5 points	Seasonal fruits and vegetables	3.0 ± 1.1	3.6 ± 1.2	0.7	**< 0.0005**
	Ruminant meat and pigs	3.7 ± 1.6	4.1 ± 1.3	0.3	**< 0.01**
	Poultry, fish and eggs	4.1 ± 1.1	4.3 ± 0.9	0.1	0.129
	Milk, yoghurt and cheese	3.0 ± 1.1	2.6 ± 1.1	-0.4	**< 0.0005**
	Individually packaged EDNP foods and beverages	2.1 ± 1.7	2.9 ± 1.8	0.8	**< 0.0005**
	Food (plate) waste	3.8 ± 1.3	4.2 ± 1.2	0.3	**< 0.005**
Total score	**Out of 90**	**42.8 ± 9.4**	**46.9 ± 10.2**	**4.1**	**< 0.0005**

*A higher HSDI score indicates closer alignment to a healthy and sustainable diet

8.5 Discussion

This study aimed to assign weighting to individual components of the theoretically driven Healthy and Sustainable Diet Index (HSDI) and then apply and evaluate the novel method on images captured using the mobile food record (mFR). This involved a secondary analysis of all mFRs collected at baseline and at the six-month return visit of the CHAT study.

This study found people who take vitamin supplements had an increased likelihood of having diets more aligned with a H&S diet (regardless of age, sex or BMI). Previous studies have found those who are least at risk of poor nutrient intake are more likely to use nutritional supplements (Balluz, Okoro, Bowman, Serdula, & Mokdad, 2005). However, no research has examined the relationship between sustainable dietary behaviours and supplement use. Another key finding was that dietary health consciousness was the only independent predictor of one's likelihood of being in the lowest tertile of HSDI scores, when all other variables were included in the multivariate regression model. These findings support the inclusion of this survey question ("*Which of the following best describes how you feel about your diet?")* in future research in the area of healthy and sustainable diets. Previously in this thesis, the candidate found this question (asked in both the NMSS and CHAT study) to be associated with high level of concern regarding the impact of the environment on the food supply (Harray, Meng, Kerr, & Pollard, 2018) (Chapter 3) and EDNP food and SSB intake (Harray et al., 2017) (Chapter 5).

The evaluation of the HSDI found that individual components were related to each other, with people who displayed one behaviour significantly more or less likely to also display another behaviour. For example, the intake of non-animal protein foods was associated with fruit ($p< 0.001$) and vegetable intake ($p< 0.001$) and all aligned with a H&S diet. Conversely, the intake of EDNP foods, beverages and individually packaged foods were associated and all unsupportive of a sustainable diet. The ability to detect these associations shows an element of sensitivity within the index. Further research applying principle component analysis to the HSDI scores will help determine if there are independent components of the Index and if any components can be ruled out.

To date, there is no evidence available on the use of individually packaged foods by consumers in Australia or internationally. The novel findings in this study show these foods and beverages, both EDNP and healthy individually packaged items, are consumed daily (1.9 ±1.4 items and 1.6 ±1.2 items per day, respectively). This dietary behaviour is of concern when considering a sustainable diet as ultra-processed EDNP foods and beverages: 1) provide minimal, if any, nutritional value; 2) encourage the overconsumption of kilojoules above energy requirements and; 3) require resources (such as water and electricity) in the extensive levels of food processing and packaging. Conducting image-based dietary assessment (using the mFR) to measure plate waste and the use of individually packaged foods and beverages, including both healthy and EDNP items, was a unique aspect of this study.

The low mean scores for fruits (4.6 (± 3.3) out of a possible 10 points) and vegetables (3.9 (±2.1) out of a possible 10 points) were not surprising due to national Australian data on poor compliance with recommendations for these food groups (Australian Bureau of Statistics, 2014) (Table 8.2). The high intake of EDNP foods were similarly expected and reflected in the mean scores (2.1 (±2.4) out of a possible 10 points) due to an estimated 36% of the energy of Australian adults' energy intake coming from these discretionary foods (Australian Bureau of Statistics, 2014).

The study sample were predominantly females in the healthy weight range, although the mean BMI for both males and females was at the upper end with 24.7 and 24.1kg/m^2, respectively. Strengths of this study were that a population-based sample of participants were recruited via the Federal Electoral Roll and data were collected from the same participants on two separate occasions, six months apart. This enabled the test re-test reliability of the index to be evaluated using a paired sample t-test.

The HSDI is the only known index to combine the assessment of dietary behaviours that influence health outcomes (e.g. EDNP foods and beverages) and those that significantly burden the environment (e.g. ultra-processed foods, food waste). It is also the first diet quality index to use image-based mFRs for the assessment of behaviours not assessed in traditional forms of dietary assessment, such as individually packaged foods and edible plate waste. In the absence of a gold standard for a H&S diet and the rudimentary evidence on the environmental impact of specific food groups in an Australian context, challenges arose when it came to its evaluation. Although validation of all dietary assessment methods is important to measure whether they accuracy achieve what they aim to , first a 'gold standard' is required (Gold et al., 2010). Such a standard requires a strong evidence base, such as Dietary Guidelines for good health, and does not exist regarding a H&S diet. First, a reference standard is required (Gold et al., 2010). The present study developed a new reference standard to examine healthy and sustainable diets using images, which can be used in future studies and applied to a larger population group and wider age range. The HSDI maximum score of 90 points was developed as a result of equal weighting of the elements of a healthy and/or sustainable diet that could be retrospectively assessed using the mFR images. There is potential to modify the weighting of individual components of the HSDI, and include additional components, as evidence on the environmental impact of foods evolves, or if the index is applied to different settings. This novel method demonstrated its ability to assess the multidimensional nature of a healthy and sustainable diet by incorporating twelve components into the index and finding significant associations between behaviours. Future research involving the application of the HSDI to a larger more diverse sample, in addition to the collection of markers of health outcomes (such as blood cholesterol levels as a risk factor for cardiovascular disease) will strengthen the evaluation of the index.

Similar to other methods, using the mFR to assess diet is accompanied by limitations. The primary limitation being participants forgeting to capture an image of an eating occasion. This can be minimised by the ability to set alerts on the mobile device to remind participants to capture images of all foods and beverages consumed. These alerts have previously been described by Ahmad et al. (2014). Another limitation is the potential for estimation error inherent in dietary assessment methods involving humans, including the use of a trained analyst in this study. The advantacements in the use of mFR technology toward automated image analysis in the future may reduce this error. The influence of social desirability bias (as discussed in Section 2.6.4.1) is a potential limitation of this study. In addition, due to the secondary analysis of existing data, the dietary behaviours of focus were limited to those collected from existing mFRs during the CHAT study.

Further research exploring consumer interest and awareness of H&S diets and modifications to the existing mFR App would strengthen the proposed method . For example, short survey questions could be included in the App to measure variables, such as dietary health consciousness or supplement use to increase the level of detail collected using on edietary assessment method.

8.6 Summary

This study provides a contribution to the field as a new reference standard has been proposed in the Healthy and Sustainable Diet Index. This prediction model can be applied to other population groups and datasets, along with refinements to the mFR App, to further evaluate its ability to measure adherence to a healthy and sustainable diet.

Chapter 9 Discussion

9.1 Introduction

The attitudes and behaviours of Western Australian adults relating to a healthy and sustainable diet explored in this research have identified novel findings and created directions for future research. This chapter addresses each objective chronologically to ensure the results, learnings and limitations are discussed. The overarching themes to emerging from this research are addressed at the end of the chapter.

9.2 Determine the factors associated with measures of adults' support for a sustainable food supply using Western Australian population-based survey data (Objective 1)

This study was unique in that it used a population-based sample of Western Australian adults to assess the relationship between attitudes and behaviours relating to a sustainable food supply. Additional strengths include reporting of a population's perceptions of current and topical policy issues and the use of data from repeated survey questions, collected three years apart. The findings from this study highlight the need to measure knowledge and attitudes when investigating this complex area of nutrition, as there are discrepancies between translating these attitudes to dietary behaviours.

This study found people are very concerned about the effect of the environment on future food supplies but there are limited associations between these attitudes and the intake of key foods related to a sustainable diet. This may be due to low awareness or understanding of what constitutes environmentally friendly food choices, or the influence of social desirability bias when answering survey questions (especially as the detrimental impact of global warming is commonly in the media). Gaps between attitudes and intended behaviours have previously been explored in young people in Belgium (Vermeir & Verbeke, 2006). This study found people's intentions to consume 'sustainable foods' are influenced by social pressure, perceived availability and knowledge of what constitutes sustainable food choices (Vermeir & Verbeke, 2006). A limitation of this study was that actual food intake was not measured, so the researchers were unable to assess whether there were associations between these attitudes and dietary behaviours. In Western Australia, there have been no public health messages or strategies to educate people on what constitutes sustainable food choices. Given the high and increasing level of concern

Western Australian adults place on the environment's impact on future food supplies found in the present study, such messages promoting the synergies between a diet that is good for health and supportive of the environment are warranted.

Western Australian adults place a high level of importance on government regulatory control of a sustainable food supply. This novel finding may be due to high awareness of the impact of the food supply on the environment, a lack of trust in food manufacturers and retailers self-regulating the issue, or limited knowledge of what government regulation would involve. Regulatory options to reduce the impact of the food supply on the environment could include taxes on landfill, tightening trade laws, or changes to farming practices and food production methods. To assist consumers in making more sustainable choices at the point of food selection, governments could mandate carbon footprint levels on packaged food labels, similar to the UK. However, this would require significant investment in measuring the life cycle analysis values of individuals foods and also cooperation from the food industry (Lang et al., 2009).

Limitations of this study include the fact it was a secondary analysis of an existing dataset and therefore was restricted to the information collected from past surveys. Also, self-reported responses to attitudinal questions may be influenced by social desirability bias, a sense of social responsibility as a result of increasing awareness of sustainability and its importance (Vermeir & Verbeke, 2006). It is worth noting, this bias would exist across both the 2009 and 2012 surveys included in the present study and about one quarter of respondents did not show concern for the impact of the environment on the food supply. Another limitation is the dietary assessment method used (short screener questions) in the Nutrition Monitoring Survey Series, which is accompanied by a level of systematic error (Kirkpatrick et al., 2014). However, the cost effectiveness of this method makes it an appealing option when limited funding is available or surveys have objectives beyond purely food intake.

9.3 Evaluate perceptions toward current energy-dense nutrient-poor food and beverage intake, compared to actual intake collected using the mobile food record (Objective 2)

Increasing one's awareness about areas for dietary change can encourage motivation to make improvements. This study found people who perceived their diet to be low in 'junk food' consumed significantly less than those who reported trying to eat less junk food. However, even participants with the lowest intake of these EDNP foods and SSBs consumed well above the dietary recommendations for good health (NHMRC, 2013). A strength of this study is that EDNP foods and SSBs play a key role in influencing both health (as diets high in these foods are associated with weight gain and poor health outcomes) and environmental sustainability (as they require input of natural resources in the production, processing, packaging, storage and transport) for little to no nutritional benefit. The intake of these foods and beverages also encourages the overconsumption of kilojoules above energy requirements, a dietary behaviour which is nor healthy or sustainable (NHMRC, 2013).

The findings in this study identified a disconnect between how people perceived their diet and their actual dietary behaviours. This gap needs to be explored in the context of a sustainable diet, as people may perceive their current intake to be more closely aligned with a sustainable diet than it actually is. Using the mobile food record (mFR) to collect objective data on healthy and sustainable dietary behaviours, alongside attitudes and perceptions of diet, will assist in strengthening understanding of the relationship between perceived diet quality and intake as a potential barrier to change (Powell-Wiley et al., 2014). Understanding this association, in relation to a sustainable diet, may help the targeting and testing of messages and interventions. Further research investigating how to change perceptions of diet to be more accurate is warranted.

In this study, a question assessing dietary health consciousness was significantly associated with intake of EDNP foods and SSBs. Young adults who paid more attention to the health aspects of their diet consumed significantly less of these foods and beverages than those who paid little to no attention. This may be due to knowledge about what these foods are and the health risks associated with eating them, and therefore a greater ability to translate knowledge to food choice. Further research investigating how much attention people pay to the impact of their food choices on the environment could help measure the attitude-behaviour intention gap when it comes to a sustainable diet. Another avenue for future research in the area would be providing people with personalised feedback on their food intake and the environment impacts of their dietary behaviours. This may be a motivator to adopt healthier and more sustainable diets. As healthy and sustainable food choices often go hand-in-hand, such research in this area could provide insight into whether the environmental impacts of diet are motivators for people to eat healthier foods, especially for those who are not motivated by potential health consequences. It is not known which foods WA adults perceive to be environmentally sustainable choices and whether this knowledge translates to dietary behaviours.

Notable strengths of this study were the use of a population-based sample of young adults and the collection of dietary intake data over four consecutive days (including weekdays and a weekend day), giving a greater indication of dietary fluctuations than the 24-hour recall method. Using the mFR to measure dietary intake provides a more objective method compared to short screener questions due to the level of systematic error inherent in methods whereby people are expected to estimate or recall usual dietary intake (Boushey, Spoden, Zhu, et al., 2017; Kirkpatrick et al., 2014; Nelson & Lytle, 2009). There is potential to incorporate survey questions into the mFR App, so all information can be collected using one dietary assessment method.

Some limitations need to be considered when interpreting these results. Firstly, a definition of 'junk foods and sugary drinks' was provided to CHAT study participants in the written questionnaire, with examples of foods in this category (Appendix K). However, it was not a complete list, as per the Australian Guide to Healthy Eating (NHMRC, 2013) and therefore, all of the foods classified as EDNP in the analysis of images may not have been perceived as 'junk foods or sugary drinks' by the participants (for example, mayonnaise or fruit drinks). Secondly, misreporting of EDNP food and SSB intake may have occurred due to participants modifying their usual dietary intake during the mFR or being selective in the foods and beverages they captured in images. Under reporting the intake of EDNP foods and beverages and over reporting fruit and vegetable intake commonly occurs in dietary assessment (Macdiarmid & Blundell, 1998).

9.4 Determine the association between eating frequency and the intake of foods related to a healthy and sustainable diet, as defined by the consumption of fruits, vegetables and energy-dense nutrient-poor foods and beverages (Objective 3)

It is important to determine influences on food choice when exploring dietary patterns and behaviours. The influence of how often people eat and drink had not previously been examined relating to healthy and sustainable diets. Two main inconsistencies in previous studies on eating frequency were identified in the literature review (Chapter 2). The first being the variety of self-reported dietary assessment methods used to collect data on the times at which people eat and drink. The other being the lack of consistent terminology and definitions to classify eating occasions. The mFR has the ability to collect objective data on eating occasions, while minimising reporting bias due to the participant not being required to record this information. The mFR had not previously been used to assess eating frequency and its association with dietary behaviours. The automatically assigned time and date stamps on each image captured using the mFR limits burden on participants. To help address issues relating to the lack of consistency with the terminology used in this area of nutrition research, the candidate created objective labels for different eating occasions (e.g. food only, food and beverage, beverage only, single item or water only). Researcher assigned labels helped lessen participant subjectivity around what constitutes a meal or snack. Using the mFR to assess eating frequency, by use of automated time and date stamps, reduces reliance on participants and therefore is likely to improve compliance and accuracy.

Due to the cross-sectional nature of this analysis, causal relationships cannot be drawn upon and eating frequency cannot be considered in isolation of other influences on food intake. Collecting additional information on factors influencing eating frequency, such as physiological hunger, behavioural habits, or environmental triggers, would add to the understanding of eating frequency (Mattes, 2014b). Such information could be collected using the mFR by questions appearing on the App before participants capture an image.

A limitation of this study was the types and volumes of foods consumed at specific eating occasions were not measured (i.e. contents of food images were not matched with each specific eating occasion). Therefore, the types of foods and beverages consumed at certain times of the day or in what combinations could not be determined. Future analyses could address this by modifying the purpose built Microsoft Access database, which was used to record the image contents. No changes would need to be made to the mFR App itself or the level of participant involvement. Another limitation is that this study involved analysis of eating occasions and specific food groups, but not kilojoule and nutrient analysis. Therefore, overall energy intake could not be adjusted for.

9.5 Development, application and evaluation of the Healthy and Sustainable Diet Index (Objectives 4 & 5)

This research is novel in that a method was developed to assess mutiple components of a healthy and sustainable diet, which have not been previously measured using a single dietary assessment method. There is limited evidence on whether Australian adults have dietary habits consistent with a sustainable diet and without such evidence recommending changes to nutrition policy is challenging. This present study demonstrated that the mFR is an appropriate method to measure compliance with a healthy and sustainable diet and that adhereance to this dietary pattern is low.

The Healthy and Sustainable Diet Index (HSDI) was applied to a population-based sample of young adults, which strengthened the evaluation of the new method. The results from the regression analyses helped determine which variables predict the likelihood of having a low overall HSDI score. After adjusting for age, sex and BMI, people who reported not taking vitamin supplements and those who reported only taking a bit or no notice of the health aspects of their diet were significantly more likely to have a total HSDI score in the lowest tertile. The development of this theoretically derived prediction model is a novel contribution to the field as an index relating to a healthy and sustainable diet did not exist previously. This provides a reference standard for future studies in the area.

To increase accuracy in collecting data on healthy and sustainable dietary behaviours and allow for upscaling research into sustainable diets, a purpose built App could be designed by enhancing the version of the mFR App used in the CHAT study. Making adaptations to the current version of the mFR App would enable researchers to assess a wider range of sustainable dietary behaviours in a more efficient manner. This would mean participants would not need face-to-face contact with a research team, reducing cost and expanding reach. For example, currently the mFR App has probes to alert users when the fiducial marker is not located in the image, as described by Ahmad et al. (2014). A similar feature could assess food waste practices by asking users whether food detected in the 'after eating' image was thrown in the rubbish bin, composted, fed to a pet, saved for consumption at a later time or eaten by another. A similar feature could ask users whether food packaging was recycled or put in general waste. In addition, short survey questions could be included in the App to measure variables shown to be associated with healthy and sustainable dietary behaviours, such as dietary health consciousness or supplement use. Including such features within the App itself would reduce researcher burden as other methods, such as in a written questionnaire, would not need to be used. Such changes would also enable the assessment of sustainable diets to be measured in a wider population, including those living rurally and remotely. The HSDI could then be applied to dietary intake data collected from people in other age groups and residing in different geographic locations, enabling the HSDI to be further evaluated and refined.

Australian researchers have highlighted that food-based diet quality indices, similar to the HSDI, opposed to nutrient-based indices, are preferred as they can be more easily adapted (Collins et al., 2015). Future developments can be made to the HSDI by adding components to the index and adjusting the weighting of existing components accordingly, assuming the foods or dietary behaviours can be assessed using the mFR. The candidate expects this to be possible as more evidence on the environmental impacts of certain dietary behaviours strengthens in a Western Australian context, and the mFR is adapted to assess a wider range of sustainable dietary behaviours.

The primary limitation of this study is that it was a secondary analyses of an existing dataset and the dietary assessment method used (the mFR) was not specifically designed to assess sustainable diets. Therefore, the dietary behaviours of focus in this study were limited to those collected using image-based mFRs during the CHAT study. Similar to other dietary assessment methods, using the mFR to assess diet is accompanied by limitations, namely participants forgeting to capture an image of an eating occasion (Kerr et al., 2017). This particular limitation can be minimised using a feature of the current mFR App which enables users to set alerts as reminders to capture images of all foods and beverages consumed (Kerr et al., 2016). However, the influence of social desirability bias, whereby people report what they think they should either consciously or subconsciously, remains a limitation in dietary assessment (as discussed in Section 2.6.4.1).

9.6 Overarching themes to emerge from this research

- The mFR is an appropriate assessment method to measure healthy and sustainable dietary behaviours as ‘before’ and ‘after eating’ images have the ability to collect such information without placing unrealistic burden on participants or researchers.
- The dietary behaviours of Western Australian adults do not align with a healthy and sustainable diet.
- Attitudes toward the impact of the environment on future food supplies are positive but do not translate to more sustainable food choices.
- Perception of current dietary intake and eating frequency are related to the intake of foods that play a key role in a healthy and sustainable diet.
- Levels of dietary health consciousness are associated with concern about the effect of the environment on future food supplies and the intake of foods associated with a healthy and sustainable diet in the NMSS and CHAT study, respectively. This survey question could reflect a broader concern about food and health, including consideration of the source of food.

Chapter 10 Summary, recommendations and final conclusions

The objectives of this thesis were to:

1. Determine the factors associated with measures of adults’ support for a sustainable food supply using Western Australian population-based survey data.
2. Evaluate perceptions toward current energy-dense nutrient-poor food and beverage intake compared to actual intake data collected using a 4-day image-based mobile food record.
3. Determine the association between eating frequency and the intake of foods related to a healthy and sustainable diet, as defined by the consumption of fruits, vegetables and energy-dense nutrient-poor foods and beverages.
4. Develop a Healthy and Sustainable Diet Index to measure key components of a healthy and sustainable diet using images.
5. Apply and evaluate the Healthy and Sustainable Diet Index using 4-day image-based mobile food records.

10.1 Summary of findings

The findings from this research suggest the dietary behaviours of Western Australian adults are inconsistent with a healthy and sustainable diet, however, the issue of a sustainable food supply has the attention of consumers. The majority of adults believe the issue of environmentally friendly foods is very important, however these attitudes do not translate to sustainable food choices. This attitude-behaviour intention gap could be, in part, related to no public education to increase awareness of what constitutes sustainable food choices in Western Australia. Given the salience of the issue of environmental sustainability, such education could be an independent motivator for healthier more sustainable food choices. More work needs to be done to help integrate recommendations around healthy and sustainable diets into policies and programs in Australia. Such work could involve assessing healthy and sustainable dietary behaviours in wider population groups to strengthen the evidence base and argument toward adopting such policies and programs. In addition, educating key players within the government and food industry, such as Meat and Livestock Australia, would improve their understanding of the importance of the issue and strengthen their support for healthy and sustainable diet recommendations. In addition, measuring the HSDI against existing indices that measure similar dietary behaviours would help evaluate its accuracy.

This study found a mismatch between the perception of current diet and actual food intake, with young adults having an overly optimistic perception of how healthy their diet is. Qualitative research exploring how a wider age group of Australian's perceive their dietary intake from an environmental lens, how relevant they believe it is, and what changes they would be willing to make to lessen the environmental impact of their dietary behaviours, would help strengthen the evidence around sustainable diets and help inform policy. Such information would also enable programs to be targeted toward less commonly perceived pro-environmental dietary changes.

Images captured using the mobile food record can objectively assess how often people eat or drink. This study found eating frequency was significantly associated with fruit, vegetable, EDNP food and alcohol intake, all of which are related (positively or negatively) to a healthy and sustainable diet. Further analyses on the impact of eating occasions on other healthy and sustainable dietary behaviours, such as food waste, would help strengthen evidence around eating frequency and a sustainable diet.

Current dietary assessment methods have not been designed to measure multiple components of a healthy and sustainable diet. This research proposed and demonstrated the advantages of using an image-based method to assess healthy and sustainable dietary behaviours. To measure these behaviours in other population groups, researchers could adopt the methodology developed in this research as the mFR can assess elements of a sustainable diet that are not captured with any other single dietary assessment method, such as individual food packaging and edible plate waste. With advances in technology and learnings from the present study, the level of detail collected could be enhanced by refining the mFR. For example, if the 'after eating' image identified left over food, a prompt could appear on the mobile device to ask users whether the remaining food was a) thrown in the bin; b) composted; c) eaten by someone else; d) saved for left overs; e) eaten by a pet or; f) put in a worm farm.

The theoretically derived Healthy and Sustainable Diet Index developed in this research has demonstrated its ability to detect adherence to multiple different healthy and sustainable dietary behaviours, the overall score being reflective of the multidimensional nature of such a diet. As more evidence on the environmental impact of individual foods and food groups becomes available in an Australian context, namely life cycle analysis values, the weighting of components in the prediction model could be modified to reflect this. This study found no association between body mass index and adherence to a healthy and sustainable diet in young adults. Future wider application against other health outcomes, such as cardiovascular disease risk factors, should be undertaken. The Healthy and Sustainable Diet Index is modifiable to other contexts and the scoring system could be adapted to reflect the evidence on the environmental impact of foods in other countries. Future studies designed to assess the application and feasibility of the Healthy and Sustainable Diet Index in a wider age range would strengthen the index.

10.2 Implications and recommendations for research and practice

Implications

- This research proposed and justified why the use of the mobile food record is the dietary assessment method of choice when measuring how young people's dietary behaviours align with a healthy and sustainable diet. This is due to its ability to assess multiple elements of a healthy and sustainable diet, not captured using other dietary assessment methods, without placing unrealistic burden on participants or researchers.
- A diet quality index incorporating behaviours that influence health and the environment was created for the first time and has the ability to capture the multidimensional nature of healthy and sustainable diets. The Healthy and Sustainable Diet Index has potential for further application to inform policy, guide future interventions, and raise consumer awareness of the impact of their dietary behaviours on both health and the environment.
- Dietary health consciousness has shown to be associated with key components of a healthy and sustainable diet and one's overall Healthy and Sustainable Diet Index score. Further research is needed to identify the drivers of and barriers to higher levels of dietary health consciousness.
- Perceptions of dietary intake are associated with the actual intake of foods related to a healthy and sustainable diet, such as EDNP foods and SSBs. Measuring current perceptions of diet should be incorporated when assessing additional elements of healthy and sustainable diets.

- How often people eat and drink throughout the day is associated with what they eat but confounding factors, such as environmental and physiological triggers should be considered when assessing eating frequency.

Recommendations

1. Investigate strategies to increase consumer awareness of what constitutes a healthy and sustainable diet and practical applications to food choice.
2. Continue asking questions about sustainable food supplies in future Nutrition Monitoring Survey Series in Western Australia. Modifying questions to include more detail on what environmentally friendly foods are, and including questions on other elements of a sustainable diet, such as ruminant animal intake, food waste and food packaging use would provide further detail on sustainable dietary practices.
3. Investigate the feasibility of using a more comprehensive dietary assessment method in the Nutrition Monitoring Survey Series to reduce systematic error inherent in short screeners.
4. Investigate whether the environmental impacts of food choice are a motivating factor for changing dietary behaviours in Western Australian adults.
5. Adapt the mobile food record App to assess healthy and sustainable diets in more detail by including real-time questions. These could be used to assess how environmentally sustainable users perceive their meal to be, or where uneaten plate waste was disposed of, for example, composted, thrown in rubbish bin, or fed to a pet.
6. Test the refined version of the mobile food record App in a randomised controlled trial on a larger population group and in a wider age range, and apply the Healthy and Sustainable Diet Index to the dietary data.
7. Assess whether providing tailored feedback to individuals on how their diet aligns with a healthy and sustainable diet (collecting using an image-based mobile food record) influences food choice behaviours.
8. Modify the weighting of individual components of the Healthy and Sustainable Diet Index to reflect life cycle analysis values as they become available in Australia.

9. Dietary behaviours that are supportive of good health and environmental sustainability should have more prominence in the Australian Dietary Guidelines' key recommendations.

10.3 Final conclusions

This research contributed new evidence on the attitudes and behaviours of Western Australian adults relating to healthy and sustainable diets. The novel method developed to capture multiple components of a healthy and sustainable diet using technology, and evaluated on a population-based sample of young adults' mobile food records was the first of its kind. This contribution to the field enables future researchers to apply this method to gather evidence from other population groups.

Dissemination of the research findings would be useful in informing policy makers and food industry of community concern, educating nutrition professionals and guiding future interventions and research studies. Given the salience of the issue of diet and its impact on environmental sustainability, this is an important area for public education. Findings from this research suggest consumers think the issue is important but these attitudes do not translate to dietary practices.

This research has shown that the two concepts of a healthy diet and a sustainable diet should not be considered in isolation as many dietary behaviours overlap. There continues to be a lack of data on how current behaviours adhere to a healthy and sustainable diet to directly inform the dietary guidelines. The findings from this research help build the evidence to support the adoption of a dietary guideline on sustainability in Australia.

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APPENDICES

Appendix A Ethics approvals

A.1 Nutrition Monitoring Survey Series ethics approval

Curtin University

Memorandum

To	Dr Christina Pollard, Public Health
From	Miss Linda Teasdale, Manager, Research Ethics
Subject	Protocol Approval **RD-22-11**
Date	16 August 2011
Copy	

Office of Research and Development

Human Research Ethics Committee

Telephone 9266 2784
Facsimile 9266 3793
Email hrec@curtin.edu.au

Thank you for your "Form A Application for Approval of Ethical Approval of Research involving Humans" for the project titled "*Food Law, Policy and Communications to Improve Public Health*".

The reviewer is satisfied that this application can be approved under the expedited process for low-risk research. On behalf of the Human Research Ethics Committee I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **16-08-11** to **16-08-12**.

The approval number for your project is **RD-22-11**. *Please quote this number in any future correspondence*. If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

Miss Linda Teasdale
Manager, Research Ethics
Office of Research and Development

Please Note: The following standard statement must be included in the information sheet to participants:
*This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number **RD-22-11**). If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or hrec@curtin.edu.au*

CRICOS Provider Code 00301J

A.2 Connecting Health and Technology Study ethics approval

Curtin University

Memorandum

To	Associate Professor Deb Kerr, Public Health
From	A/Prof Clare Rees, Deputy Chair Human Research Ethics Committee
Subject	Protocol Amendment Approval **HR 181/2011**
Date	26 November 2014
Copy	Amelia Hanbury, Public Health Dr Christina Pollard, Public Health Professor Peter Howat, Public Health

Office of Research and Development
Human Research Ethics Committee

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

Thank you for keeping us informed of the progress of your research. The Human Research Ethics Committee acknowledges receipt of your progress report, indicating modifications / changes, for the project *"The effectiveness of messages delivered via mobile phone to promote dietary change in young adults"*. Your application has been ***approved***.

The Committee notes the following amendments have been approved:

1. Kusuma Dewi is no longer working on the project and therefore needs to be removed.
2. Amelia Hanbury - Doctoral Student - needs to be added to the project team.

Approval for this project remains until **07-02-2016.**

Your approval number remains **HR 181/2011,** please quote this number in any further correspondence regarding this project.

Yours sincerely

A/Prof Clare Rees
Deputy Chair Human Research Ethics Committee

Appendix B Statements of authorship and permissions to reproduce published manuscripts from copyright owners

B.1 Harray et al. 2018 Appetite

To Whom It May Concern

I, Amelia Jeanne Harray, contributed (formulated the research question; assisted in data analysis; wrote the first draft; contributed to and approved the final written manuscript; submitted the manuscript to Elsevier; addressed reviewers' comments; made amendments as required and; resubmitted revised manuscript for final publication) to the manuscript entitled:

Harray, A. J., Meng, X., Kerr, D. A., and Pollard, C. M. (2018) Healthy and sustainable diets: community concern about the future food environment and support for government regulating sustainable food supplies in Western Australia. *Appetite*. 125, 225-232.

I, as a Co-Author, endorse that the level of contribution by the candidate indicated above correct and appropriate.

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Christina M Pollard

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B.2 Harray et al. 2017 Public Health Nutrition

To Whom It May Concern

I, Amelia Jeanne Harray, contributed (assisted in data collection and data entry; developed research question; lead data analysis; wrote the first draft; contributed to and approved the final written manuscript) to the manuscript entitled:

The candidate was involved in; the screening and recruitment of participants in the CHAT study; collection of data; food group analysis of food images; formulating the research question; sorting and analysing data and; drafting and submitting the manuscript.

Harray, A. J., Boushey, C. J. Pollard, C. M., Panizza, C. E. Delp, E. J., Dhaliwal, S. S. and Kerr, D. A. (2017). Perception *v.* actual intakes of junk food and sugar-sweetened beverages in Australian young adults: assessed using the mobile food record. *Public Health Nutrition 20(13), 2300-2307.*

I, as a Co-Author, endorse that the level of contribution by the candidate indicated above correct and appropriate.

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B.3 Kerr et al. 2016 International Journal of Behavioral Nutrition and Physical Activity

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I, Amelia Jeanne Harray, contributed (undertook all data collection related to dietary intake; analysed all food images; assisted in data analysis; contributed to and approved the manuscript; contributed to amendments as per external reviewer comments) to the manuscript entitled:

Kerr, D. A., **Harray, A. J.,** Pollard, C. M., Dhaliwal, S. S., Delp, E. J., Howat, P. A., et al. (2016). The connecting health and technology study: a 6-month randomized controlled trial to improve nutrition behaviours using a mobile food record and text messaging support in young adults. *The International Journal of Behavioral Nutrition and Physical Activity, 13*(1), 52.

I, as a Co-Author, endorse that the level of contribution by the candidate indicated above correct and appropriate.

Deborah A Kerr

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With kind regards,

Joel Lagmay
Global Open Research Support Executive
Global Open Research Support

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8th April 2018
BioMed Central Editorial Office
The Campus, 4 Crinan Street, London N1 9XW, United Kingdom

Dear BioMed Central Editorial Office

It is my understanding that your organisation is the copyright holder for the following journal article:

Kerr, D. A., Harray, A. J., Pollard, C. M., Dhaliwal, S. S., Delp, E. J., Howat, P. A., et al. (2016). The connecting health and technology study: a 6-month randomized controlled trial to improve nutrition behaviours using a mobile food record and text messaging support in young adults. The International Journal of Behavioral Nutrition and Physical Activity, 13(1), 52.

I would like to reproduce an extract of this work in my Doctoral thesis which I am currently undertaking at Curtin University in Perth, Western Australia. The subject of my research is healthy and sustainable dietary behaviours in Western Australia adults. I am carrying out this research in my own right and have no association with any commercial organisation or sponsor.

Once completed, my thesis will be made available in online form via Curtin University's Institutional Repository espace (https://urldefense.proofpoint.com/v2/url?u=http-3A__espace.curtin.edu.au&d=DwIFAg&c=vh6FgFnduejNhPPD0fl_yRaSfZy8CWbWnIf4XJhSqx8&r=mUNpGR_1TZK_P0GEJO7mw9ZtzqxmulmlqdaL1HKTj5M&m=yzjvT3z7zvHGsE08Iwe2de6TzW6WLEiM_HUV4vfhNaI&s=kKybMKCRn2TCPUSPNrTc0Mfqw2jSMB

B.4 Harray et al. 2015 Nutrients

To Whom It May Concern

I, Amelia Jeanne Harray, contributed (conceived the concept of using the mFR to assess sustainable dietary behaviours; wrote the first draft, contributed to and approved the final written manuscript, submitted the manuscript to the publisher, addressed reviewer comments, made amendments as required and resubmitted revised manuscript for final publication) to the manuscript entitled:

Harray, A. J., Boushey, C. J., Pollard, C. M., Delp, E. J., Ahmad, Z., Dhaliwal, S. S., Mukhtar, S. A., & Kerr, D. A. (2015). A novel dietary assessment method to measure a healthy and sustainable diet using the mobile food record: protocol and methodology. *Nutrients*, 7(7), 5375-5395.

I, as a Co-Author, endorse that the level of contribution by the candidate indicated above correct and appropriate.

Carol J Boushey

Christina M Pollard

Edward J Delp

Ziad Ahmad

Satvinder S Dhaliwal

Syed Aqif Mukhtar

Deborah A Kerr

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Follow up. Start by Tuesday, 10 April 2018. Due by Tuesday, 10 April 2018.

Sent: Mon 9/04/2018 5:45 PM

To: Amelia Harray

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Kind regards,
Judy Hui
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On 2018/4/8 15:29, Amelia Harray wrote:

> **8th April 2018**
> ***Nutrients* Editorial Office**
> MDPI AG, St. Alban-Anlage 66, 4052 Basel, Switzerland
> Tel. +41 61 683 77 34; Fax: +41 61 302 89 18
>
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> It is my understanding that your organisation is the copyright holder for the following journal article:
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>
> I would like to reproduce an extract of this work in my Doctoral thesis which I am currently undertaking at Curtin University in Perth, Western Australia. The subject of my research is attitudes and behaviours relating to a healthy and sustainable diet in Western Australia adults. I am carrying out this research in my own right and have no association with any commercial organisation or sponsor.
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Appendix C Research dissemination

Medical Forum - Healthy Eating Good for the Planet

Amelia Harray, December 2015

Reducing our carbon footprint through the food we eat is rarely considered by people when making dietary choices. We know healthy diets are more environmentally sustainable; however, there is limited evidence on how current Australian diets are impacting the environment.

Eating a predominantly plant-based diet, limiting intake of particular foods (such as highly processed packaged foods) and avoiding kilojoule consumption above energy requirements, can support both health and the environment. However, we know that many Australians choose foods inconsistent with our national dietary recommendations for good health, with over one third of energy intake coming from junk foods, such as burgers, pies, cakes and sugary beverages. To date, most national dietary surveys have collected data on nutrient and food intake but have not collected data on sustainable diets. Research is being conducted to assess how the diets of young West Australian adults comply with a healthy and sustainable diet using a mobile food record application. Participants in the study are asked to take before and after images of their food and beverage intake. Sustainable dietary behaviours are measured from the food images supplied, including meat and dairy portion sizes, fruit and vegetable seasonality, individually packaged foods, ultra-processed foods and food (plate) waste. Once the images have been analysed, tailored feedback can be provided so people can reflect on their use of individual food packaging, the amount of food they waste and how their food choices impact their health and the environment. Future research will explore if feedback on a person's sustainable dietary behaviours is a motivation to choose healthier foods. The goal of this research is to develop a Healthy and Sustainable Diet Index. This diet quality index will assist in guiding nutrition interventions, population monitoring, informing policy makers, monitoring the effectiveness of programs, and research.

The NHMRC Dietary Guidelines currently have no direct recommendation encouraging Australians to reduce the carbon footprint of their food choices, but it does have an Appendix on the issue. European countries, such as Sweden, have incorporated sustainable food choices in their dietary guidelines.

Just as there has been a transition from nutrient to food-based dietary guidelines (as people eat food and not a main of zinc, with a side of vitamin C and a dash of folate), there needs to be a shift in the thinking of consumers, health professionals and policy makers to consider both health and environmental sustainability.

Although improved health status is of upmost importance, recommendations must address sustainability to ensure access to an adequate, nutritious food supply for future generations. Australian dietary behaviours need to change on grounds of human health and environmental health. For this to happen, policy makers need to follow in the footsteps of other countries and incorporate sustainable diet considerations into public health policy and our Dietary Guidelines.

http://www.medicalhub.com.au/wa-news/guest-opinion-editorial/4734-healthy-eating-good-for-the-planet

Appendix D Australian Guide to Healthy Eating: food serve sizes

(NHMRC, 2013)

SERVE SIZES

Vegetables and legumes/beans

Serves per day

	19–50 years	51–70 years	70+ years
Men	6	5½	5
Women	5	5	5

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

½ cup	cooked green or orange vegetables (for example, broccoli, spinach, carrots or pumpkin)
½ cup	cooked, dried or canned beans, peas or lentils*
1 cup	green leafy or raw salad vegetables
½ cup	sweet corn
½ medium	potato or other starchy vegetables (sweet potato, taro or cassava)
1 medium	tomato

preferably with no added salt

Fruit

Serves per day

	19–50 years	51–70 years	70+ years
Men	2	2	2
Women	2	2	2

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

1 medium	apple, banana, orange or pear
2 small	apricots, kiwi fruits or plums
1 cup	diced or canned fruit (with no added sugar)

Or only occasionally:

125ml	(½ cup) fruit juice (with no added sugar)
30g	dried fruit (for example, 4 dried apricot halves, 1½ tablespoons of sultanas)

Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties

Serves per day

	19–50 years	51–70 years	70+ years
Men	6	6	4½
Women	6	4	3

A standard serve (500kJ) is:

1 slice (40g)	bread
½ medium (40g)	roll or flat bread
½ cup (75–120g)	cooked rice, pasta, noodles, barley, buckwheat, semolina, polenta, bulgur or quinoa
½ cup (120g)	cooked porridge
⅔ cup (30g)	wheat cereal flakes
¼ cup (30g)	muesli
3 (35g)	crispbreads
1 (60g)	crumpet
1 small (35g)	English muffin or scone

SERVE SIZES

Lean meat and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans

Serves per day

	19–50 years	51–70 years	70+ years
Men	3	2½	2½
Women	2½	2	2

A standard serve (500-600kJ) is:

65g	cooked lean meats such as beef, lamb, veal, pork, goat or kangaroo (about 90–100g raw)*
80g	cooked lean poultry such as chicken or turkey (100g raw)
100g	cooked fish fillet (about 115g raw weight) or one small can of fish
2 large (120g)	eggs
1 cup (150g)	cooked or canned legumes/beans such as lentils, chick peas or split peas (preferably with no added salt)
170g	tofu
30g	nuts, seeds, peanut or almond butter or tahini or other nut or seed paste (no added salt)

weekly limit of 455g

Milk, yoghurt, cheese and/or alternatives, mostly reduced fat

Serves per day

	19–50 years	51–70 years	70+ years
Men	2½	2½	3½
Women	2½	4	4

A standard serve (500-600kJ) is:

1 cup (250ml)	fresh, UHT long life, reconstituted powdered milk or buttermilk
½ cup (120ml)	evaporated milk
2 slices (40g)	or 4 x 3 x 2cm cube (40g) of hard cheese, such as cheddar
½ cup (120g)	ricotta cheese
¾ cup (200g)	yoghurt
1 cup (250ml)	soy, rice or other cereal drink with at least 100mg of added calcium per 100ml

Appendix E Australian Guide to Healthy Eating: food serve recommendations

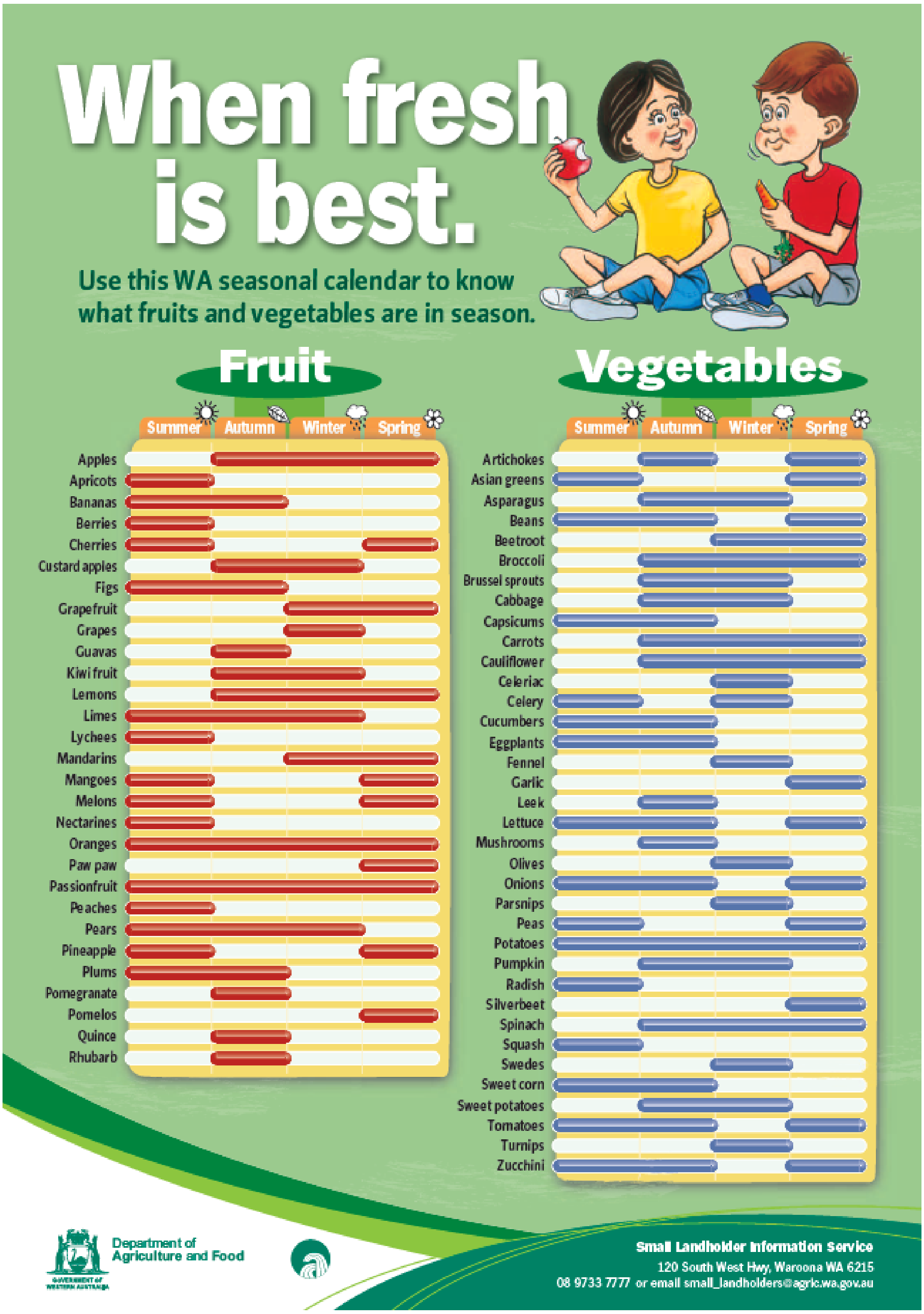
(NHMRC, 2013)

Recommended average daily number of serves from each of the Five Food Groups*								Additional serves for taller or more active men and women
	Age	Vegetables and legumes/beans	Fruit	Grain (cereal) foods, mostly wholegrain and/or high fibre cereal varieties	Lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans	Milk, yoghurt, cheese and/or alternatives, mostly reduced fat		Approx. number of additional serves from the Five Food Groups or unsaturated spreads and oils or discretionary choices
Men	19–50	6	2	6	3	2½		0–3
	51–70	5½	2	6	2½	2½		0–2½
	70+	5	2	4½	2½	3½		0–2½
Women	19–50	5	2	6	2½	2½		0–2½
	51–70	5	2	4	2	4		0–2½
	70+	5	2	3	2	4		0–2
Pregnant	(19–50)	5	2	8½	3½	2½		0–2½
Breastfeeding	(19–50)	7½	2	9	2½	2½		0–2½

* *Includes an allowance for unsaturated spreads or oils and nuts or seeds: 4 serves [28–40g] per day for men less than 70 years of age; 2 serves [14–20g] per day for women and older men.*

Appendix F Western Australian seasonal fruit and vegetable calendar

(Department of Agriculture and Food, 2013)



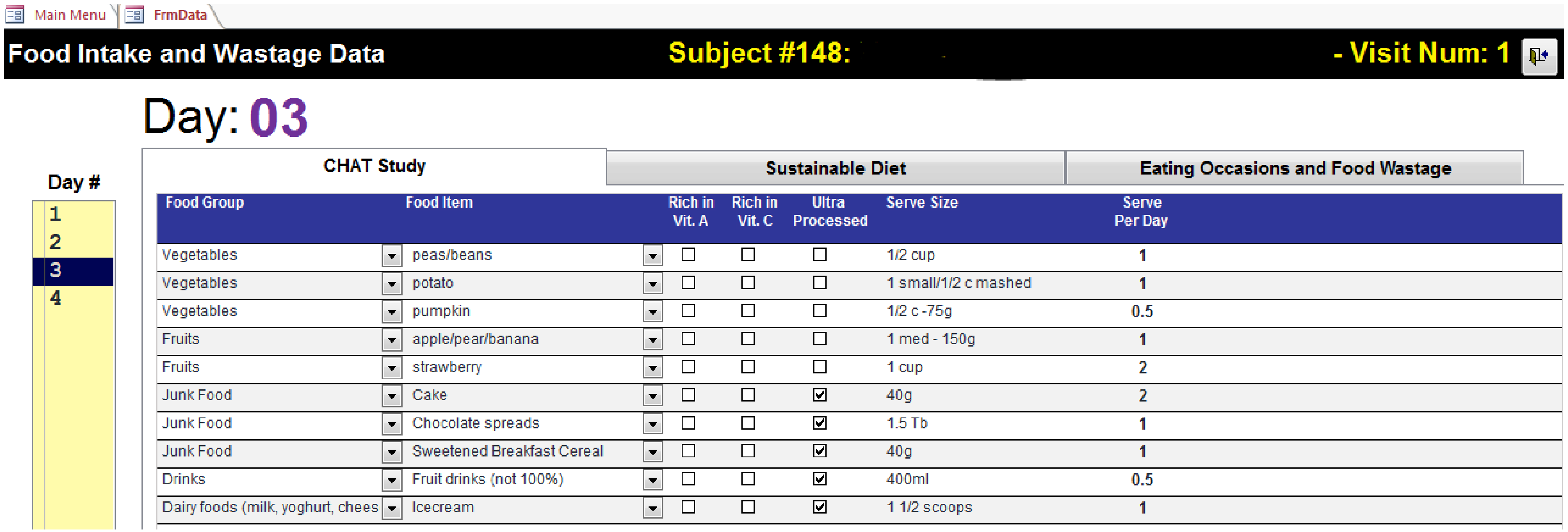
Appendix G Seasonal cut offs for fruits and vegetables

Adapted from Department of Agriculture and Food (2013)

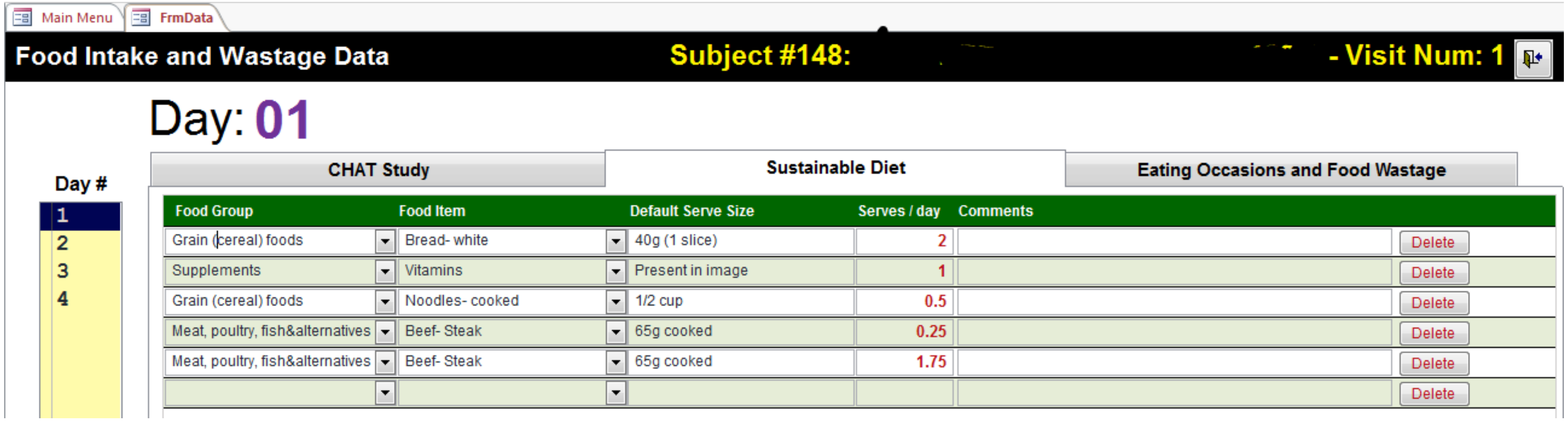
	Seasonal start date	Seasonal end date
Vegetable item		
Broccoli	March	November
Cabbage/endive	March	August
Cauliflower	March	November
Brussel sprouts	March	August
spinach	March	November
Silverbeet	September	November
Bok choy	September	February
lettuce	September	May
carrots	March	November
pumpkin	March	August
sweet potato	March	August
capsicum	December	May
tomatoes	December	May
cooked vegetables	Unidentifiable	Unidentifiable
avocado	Unidentifiable	Unidentifiable
peas/beans	September	May
corn cob/corn	December	May
dried peas/beans/lentils	Unidentifiable	Unidentifiable
potato	December	November
baked potatoes	December	November
Fruit item		
mandarin	June	November
orange	December	November
kiwi fruit	March	August
pineapple	September	February
strawberry	Unidentifiable	Unidentifiable
apricot	December	February
mango	September	February
pawpaw	September	November
rockmelon	Unidentifiable	Unidentifiable
apple/pear/banana	December	November
plums/nectarines/peaches	December	May
dice/canned fruit	Unidentifiable	Unidentifiable
100% juice	Unidentifiable	Unidentifiable
sultanas/raisins/currants	Unidentifiable	Unidentifiable
dried apricots/prunes	Unidentifiable	Unidentifiable
dried figs	Unidentifiable	Unidentifiable

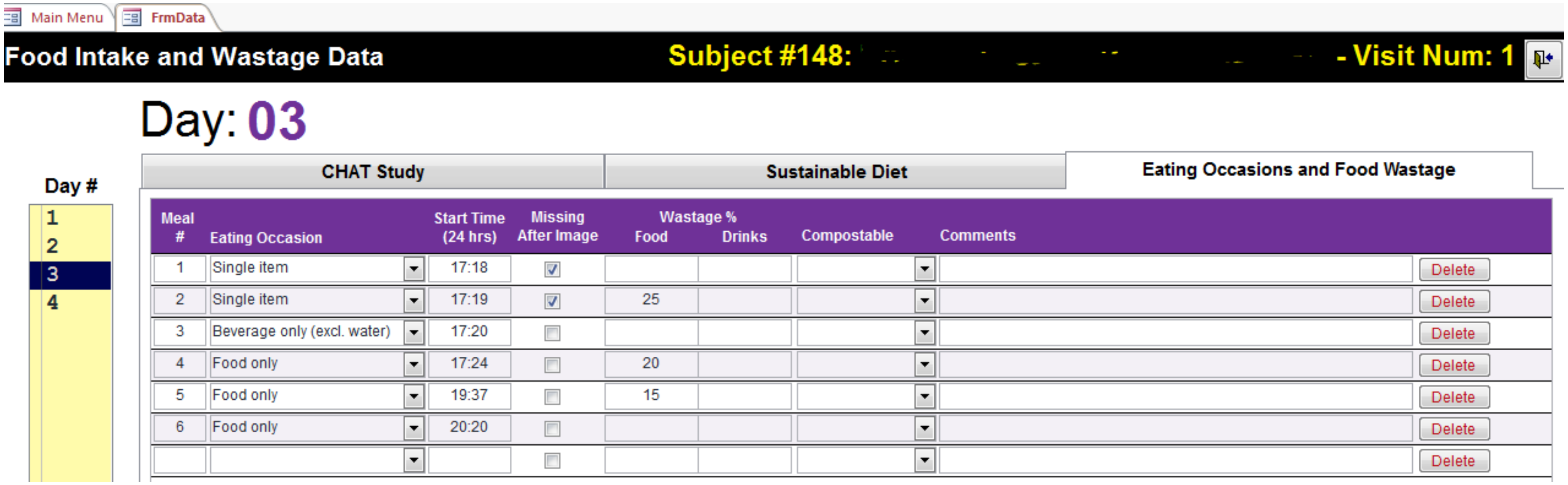
	Seasonal start date	Seasonal end date
Season		
Summer	Saturday, 1 December 2012	Thursday, 28 February 2013
Autumn	Friday, 1 March 2013	Friday, 31 May 2013
Winter	Friday, 1 June 2012	Friday, 31 August 2012
Spring	Saturday, 1 September 2012	Friday, 30 November 2012

Appendix H Screenshots of Microsoft Access Database, developed by the candidate to measure H&S diets from mFRs collected during the CHAT study



Food Group	Food Item	Rich in Vit. A	Rich in Vit. C	Ultra Processed	Serve Size	Serve Per Day
Vegetables	peas/beans	☐	☐	☐	1/2 cup	1
Vegetables	potato	☐	☐	☐	1 small/1/2 c mashed	1
Vegetables	pumpkin	☐	☐	☐	1/2 c -75g	0.5
Fruits	apple/pear/banana	☐	☐	☐	1 med - 150g	1
Fruits	strawberry	☐	☐	☐	1 cup	2
Junk Food	Cake	☐	☐	☑	40g	2
Junk Food	Chocolate spreads	☐	☐	☑	1.5 Tb	1
Junk Food	Sweetened Breakfast Cereal	☐	☐	☑	40g	1
Drinks	Fruit drinks (not 100%)	☐	☐	☑	400ml	0.5
Dairy foods (milk, yoghurt, chees	Icecream	☐	☐	☑	1 1/2 scoops	1


Main Menu
FrmData
Food Intake and Wastage Data
Subject #148: [redacted] - Visit Num: 1
Day: 01
Day #
1
2
3
4
CHAT Study
Sustainable Diet
Eating Occasions and Food Wastage
Food Group | Food Item | Default Serve Size | Serves / day | Comments
Grain (cereal) foods | Bread- white | 40g (1 slice) | 2 | Delete
Supplements | Vitamins | Present in image | 1 | Delete
Grain (cereal) foods | Noodles- cooked | 1/2 cup | 0.5 | Delete
Meat, poultry, fish&alternatives | Beef- Steak | 65g cooked | 0.25 | Delete
Meat, poultry, fish&alternatives | Beef- Steak | 65g cooked | 1.75 | Delete
Delete


Main Menu
FrmData
Food Intake and Wastage Data
Subject #148: [redacted] - Visit Num: 1
Day: 03
Day #
1
2
3
4
CHAT Study
Sustainable Diet
Eating Occasions and Food Wastage
Meal # | Eating Occasion | Start Time (24 hrs) | Missing After Image | Wastage % Food | Drinks | Compostable | Comments
1 | Single item | 17:18 | Delete
2 | Single item | 17:19 | 25 | Delete
3 | Beverage only (excl. water) | 17:20 | Delete
4 | Food only | 17:24 | 20 | Delete
5 | Food only | 19:37 | 15 | Delete
6 | Food only | 20:20 | Delete
Delete

Appendix I Components of the Healthy and Sustainable Diet Index from most ideal to least ideal eating behaviours

Item #	Item description	Category 1	Category 2	Category 3	Category 4	Category 5	Max item score
1	Ruminant animal meat (beef, sheep) and pigs	< 0.25 serve *(4 point)*	0.25-1 serve *(5 points)****	1.01-2 serves *(2 points)*	2.01-3 serves *(1 points)*	>3 serves *(0 points)*	5
2	Poultry, fish, eggs	< 0.25 serve *(3 point)*	0.25-1 serve *(5 points)****	1.01-2 serves *(4 points)*	2.01-3 serves *(2 points)*	>3 serves *(0 points)*	5
3	Milk, yoghurt, cheese	< 0.5 serve *(1 points)*	0.5-1 serve *(2 points)*	1.01-2 serves *(3 points)*	2.01-2.5 serves *(5 points)****	>2.5 serves *(4 points)*	5
4	Non-animal protein foods (legumes, tofu, nuts, seeds)	0 serves *(0 points)*	0.01-0.75 serves *(2 points)*	0.76-1.75 serves *(6 points)*	1.76-2.5 serves *(8 points)*	>2.5 serves *(10 points)****	10
5	Fruit	0 serves *(0 points)*	0.01-0.5 serves *(2 points)*	0.51-1.25 serves *(5 points)*	1.26-1.99 serves *(8 points)*	≥2 serves *(10 points)****	10
6	Vegetables	< 0.5 serve *(1 point)*	0.5-1.5 serves *(2 points)*	1.51-3 serves *(5 points)*	3.01-4.99 serves *(8 points)*	≥5 serves *(10 points)****	10
7	Seasonality of fruit and veg*	0-20% (1 point)	21-40% *(2 points)*	41-60% *(3 points)*	61-80% *(4 points)*	>80% *(5 points)*	5
8	UP EDNP foods**	>2.75 serves *(0 points)*	1.76-2.75 serves *(2 points)*	0.76-1.75 serves *(4 points)*	0.01-0.75 serves *(8 points)*	0 serves *(10 points)****	10
9	UP beverages (SSBs and alcohol)**	>2 serves *(0 points)*	1.26-2 serves *(2 points)*	0.51-1.25 serves *(4 points)*	0.01-0.50 serves *(8 points)*	0 serves *(10 points)****	10
10	Individually packaged **EDNP** foods and beverages	>2.25 items (0 points)	1.51-2.25 items (2 points)	0.76-1.5 items (3 points)	0.01-0.75 items *(4 points)*	0 items *(5 points)****	5
11	Individually packaged **healthy** foods and beverages	>2.25 items *(2 points)*	1.51-2.25 items *(4 points)*	0.76-1.5 items *(6 points)*	0.01-0.75 items *(8 points)*	0 items *(10 points)*	10
12	Edible plate waste	>40% *(1 point)*	30.1-40% *(2 points)*	20.1-30% *(3 points)*	10.1-20% *(4 points)*	≤10% *(5 points)*	5

* Percentage of fruits and vegetables in season at time of consumption (calculated from automated time and date stamp against WA seasonality chart (Appendix G)

** Ultra-processed energy-dense nutrient-poor foods or sugar-sweetened beverages.

*** Ideal daily serve amount adapted from the Australian Guide to Healthy Eating for adults 19-50 years (Appendix E)

Appendix J Relevant questions from the 2009 and 2012 Nutrition Monitoring Survey Series questionnaires

NUTRITION MONITORING SURVEY

DEM1 Sex
RECORD SEX
DON'T ASK

Male 1
Female 0

DEM2 What was your age last birthday? Age
(Single Response)
Enter age_____ (years)

Now for a few questions about you and how you would describe yourself. These questions will help us to interpret the results about nutrition.

opin15 Which of the following statements would best describe how you feel about your diet? feeldiet
(Read out, single response)
1 I pay a lot of attention to the health aspect of the food I eat to make sure my diet is as healthy as possible
2 I take a bit of notice of the health aspect of the food I eat to make sure I have a fairly good diet
3 I don't really think much about the health aspect of food I eat
998 Can't remember/Don't know
999 Refused

Now I would like to ask you some questions what you ate yesterday.

con1 How many pieces of fruit did you eat yesterday? A piece of fruit would be, for example, an apple, a small bunch of grapes, 3 prunes, a quarter of a rock melon or half a cup of stewed, pureed or canned fruit.
(Single Response. Code NONE as 0 and less than one serve a day as 991. Code Unsure/Don't Know/Can't remember as 998 and Refused as 999)

Enter number of pieces ___ **frtpieceno**

con2 How many different types of vegetables, did you eat yesterday? Please remember to include salad, fresh, frozen, canned, raw and cooked vegetables.
(Record no vegetables as 0, don't remember as 998 and refused as 999) vegtypeno _____

con3 How many serves of vegetables do you <u>usually</u> eat each day? A serve of vegetables is equal to half a cup of cooked vegetables or 1 cup of salad.
(Single Response. Code NONE as 0 and less than one serve a day as 991. Code Unsure/Don't Know/Can't remember as 998 and Refused as 999)

Enter number of serves _____ **vegserves**

This section is about dairy and dairy related products including soy based.

dairy1 How many cups of any type of milk did you have or use yesterday? Include milk used in cereal, tea, coffee, other drinks or cooking, including powdered milk. milkcups
(Record I didn't use any milk as 0 and fractions of a cup as 1/4=.25; 1/3=.33 1/2=.5 2/3=.66 3/4=.75). If the respondent says that they only used milk in tea or coffee record that a .1, don't know as 998 and refused as 999) ______ **(If 0, go to dairy5)**

DEPARTMENT OF HEALTH

dairy5 How many cups of yoghurt did you have yesterday? yoghurtamt
(Record I didn't use any milk as 0 and don't know as 998 and refused as 999 and go to ch1, code fractions of a cup as 1/4=.25; 1/3=.33 1/2=.5 2/3=.66 3/4=.75) _______

---

ch1 How much soft cheese such as ricotta, cottage, brie, camembert, castello, cream cheese, did you eat yesterday? A serve of soft cheese is equal to one rounded tablespoon. softcheese
(Record none as 0, don't know as 998 and refused as 999) ______

---

ch2 How much hard cheese such as cheddar, edam did you eat yesterday? A serve of hard cheese is equal to one slice or a 2.5 cm cube. hardcheese
(Record none as 0, don't know as 998 and refused as 999) ______

ch3 How much grated cheese yesterday such as grated cheddar, mozzarella, parmesan or Romano did you eat yesterday? A serve of grated cheese is equal to a rounded tablespoon. Gratedcheese
(Record none as 0, don't know as 998 and refused as 999) ______

I am going to ask you about the red meat that you ate yesterday. I am only interested in whether or not you ate any beef, lamb or veal.
Questions relating to meat and fish intake only asked in 2012 (not 2009)

mt1 Did you eat any beef, lamb or veal yesterday? 0 No (Go to Fish 1) 1 Yes **atemeat**

mt2 How much beef, lamb or veal as a piece of steak did you eat yesterday? A steak serve is a piece of steak that is about the size on your palm.
(Record none as 0, don't know as 998 and refused as 999) Serves steak ________**steak**

mt3 How many beef, lamb or veal chops did you eat yesterday? 1 serve is 2 small chops
(Record none as 0, don't know as 998 and refused as 999) Serves chops ________**chops**

mt4 How much roast beef, lamb or veal did you have yesterday? 1 serve is 3 slices of roast meat.
(Record none as 0, don't know as 998 and refused as 999) Serves roast ________**roast**

mt5 How many beef, lamb or veal, hamburger/patties did you eat yesterday? 1 serve is 1 ½ patties
(Record none as 0, don't know as 998 and refused as 999) Serves patties ________**patties**

mt6 How much beef, lamb or veal, mince did you eat yesterday? 1 serve is ½ cup of mince
(Record none as 0, don't know as 998 and refused as 999) Serves mince ________**mince**

mt7 How many beef, lamb or veal, sausages did you eat yesterday? 1 serve is 1 thin sausages (1 thick is 2 serves)
(Record none as 0, don't know as 998 and refused as 999) Serves sausages ________**sausage**

Now I will ask you about the fish you ate yesterday. I am only interested in fish not in all seafood, that is I don't need to know if you ate prawn or oysters or any other crustaceans.

fish1 Thinking only of fish fillets or tinned fish such as tuna or salmon, how much fish did you eat yesterday?, 1 serve of fish weighs 115 grams or 1 100 gram tin
(Record none as 0, don't know as 998 and refused as 999) Serves fish ________**fish**

Now we will move on to what you drank yesterday

oth2 In total, how many cans, bottles, glasses or cups of soft drink, energy drinks, sports drinks, flavoured mineral water or vitamin water, did you drink yesterday? Please say how large the container was in your answer, for example, 2 375 ml cans of RedBull or 1 litre bottle of Coke.
(Record didn't drink any as 0 in the first field (cans), don't know as 998 and refused as 999)
(Interviewer - prompt for size of can or bottle)

___oth2a cans **softcan** ____ oth 2b cups **softcup** ____ oth 2c glasses **softglass** ____ oth 2d 300ml bottles _____ **soft300bot** oth 2e 600 ml bottle ___ **soft600bot** oth 2f 1 litre bottle_____ **soft1lbot** oth 2g 2 litre bottle ___ **soft2lbot**

oth3 How much diet soft drink did you drink yesterday? Please say how large the container was in your answer, for example, 375 ml can. dietdrinks (Record didn't drink any as 0 in the first field (cans), don't know as 998 and refused as 999) (Interviewer - prompt for size of can or bottle)

____ oth 3a cans **dietcan** ____ oth 3b cups **dietcup** ____ oth 3c glasses **dietglass**____ oth 3d 300ml bottles _____ **diet300bot** oth 3e 600 ml bottle ___ **diet600bot** oth 3f 1 litre bottle_____ **diet1lbot** oth 3g 2 litre bottle ___ **diet2lbot**

oth4 How many cups, glasses, mls or litres of plain water did you drink yesterday? water
(Record didn't drink any as 0 in the first field (cans), don't know as 998 and refused as 999 and go to beh1)

____ oth 4a cups **watercup** ____ oth 4b glasses **waterglass**____ oth 4c mils _____ **watermils** oth 4d litres _____ **waterlitres**

---

oth5 Was this water mainly tap water or bottled water? watertype
1 Tap
2 Filtered tap
3 Bottled
998 Can't remember/Don't know
999 Refused

The next section is about weight and how you feel about it and your diet. It is important to get a picture of all the different groups in our community.

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bod1 What is your height without shoes?
(Single Response. Code Unsure/Don't Know/Can't remember as 998 and Refused as 999 in FIRST field)

bod1a Centimetres ___ **hghtcm** OR **bod1b** Feet ___ **hghtft** **bod1c** Inches ___ **hghtin**

bod2 How much do you weigh without clothes or shoes?
(Single Response. Code Unsure/Don't Know/Can't remember as 998 and Refused as 999 in FIRST field)

bod2a Kilograms (Kg) ____ **wghtkg** OR **bod2b** Stones ____ **wghtst** **bod2c** Pounds ____ **wghtlb**

How important would you say it is that the government has control over or regulates the following:

act8a The supply of environmentally friendly food ____ envcont
(Single response, read out)
1 Very important
2 Quite important
3 Neither important nor unimportant
4 Not very important
5 Not al all important
998 Can't remember/Don't know
999 Refused

On a scale of very concerned to not at all concerned, how concerned would you say you are about the following:

---

act26 The effect of the environment on the future of food supplies concfutfd
(Read out, single response)
1 Not very concerned
2 Somewhat concerned
3 Neither unconcerned nor concerned
4 Quite concerned
5 Very concerned
998 Can't remember/Don't know
999 Refused

Finally a few questions about you. These will help us to understand the answers we get in this survey

cha1 What is the highest level of primary or high school that you have completed? schooling
(Single Response. *Interviewer note: Prompt if necessary)*
1. Never attended school
2. Currently still at school
3. Year 8 or below
4. Year 9 or equivalent
5. Year 10 or equivalent
6. Year 11 or equivalent
7. Year 12 or equivalent (matriculation/leaving)
998 Unsure/Don't Know/Can't Remember
999 Refused

cha2 Have you completed any qualifications (since leaving school)? otherquals
(Single Response. *Interviewer note: Prompt if necessary)*
0. No **Go to CHA7**
1. Yes **Go to CHA28**
998 Unsure/Don't know/Can't remember
999 Refused

cha3 What is the highest qualification you have completed? whatquals
(Single Response. *Interviewer note: Prompt if necessary)*
1. Bachelor degree or higher
2. Diploma or certificate taking more than 12 months full time
3. Diploma or certificate taking less than 12 months full time
4. Trade / apprenticeship
998 Unsure/Don't know/Can't remember
999 Refused

cha4 Which geographic area were you born in? birthcob
(Single Response)
1 Australia
2 Eire and UK including Wales, Scotland and Northern Ireland
3 New Zealand
4 North America
5 Central and South America
6 Africa
7 Europe
8 Middle East
9 ASEAN Country (These include Burma, Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand and Vietnam)
10 China
11 India
12 Other
998 Unsure/Don't know/Can't remember
999 Refused

---

cha7 Which ONE of the following best describes your current employment status? Are you: empstat
(Single Response. Read options. Interviewer note: This question relates to MAIN occupation. A full-time student who works part-time is coded as a student)
1. Self employed
2. Employed for wages, salary or payment-in-kind
3. Unemployed for less than one year
4. Unemployed for more than one year
5. Engaged in home duties
6. Retired
7. Unable to work
8. A student
9. Other
998 Unsure/Don't Know/Can't Remember
999 Refused

---

cha10 I would now like to ask you about your household's income. We are interested in how income relates to health, lifestyle and access to food. Before tax is taken out, which of the following ranges best describes your household's income, from all sources, over the past 12 months? income
(Read Options. Single Response)
1. Under $20,000
2. $20,000 - $40,000
3. $40,000 - $60,000
4. $60,000 - $80,000
5. $80,000 - $100,000
7. $100,000 - $120,000
8. $120,000 - $140,000
9. More than $140,000
998 Unsure/Don't Know/Can't Remember
999 Refused

Appendix K Connecting Health and Technology Study demographic and personal characteristics questionnaire

Office use only Visit 1 Form 1	The CHAT (Connecting Health & Technology) Study Demographic and personal characteristics	**Name:** **Participant ID:** **Randomisation ID:** **Date completed:** ____/____/____ Day Month Year

Welcome to the CHAT study (Connecting Health and Technology). This series of questions will take around 10 minutes to complete. Firstly we would like to ask some questions about you. We recognise that some of the questions are personal in nature. These questions will help us interpret the results of the study. Please note that the information you provide will remain strictly confidential.

1. **Name** ____

2. **What is your gender? (✓one)**

   ❑ Male
   ❑ Female

3. **Date of Birth** _____/________/_______
   Day Month Year

4. **What is your current occupation?** ______________________

5. **How would you best describe yourself with respect to ethnicity?**

ETHNICITY	
You may check (✓) more than one box.	
❑	**White.** A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.
❑	**Aboriginal or Torres Strait Islander.** A person of Aboriginal or Torres Strait Islander descent, who identifies as being of Aboriginal or Torres Strait Islander origin and who is accepted as such by the community with which the person associates".
❑	**Asian.** A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand and Vietnam.
❑	**Pacific Islander.** A person having origins in any of the original peoples of New Zealand, Samoa, Hawaii or other Pacific Islands.
❑	**Black or African American.** A person having origins in any of the Black racial groups of Africa.
❑	**Other, please describe**

6. **What type of mobile phone do you have? (can ✓ more than one)**
   - ❑ iPhone, please state what model____________________________
   - ❑ Samsung Galaxy
   - ❑ Motorola Razr
   - ❑ Nokia Lumia or N9
   - ❑ Sony Xpeia
   - ❑ Blackberry
   - ❑ HTC Sensation or Rhyme
   - ❑ Other, please specify the type of mobile phone (e.g. brand, model)

____

7. **Are you currently taking any vitamin supplements?**
   - ❑ No
   - ❑ Yes (If yes, please fill in the information below)

Name	Amount	Frequency

8. **What is the highest level of education you have completed**
   - ❑ Year 10 or equivalent
   - ❑ Year 12 or equivalent
   - ❑ Trade / apprenticeship
   - ❑ Diploma or certificate
   - ❑ University bachelor degree or higher
   - ❑ Unsure / don’t know
   - ❑ Other, please state____

9. **Which best describes your current employment situation? (✓one)**
   - ❑ Self-employed
   - ❑ Employed full-time
   - ❑ Part-time/casual job
   - ❑ Engaged in home duties
   - ❑ A student
   - ❑ Unable to work
   - ❑ Not currently working
   - ❑ Other, please state_______________________________________

Which best describes your current living arrangements? (✓one)

- ❑ Living with my parent(s)
- ❑ Living with other family members
- ❑ Living with friends
- ❑ Living with a partner and children
- ❑ Living with a partner but no children
- ❑ Living alone
- ❑ Other living arrangements, please state______________________________

10. Which statement best describes your role in your household's food shopping? (✓one)

- ❑ I am the main food shopper
- ❑ I have shared responsibility
- ❑ I have little/no responsibility
- ❑ I rarely/never do food shopping

11. Which statement best describes your role in your household's food preparation? (✓one)

- ❑ I am the main food preparer
- ❑ I have shared responsibility
- ❑ I have little/no responsibility
- ❑ I rarely/never prepare food at home
- ❑ Other role, please state___________________________________

12. Which statement best describes your cooking skills? (✓one)

- ❑ I can't cook
- ❑ Can boil an egg, or BBQ meat or heat frozen meals
- ❑ Can cook basic meat and 3 veg type meals
- ❑ Can cook a wide variety of meals
- ❑ Can cook almost anything
- ❑ Unsure / don't know

13. Are you currently following a specific diet? (can ✓ more than one)

- ❑ No special diet
- ❑ Weight loss
- ❑ Vegetarian, please state type_______________________________
- ❑ Gluten-free
- ❑ Lactose-free
- ❑ Other, please state____

14. **Which statement best describes how you feel about your diet? (✓one)**
- ❑ I pay a lot of attention to the health aspect of the food I eat to make sure my diet is as healthy as possible
- ❑ I take a bit of notice of the health aspect of the food I eat to make sure I have a fairly good diet
- ❑ I don't really think much about the health aspect of food I eat
- ❑ I don't think at all about the health aspect of the food I eat
- ❑ Unsure / don't know

15. **How important is eating a healthy diet to you? If 1 was 'not at all important' and 10 was 'very important' (circle one)**

1	2	3	4	5	6	7	8	9	10
Not at all important									Very important

16. **How confident are you in being able to choose a healthy diet? If 1 was 'not at all confident' and 10 was 'very confident' (circle one)**

1	2	3	4	5	6	7	8	9	10
Not at all confident									Very confident

17. **How motivated are you to eat a healthy diet? If 1 was 'not at all motivated' and 10 was 'very motivated' (circle one)**

1	2	3	4	5	6	7	8	9	10
Not at all motivated									Very motivated

18. **In general, when it comes to my health I would rather an expert just tell me what I should do. If 1 was 'strongly disagree' and 10 was 'strongly agree' (circle one)**

1	2	3	4	5	6	7	8	9	10
Strongly disagree									Strongly agree

19. **Which of the following best describes you? (✓one)**
- ❑ I am currently trying to eat more fruit
- ❑ I am thinking about trying to eat more fruit
- ❑ I am not thinking about increasing the amount of fruit I eat
- ❑ I already eat enough fruit
- ❑ Unsure / don't know

20. Which of the following best describes you? (✓one)

- ❑ I am currently trying to eat more vegetables
- ❑ I am thinking about trying to eat more vegetables
- ❑ I am not thinking about increasing the amount of vegetables I eat
- ❑ I already eat enough vegetables
- ❑ Unsure / don't know

21. *Junk food or unhealthy food has been defined as food high in fat, sugar and/or salt with little nutritional value such as fast foods, crisps, sweetened breakfast cereals, confectionery or fizzy drinks.*

Which of the following best describes you? (✓one)

- ❑ I am currently trying to eat less junk food
- ❑ I am thinking about cutting down on the amount of junk food I eat
- ❑ I am not thinking about cutting down on the amount of junk food I eat.
- ❑ I already eat a diet low in junk food
- ❑ Unsure / don't know

22. How many times a week on average, do you have meals or snacks such as burgers, pizza, chicken or chips from places like McDonalds, Hungry Jacks, Pizza Hut, KFC or Red Rooster?

- ❑ Daily or almost daily
- ❑ 2-3 times a week
- ❑ 4 or more times a week
- ❑ I do not eat take-away meals or snacks/rarely
- ❑ Unsure / don't know

23. How often do you eat breakfast?

- ❑ I do not eat breakfast/rarely
- ❑ Daily or almost daily
- ❑ 2-3 times a week
- ❑ 4 or more times a week
- ❑ Unsure / don't know

24. Which of the following best describes you? (✓one)

- ❑ I am currently trying to drink less sugary drinks (e.g. soft drinks, cordial, energy drinks or sports drinks)
- ❑ I am thinking about trying to drink less sugary drinks
- ❑ I am not thinking about cutting down on the amount of sugary drinks I have
- ❑ I already drink very little sugary drinks
- ❑ I don't drink sugary drinks

25. Which of the following best describes you? (✓one)

- ❑ I am currently trying to drink less alcohol
- ❑ I am thinking about cutting down on the amount of alcohol I drink
- ❑ I am not thinking about cutting down on the amount of alcohol I drink.
- ❑ I drink very little alcohol
- ❑ I don’t drink alcohol
- ❑ Unsure / don’t know

26. Which of the following best currently describes you? (✓one)

- ❑ I am currently trying to lose weight.
- ❑ I am currently trying to gain weight
- ❑ I am thinking about trying to lose weight
- ❑ I am thinking about trying to gain weight
- ❑ I am not thinking about trying to lose or gain weight
- ❑ Unsure / don’t know.

27. Do you consider yourself to be? (✓one)

- ❑ Underweight
- ❑ About right
- ❑ Somewhat overweight
- ❑ Very overweight
- ❑ Unsure / don’t know

28. What do you think is the recommended number of serves of <u>fruit</u> that should be eaten each day?

ONE serve of fruit is equal to one medium piece of fruit e.g. an apple, or 2 small plums/apricots or one cup of diced/stewed/canned fruit.

- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5 or more

29. What do you think is the recommended number of serves of <u>vegetables</u> that should be eaten each day?

ONE serve of vegetable is equal to one medium potato or half a cup of cooked vegetables or one cup of salad vegetables.

- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5 or more

30. **How do you think your consumption of <u>fruit</u> compares to other West Australian adults of the same gender and age group?**
- ❑ Much less
- ❑ Less
- ❑ Somewhat less
- ❑ Somewhat more
- ❑ More
- ❑ Much more
- ❑ Unsure / don't know

31. **How do you think your consumption of <u>vegetables</u> compares to other West Australian adults of the same gender and age group?**
- ❑ Much less
- ❑ Less
- ❑ Somewhat less
- ❑ Somewhat more
- ❑ More
- ❑ Much more
- ❑ Unsure / don't know

32. **How do you think your consumption of <u>junk food</u> compares to other West Australian adults of the same gender and age group?**
- ❑ Much less
- ❑ Less
- ❑ Somewhat less
- ❑ Somewhat more
- ❑ More
- ❑ Much more
- ❑ Unsure / don't know

33. **How do you think your consumption of <u>alcohol</u> compares to other West Australian adults of the same gender and age group?**
- ❑ Much less
- ❑ Less
- ❑ Somewhat less
- ❑ About average
- ❑ Somewhat more
- ❑ More
- ❑ Much more
- ❑ Unsure / don't know

34. How often do you have a drink containing alcohol?

- ❑ Never – ***please go to Question 39***
- ❑ Monthly
- ❑ 2-4 times a month
- ❑ 2-3 times a week
- ❑ 4 or more times a week

35. On how many days of a week do you usually drink alcohol?

- ❑ Don't drink alcohol
- ❑ Number of days a week, please state _______days
- ❑ Unsure / don't know

36. On a day when you drink alcohol, how many standard drinks do you have? A Standard Drink is equivalent to a schooner or midi of full strength beer, a glass of wine or a nip of spirits.

- ❑ 1 or 2
- ❑ 3 or 4
- ❑ 4 to 6
- ❑ 7 to 9
- ❑ 10 or more

37. How often do you have six or more drinks on one occasion?

- ❑ Never
- ❑ Less than monthly
- ❑ Monthly
- ❑ Weekly
- ❑ Daily or almost daily

38. Which of the following best describes your smoking status?

- ❑ I smoke daily
- ❑ I smoke occasionally
- ❑ I don't smoke now but I used to
- ❑ I've tried it a few time but never smoked regularly
- ❑ I've never smoked

39. Which, if any of the following <u>changes</u> have you made to your diet over the last 4 weeks? (Please ✓ which best applies to you)

	Yes (have changed)	No change	Unsure /don't know
Eating more servings of fruit			
Eating more servings of vegetables			
Eating more variety of fruits and vegetables			
Drinking less sugary drinks (e.g. fizzy drinks, sports drinks, cordial or energy drinks)			
Switching to diet drinks or water			
Eating less confectionary (e.g. chocolate, lollies)			
Eating less sugary foods (e.g. cakes, muffins, sweet biscuits)			
Eating less fatty foods (e.g. pies, pastries)			
Drinking less alcohol			
Switching to lower-alcohol or non-alcoholic drinks			
Having more alcohol free days every week			
Eating less fast food or takeaway foods (e.g. McDonalds, Hungry Jacks, KFC)			
Switching to healthier options when eating out			
Adding more vegetables or salad to meals			
Cooking and preparing more food			
Tried new recipes			

End of survey

Thank you for taking the time to complete this survey