THE ASSOCIATION BETWEEN DIET QUALITY AND WEIGHT CHANGE IN YOUNG AND MID-AGE WOMEN OVER TIME

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Publications and presentations arising from this thesis

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1. H. Aljadani, A. Patterson, D. Sibbritt and C. E. Collins (2013). "The association between dietary patterns and weight change in adults over time: a systematic review of studies with follow up." JBI Database of Systematic Reviews and Implementation Reports 11(8).
2. H. Aljadani, A. Patterson, D. Sibbritt and C. E. Collins (2013). The association between diet quality and weight change in adults over time: A systematic review in perspective studies. Diet quality- an evidence approach. L. L. a. V. P. Victor R Preedy. New York, Springer. 2: 3 -27.
3. H. Aljadani, A. Patterson, D. Sibbritt, M. J. Hutchesson, M. E. Jensen and C. E. Collins (2013). "Diet Quality, Measured by Fruit and Vegetable Intake, Predicts Weight Change in Young Women." Journal of Obesity 2013: 10.
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Manuscripts will be submitted to a peer reviewed journal

1. H. Aljadani, L. Al-Oboudi, A. Patterson, D. Sibbritt, and C. E. Collins. "Frequency and variety of healthy foods, fruit and vegetables predicts lower six year weight gain in young women".

Conferences abstracts: Published in conference

1. Title: The association between diet quality and weight change in adults over time: A systematic review of cohort studies.
   Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C. E. Collins
   Event: The Australian New Zealand Obesity Society annual Meeting (ANZOS) in Adelaide 2011.
2. Title: Does higher diet quality protect weight change in adults over time: A systematic review of cohort studies.
   Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C. E. Collins
   Event: The International Conference of Diet and Activity Methods (ICDAM) at Rome 2012.
3. Title: The role of total energy intake and energy density on changes in body weight: A systematic review of cohort studies.
   Authors: H. Aljadani, C.E. Collins, D. Sibbritt, A. Patterson.
   Event: The International Congress Nutrition, at Sydney 2012
4. Title: Development of overweight and obesity in mid-age women from the Australian Longitudinal on Women Health Study
   Author: H. Aljadani, A. Patterson, D. Sibbritt, and C. E. Collins.
   Event: in ANZOS 2013, Melbourne, Australia.

5. Title: Frequency and variety of fruit and vegetable consumption did not predict 6-year weight change in mid–aged women from the Australian Longitudinal Study on Women's Health

   Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C. E. Collins.

   Event: ANZOS 2013, Melbourne, Australia.

6. Title: Diet Quality is not associated with Obesity risk in mid-age women in the Australian Longitudinal Study on Women's Health

   Authors: Aljadani, Patterson, Sibbritt, and Collins

   Event: The Australasian Epidemiological Association Annual Scientific Meeting 2014, New Zealand.

7. Title: Prospective changes in diet quality in mid-age Australian women and its association with weight change during nine years of follow-up

   Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C. E. Collins.

   Event: ICDAM in Brisbane, Australia.

Presentations arising from this thesis

1. Title: Does eating better predict weight change

   Location: The Priority Research Centre in Physical Activity and Nutrition. That was part of a presentation for the public at an afternoon tea ("Eat our words"), 2012.

2. Title: Diet Quality indexes in the young women from the ALSWH.

   Location: The Priority Research Centre in Physical Activity and Nutrition, 2012.

3. Title: Diet quality does not predict six year weight changes in mid-age women from Australian Longitudinal Study on Women's Health

   Location: The Australian and New Zealand Society of Obesity Annual Scientific Meeting (2012), at Auckland New Zealand.

   Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C. E. Collins.

Abbreviations

The following are the common abbreviations are used in this thesis:

15-point PNNS-GS	15-point French Programme National Nutrition Santé-Guideline score
ABS	Australian Bureau of Statistics
AHEI	Alternative Healthy Eating Index
AIHW	Australian Institute of Health and Welfare
ALDRS	Adult life diet risk score
ALSWH	Australian Longitudinal Study on Women's Health
aMDS	Alternative Mediterranean Diet Score
ANHPA	Australia National Health Priority Areas
ARFS	Australian Recommended Food Score
Au-DGI	Australian version of the DGI
Au-HEI	Australian version of the HEI
BMD	Bone Mineral Density
BMI	Body Mass Index
CBMI	Change in Body Mass Index
Ch-DQI	Chinese Diet quality Index
C-HEI	Canadian version of the HEI
CHFP	Chinese Food Pagoda
CI	Confident Intervals
CVD	Cardiovascular Dieses
CWT	Change in weight
DASH	Dietary Approaches to stop hypertension score
DBS	Dietary Behaviour Score
DDS	Diet Diversity Score
DDS-R	Dietary diversity scores for recommended foods
DDV	Dietary Diversity Score
DGI	Dietary Guideline Index
DGI	Dietary Guideline Index
DHA	Docosa-Hexaenoic Acid (long Chain Omenga-3 fatty acids)
DQESv2	the Dietary Questionnaire for Epidemiological Studies Version 2
DQI	Diet Quality Index
DQI-I	Diet Quality Index-International
DQI-R	Diet Quality Index-Revised

DQS	Diet Quality Score
DRS	Dietary Risk Score
DVRS	Dietary Variety score for recommended food
ED	Energy Density
EDNP	Energy-Dense Nutrient-Poor food score
EPA	Eicosa-Pentaenoic Acid (long Chain omega-3 fatty acids)
EPIC	European Prospective Investigation into Cancer
FDS	Food Diversity Score
FFQ	Food Frequency Questioners
FIS	Fat Intake Score
FNRS	Framingham Nutritional Risk Score
FVS	Food Variety Score
HDI	Healthful Diet Indicator
HDL	High-Density lipoprotein
HDS	Healthy Diet Score
HEI	Healthy Eating Index
HFI	Healthy Food Index
HFNI	Healthy Food and Nutrients Index
HRT	Hormone Replacement Therapy use
KSA	Kingdom of Saudi Arabia
LDL	Low Density Lipoprotein
LSS	Life summary score
MDP	Mediterranean Diet Patterns
MDQI	Mediterranean Diet Quality Index
MDS	Mediterranean Diet score
MUFA	Monounsaturated fatty acids
NCDs	Non-Communicable Diseases
ND	Not the correct time period
NE	Not the exposure
NHMRC	National Health and Medical Research Council
NI	No intervention of the interest
NNR	Nordic Nutrition Recommendation
NNRS	Naturally Nutrient Rich Score
NO	No outcome of interest
NP	Not participants of interest
NRFS	Not Recommended Food Score
NS	Not a study design of interest

OBS	Oxidative balance Score
OCP	Oral Contraceptive Pill
OR	Odds Ratio
OSA	Obstructive Sleep Apnoea
PANDiet	Probability of Adequate Nutrient Intake
PCOS	Polycystic Ovary Syndrome
PNNS-GS	The Programme National Nutrition Santé Guideline Score
PUFA	Polyunsaturated fatty acids
RCT	Randomized Control Study
RDA	Recommendation Dietary allowance
RFBS	Recommended Food and Behaviour Score
RFS	Recommended Food Score
rMed	Relative Mediterranean Diet Score
RR	Relative Risk
RRR	Reduced Rank Regression
SD	Stranded Deviation
SDQ	Short Dietary Questions
SFA	Saturated Fatty Acids
SoFAAS	Solid Fat, Alcoholic beverages, Added Sugar
SWAN	Study of Women's Health Across the Nation
TEI	Total energy Intake
UAE	The United Arab Emirates
UK	The United Kingdom
USA	The United States of America
USDAFG	USA Department of Agriculture Food Guide Recommendations
WHO	World Health Organization

Table of Contents:

List of Tables

List of Figures

Abstract

Background:

Weight gain is one of the serious health-related issues facing people in all age groups worldwide. Excessive weight gain is linked to increased risk of type 2 diabetes, cardiovascular disease (CVD), some cancers, premature death, and reduced quality of life. Weight gain is a result of an imbalance between total energy intake and the expenditure of energy. Measuring both energy intake and energy expenditure accurately is problematic, especially in large cohorts. Hence, measures of dietary patterns, developed using *a priori* decisions, is becoming one of the most used methods in epidemiological research. The concept of diet quality is defined as a summary measure of the nutritional quality of the whole diet in comparison to accepted nutrition recommendations. Diet quality tools aim to assess the quality of an individual's overall eating patterns using a score or index to determine how closely dietary intake aligns with national dietary guidelines and/or recommended nutrient intakes. Evidence shows that diet quality assessments are an acceptable tool which can predict the risk of developing chronic diseases and mortality. However, there is still limited evidence on the relationship between diet quality and some risk factors for health outcomes such as weight change.

Aims:

This thesis had six main interconnected aims, as follows:-

1) To synthesise the best available evidence on the relationship between diet quality indexes or scores and body weight change in prospective studies;

2) To compare the predictive association between a number of diet quality indexes with weight change in young women from the Australian Longitudinal Study On Women's Health (ALSWH) over six years;

3) To evaluate the relationship between different diet quality indexes and weight change in a sub-cohort of 'healthy' weight young ALSWH women followed for six years;

4) To test the relationship between diet quality, measured by the Australian Recommended Food Score (ARFS) and six year weight change in mid-age ALSWH women;

5) To examine the association between diet quality (ARFS) in women reporting a healthy weight and valid Total Energy Intake (TEI) and incidence of overweight or obesity in mid-age ALSWH women during six years of follow-up; and

6) To investigate whether improved diet quality scores (ARFS) over nine years of follow-up are associated with weight gain in mid-age ALSWH women with a valid TEI.

Methods and Results:

To achieve these aims systematic reviews (in 2011 and 2014) and secondary data analyses of ALSWH data were conducted. Both systematic reviews considered the relationship between diet quality and weight change in adults over time. In 2011, the search was performed on literature published between 1970 to March 2011 in four databases (MEDLINE, CINAHL, EMBASE and Scopus).

This review indicated that there was limited and inconsistent evidence on the relationship between diet quality and prospective body weight change in adults, especially among women in cohort studies. The evidence suggests that there was an inverse association between diet quality and weight change longitudinally, but the studies were too heterogeneous for any clear conclusions. A significant number of recent studies have been published in this area, and so the search was re-run in 2014. The 2015 systematic review confirms that higher diet quality is associated with lower body weight gain or lower incidence of overweight or obesity. Further, it found that diet quality tools based on food alone may have a stronger association with weight change in adults than those that rely on or incorporate nutrient sub-scales. However, there is a dearth of studies that use diet quality measures based on food components only.

Following the reviews, two analyses were conducted in sub-cohorts of young women from the ALSWH in order to evaluate aims two and three. First, a multivariate linear regression was used to evaluate the predictive relationship between a number of diet quality indexes, with weight change in a sub-cohort of disease-free young women, from the ALSWH who were followed for six years. The three diet quality indexes were the existing ARFS, an adapted version of the Diet Quality Index (DQI) and a newly developed diet quality score named the Fruit and Vegetable Index (FAVI), which have been used to measure diet quality in these women. A second analysis was run on a similar sub-cohort of young women from the ALSWH, but differed in that it included only those women within the healthy weight at baseline. Both studies revealed that young women's baseline dietary patterns, which contained a greater variety of healthy food such as vegetables, fruit and low fat dairy, legumes and lean protein, are associated with relatively low weight gain compared with those who consumed a less healthy dietary pattern.

Three additional analyses were also conducted on data obtained from mid-age women from the ALSWH. The first of these analyses was conducted on a sub-cohort of disease-free women, who were followed for six years. The analyses involved using multivariate linear regression to explore the association between diet quality, defined by the ARFS, and weight change during six years of follow-up. In the second of these analyses data from those women who were identified as having a healthy weight at baseline, had valid TEIs, and were followed for the same six year period, were analysed using multiple linear regression to assess the impact of the ARFS on the risk of becoming overweight or obese over six years of follow-up (i.e. six year incidence of overweight and obesity). From these studies, it was found that higher diet quality, as measured by the ARFS, was not associated with weight gain in mid-age women, nor was it associated with either a decreased or increased risk of becoming overweight or obese. The third of the analyses on mid-aged women from the ALSWH aimed to test whether improvements in diet quality over time can effect weight change in mid-age women during nine years of follow-up. Women were eligible for this analysis if they reported not having any medical conditions at baseline such as type 2 diabetes or heart disease and they reported a valid TEI at baseline. A strong inverse association between change in diet quality measured by the ARFS and weight gain was found over nine years of follow-up.

Conclusion and Implication:

Taken together, the results show that diet quality is a good predictor of weight change over time in adults in general, although the change is small. In adult women baseline diet quality measured by the ARFS or FAVI is associated with lower weight gain in young women but not in mid-age women. However, the analysis on change in diet quality in the mid-age women revealed that those who improved their ARFS score over time gained the least amount of weight, compared to those who reduced their diet quality over nine years. This research also found that weight gain over time and poor diet quality were common features among both young and mid-age women.

The findings from this thesis will help to inform public health nutrition policies, and women more generally, of the importance of consuming a wide variety of healthy foods regularly and aiming to achieve a high diet quality in order to slow the rate of weight gain in those most at risk of gaining weight. Those at greater risk of gaining weight, defined as women who are physically inactive, smokers, in the menopausal transition and less educated than other women at the same age. This thesis has added to the evidence base examining the ability of diet quality scores to predict weight change prospectively. Food based indexes appear to be a useful tool to explore and detect associations with weight change. However for research in the future, well designed studies in different population groups are required to confirm the findings, and to especially examine the role of changes in diet quality over time.

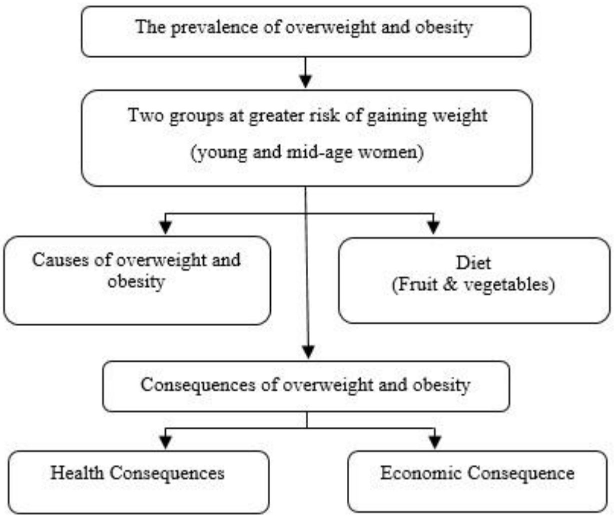
The results revealed from this thesis add valuable knowledge to the available literature. They provide justification for ongoing research in this area, specifically on the prevention of weight gain and the role of promoting healthy eating. More intervention studies are particularly required, with the aim of promoting healthy eating, to determine the long-term effects on weight gain and how it may vary for women at different life stages.

Chapter 1 Introduction

1.1 Overview

Chapter One presents the prevalence of overweight and obesity globally. It also highlights two groups at greater risk of gaining weight (mid-aged and young women), highlighting the causes leading to weight gain in these groups of women and the consequences of overweight and obesity on their health and the economic costs. In addition, this Chapter introduces the relationship between diet (fruit and vegetables) and weight changes. Figure 1-1 shows the structure of this chapter and the flow of the literature.

Figure 1-1: Overall flow of the literature for Chapter 1

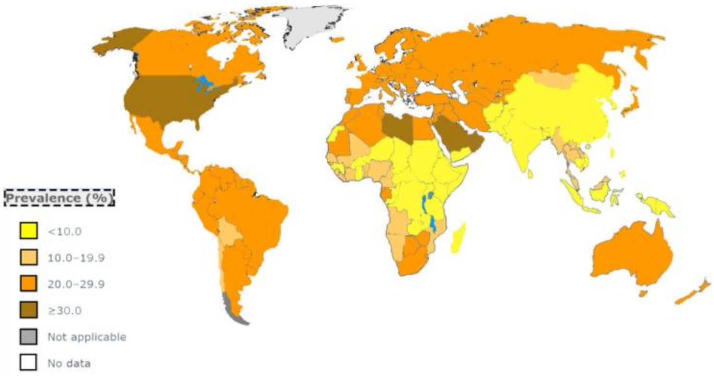


1.2 The prevalence of overweight and obesity

Overweight and obesity are defined by the World Health Organization (WHO) as conditions in which excess body fat accumulates to such a level that it increases the chance of adverse health effects, including chronic conditions such as type 2 diabetes (WHO, 2013b). Overweight and obesity can be estimated using the mathematical concept of Body Mass Index (BMI) (WHO, 2013b). BMI is calculated by dividing a person's mass in kilograms by the square of their height in metres. The concept of BMI has been used to classify people into different weight status groups according to the categories specified by WHO. Those who have a BMI$<$18.5kg/m^2 are categorised as underweight while 18.5$\leq$BMI$\leq$24.99 is considered normal weight. A person is defined as overweight if their BMI≥25.0kg/m², with BMI 25.00-29.99kg/m² considered to be pre-obese for adults, and BMI≥30.00kg/m² considered obese (WHO, 2008).

Overweight and obesity are a global problem and have attracted much attention around the world. The latest global estimate, updated by the World health Organisation (2014) of the prevalence of overweight and obesity in adults ages 18 and over was 39% and 26 % respectively (WHO, 2014). Figure 1-2 shows the prevalence of obesity (BMI≥30k/m²) among adults (2010-2014) according to the WHO. Some countries are affected by obesity more than others. For instance, of adults aged 18 and over in the USA and the United Arab Emirates (UAE), 33.6% and 33.8% respectively, were obese.

Figure 1-2: The prevalence of obesity among adults (2010-2014) by WHO



In Australia, the UK and the Kingdom of Saudi Arabia (KSA), the prevalence of obesity amongst adults was 28.4%, 26.9%, and 29.9%, respectively. Recent data revealed by the WHO (2014) shows that the prevalence of overweight (≥25kg/m²) is high internationally. For example 72.1%, 69.9%, 68 % of those aged 18 years and over were considered as overweight in the USA, Australia and the KSA respectively. This, in itself, is of major concern, but more importantly, it is the association of overweight or obesity with increased morbidity and mortality rates that poses the greatest threat (WHO, 2013b). Of serious concern is that the prevalence of overweight and obesity has greatly increased in the last few decades all over the world (WHO, 2014). The problem emerged initially in developed countries and rapidly spread to developing countries, including Asia, Africa and others (Popkin & Gordon-Larsen, 2004). For example, the annual percentage point increase in prevalence of overweight and obesity in developed countries including Europe and the USA has reached 0.5 (up from 0.3 per year), while it doubled to fourfold in developing countries over the same period (Popkin, 2004). In Australia over the last 30 years, the prevalence of overweight and obesity has also increased rapidly. In 1995, 38.6% of Australian adults aged 18 years and over were overweight or obese. By 2011, 2012 this had increased to 63.4% (Australian Health Survey, 2012, Australian Government, 2013a).

1.3 Age groups at risk of gaining weight (mid-age and young women)

Overweight and obesity are not restricted to a particular age or gender but affect people from any age group, and both males and females, children and adults. However, people from specific ethnicities, gender and at particular ages are at a higher risk of becoming overweight or obese than others. For example, evidence from several National longitudinal analyses from various countries shows that the annual increase in the incidence of overweight is greater in adults than in children (Popkin & Gordon-Larsen, 2004). Further, the incidence of both overweight and obesity is increasing rapidly in all adults, but the rate is faster and the incidence is higher in women than in men (Ng et al., 2014, WHO, 2014). The latest figures on the global prevalence of overweight and obesity revealed by the WHO indicate that the incidence of overweight (≈16%) and obesity (15%) in women is higher than for men (overweight ≈15% and obese 11%) (WHO, 2014). For example, for the period 1988 to 1994, USA National Surveys show that the prevalence of overweight and obesity increased more rapidly in women than in men (Flegal, 1999). Similarly, in the UK, the prevalence of obesity doubled in both men and women over the period from 1980 to 1995, but with a higher percentage of women (20%) reported as obese than men (17%) (Flegal, 1999). This same trend was observed for the prevalence of obesity in Australia (1980-1989), and showed increases of 5.2% in women compared to 1.7% in men (Flegal, 1999).

Figure 1-3 compares the prevalence of overweight and obesity (as one variable) among men and women aged 20 years or older, using data derived from the recent report by Ng, et al. (2014). The figure shows the percentage of overweight and obesity in men and women separately across 21 regions, based on the Global Burden of Diseases (GBD) (Murray et al., 2012). The percentages of men and women who are overweight or obese, are different across regions, with some regions, such as Australasia, having a greater percentage of men (68.6%), who are overweight or obese, than women (56.7%). However, in the same region the percentage of obese women (29.8%) is greater than that of men (27.6%). Collectively the prevalence of overweight and obesity (2014) confirms that the percentage of adults with BMI≥25kg/m^2 increased from the period 1980 to 2013 in both men and women, but in women (29.8% to 38%) the increase is even greater than for men (28.8% to 36.9%) (Ng et al., 2014, WHO, 2014).

Figure 1-3: The prevalence of overweight and obesity combined classified by gender (≥20 years) in 21 GEB regions (2013)

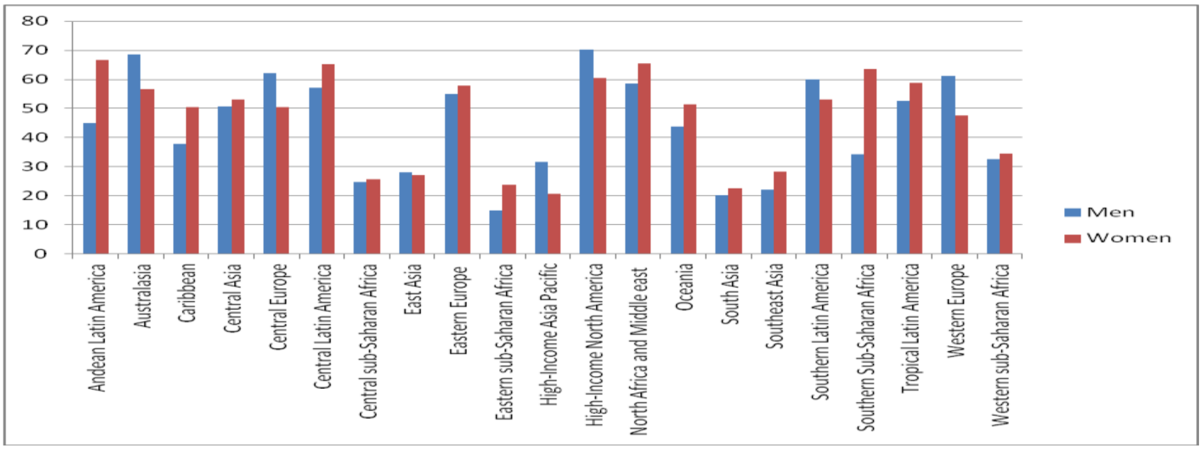
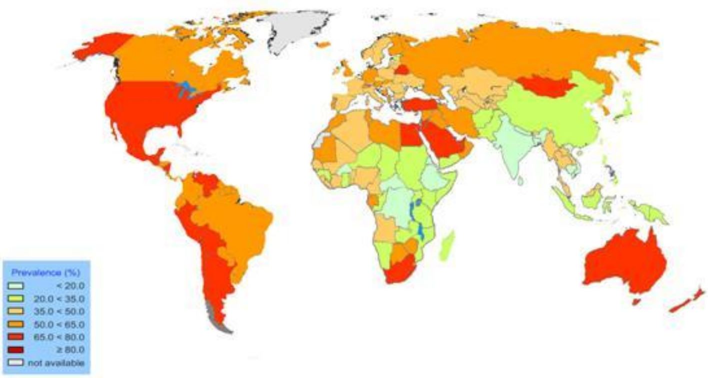


Figure 1-4 presents the global map with showing the prevalence of overweight and obesity (BMI≥25kg/m^2) in women aged ≥15 years internationally (2010). Thus, according to the WHO, women are at higher risk of weight gain than men (WHO, 2014), particularly at certain life stages, for example, in their reproductive years, during and post-pregnancy and at mid-life, and during the menopause transition (Smith et al., 2008). Evidence confirms that mid-aged women are at particular risk of weight gain due to the menopausal transition and they are more likely to gain greater amounts of weight than men of the same age (Williams et al., 2014).

Figure 1-4: The prevalence of overweight and obesity (BMI ≥25kg/m^2) in women aged ≥15 years internationally (2010).



A previous study examining weight gain in the mid-aged cohort of the Australian Longitudinal Study on Women's Health (ALSWH) found that more than 33% of the women gained 2.25 kg or more over two years (Williams et al., 2006). Fine, Colditz et al (1999) had previously shown that women who gained 2.25kg or more had a significantly higher proportion of body fat, and had higher total cholesterol and blood pressure compared with those who gained less than 2.25 kg or who lost weight over 4 years during the menopausal transition (Fine et al., 1999). Evidence also shows that women at this life-stage are at higher risk of cardiovascular disease (CVD) (Zhvania et al., 2012).

Mid-aged women at a high risk of weight gain due to many reasons, including hormones change related to menopause, and physiological changes associated with aging (Brown et al., 2005). As well as mid-aged women, young women are also at high risk of excessive weight gain. A recent study in the USA demonstrated in a nationally representative population sample that younger adults (18-64 years) have poorer diet quality when compared with both children (2-7 years) and older adults (65 years or more) (Hiza et al., 2013). The evidence indicates that early adulthood is a high-risk period for poor dietary patterns and weight gain, especially for women (Norman et al., 2003, Adamson et al., 2007). For example, the ALSWH data shows that when women from the young cohort (18-23 years old) reach their forties, they will be heavier than mid-aged women are now (Adamson et al., 2007).

More specifically, the data from ALSWH shows that women from the young cohort are gaining about 0.64 kg per year, which is a 30% greater weight gain than the mid-aged women (Adamson et al., 2007). In terms of prevalence of overweight and obesity, there has been an increase from 25.7% to 35.4% for those in the young cohort (25-34 years) during the period from 1995 to 2005 (Adamson et al., 2007). A previous review found that young women are at greatest risk of gaining weight (Wane et al., 2010). Young women at high risk of future weight gain, with future prevalence of overweight or obesity among women aged 20 years or older has been estimated to reach 75% by 2025 (Haby et al., 2012).

1.4 Causes of weight gain

1.4.1 In young women

There are many factors contributing to weight change in women. Getting older is one reason for weight gain, so age impacts on weight change status over time (Blümel et al., 2001).

There are other factors that affect weight status and these vary according to the age group. For example, pregnancy is associated with excess gestational weight gain in young women. A recent observational study which sampled 664 pregnant Australian women (de Jersey et al., 2012) reported that 38% of these women gained excess weight. Weight change was calculated from the pre-pregnancy weight and weight at 36 weeks gestation (de Jersey et al., 2012). Another study reported that post partum weight retention is found in 60 to 80% of women with some retaining ≥10 kg. (Martin et al., 2014). Other factors contributing to weight gain over time in young women include marriage, parity, transition from school to university, smoking status, employment and higher BMI at baseline (Ball et al., 2002, Brown & Trost, 2003, Wane et al., 2010). In a longitudinal analysis (1996-2000) of a sample of 8,726 women from the representative data of ALSWH with age at baseline 18-23 years, it was found that 41% women had gained weight since being married. Women who gained weight also became less active and consumed more energy-dense, nutrient-poor fast food compared with those who had maintained a healthy weight at follow-up. For the study, women whose BMI at

Survey 2 was within 5% of their BMI at Baseline BMI were classified as 'maintainers' (Ball et al., 2002).

1.4.2 In mid-aged women

For mid-aged women, some studies have demonstrated that hormonal changes and the menopause transition play important roles in weight change (Brown et al., 2005). However, other studies found hormone changes during the mid-age period are not associated with weight change (Guthrie et al., 1999, Blümel et al., 2001). One study of a group of 3,064 women aged 41 to 52 years at baseline, from the Study of Women's Health Across the Nation (SWAN), aimed to examine the association between menopausal status, physical activity and weight change over time. The researchers found that increasing or maintaining physical activity was significantly associated with lower weight gain over the three years of follow-up, while the menopause status change was not independently related to weight change (Sternfeld et al., 2004).

1.5 Some other causes of weight gain

There are multiple factors that contribute to weight gain in adults, which include physical activity, genetics and environmental or lifestyle factors (AIHW, 2014). One fundamental factor in weight change is dietary intake, which is a major contributor to energy imbalance. The diet that people consume contains a certain amount of energy depending on the type and volume of food eaten. Each individual's energy needs depend on many factors including age, weight, gender and certain conditions. For example a pregnant woman's energy needs differ from those of a woman of the same age, weight and height who is not pregnant (AIHW, 2014). The overall balance between energy intake from food and drinks consumed and energy expended in activities, basal metabolism and digestion is the key to gaining or losing weight. If a person consumes food and drink that result in a greater energy intake than they need, this will contribute to weight gain, and gradually lead to development of overweight and obesity over time (AIHW, 2014, WHO, 2013b).

Diets that are high in energy intake and energy dense are associated with greater prospective weight gain (Savage et al., 2008, Tataranni et al., 2003). Several dietary patterns have been found to be associated with weight gain and increasing BMI. These include high consumption of fast food (Chou et al., 2004), a dietary pattern high in meat, fat, dairy and potatoes (Newby et al., 2003b) and a dietary pattern which is rich in red and processed meat, refined grains, sweets and potatoes (Schulze et al., 2006). However, understanding the relationship between dietary intake, social factors and weight change is complex and difficult to define and quantify. There is more than one factor that affects eating behaviour and therefore weight change status. For example, those with higher education and of higher income are less likely to gain excess weight and are more likely to eat healthy food, especially fruit and vegetables compared to other adults who are of relative disadvantage in terms of these social factors (Devaux & Sassi, 2013, De Irala-Estevez & Groth, 2000).

A further example includes lifestyle and economic status which impacts on eating habits and physical activity patterns in women (Chou et al., 2004). For those who are in the workforce being time poor may result in the consumption of greater amounts of take-away food due to less time available to plan and prepare healthy meals and/or exercise. These make them at risk of gaining more weight and progressing to overweight and obesity (Chou et al., 2004, Wane et al., 2010). Social factors such as education, being single, having children, area of living and the work place can all impact adversely on eating habits and physical activity (MacFarlane et al., 2010, Ball et al., 2003, Compernolle et al., 2015).

Mental health status has also been found to affect weight change in women. Mental health disorders including depression are associated with prospective weight gain and the incidence of obesity (Chou et al., 2004, Wane et al., 2010, Kivimäki et al., 2009).

In terms of the trends in food consumption worldwide, the WHO has reported increased consumption of food high in Energy Density (ED), especially fat, and a reduction in physical activity for people around the world (WHO, 2013b, AIHW, 2014). The WHO have advised people to increase the consumption of foods rich in nutrients and fibre, such as fruit, vegetables, nuts, legumes and whole grains, as well as to decrease the consumption of foods containing high levels of fat and sugar in order to prevent weight gain. In addition, the WHO recommended that people increase their consumption of fruit and vegetables as a strategy to reduce the risk of obesity. The following section will provide evidence on the association between fruit and vegetable intake and weight changes. As part of my thesis, I have created a simple instrument to measure the variety and frequency of intake of fruit and vegetables in order to evaluate the association between greater intake of variety of fruit and vegetables with weight changes in women.

1.5.1 Fruit and vegetables and weight change

Fruit and vegetables are healthy foods that are low in total kilojoules yet high in nutrients, including a range of micronutrients and phytonutrients. There is substantial evidence about their benefits in terms of helping to prevent disease such as CVD and some types of cancers such as gastrointestinal cancer (WHO, 2010, Boeing et al., 2012). WHO reported that a low intake of fruit and vegetables is linked to 1.7 million (2.8%) premature deaths (WHO, 2010). Fruit and vegetables also contain large amounts of water and fibre (soluble and insoluble). Most of them are low in fat and energy density (WHO, 2010, Boeing et al., 2012). Thus, increased consumption of fruit and vegetables is associated with increased intake of fibre, and can decrease the daily total energy intake, which, in turn, is associated with a lower risk of weight gain (WHO, 2010). WHO recommends that people consume at least 400g of both fruit and vegetables (excluding potatoes and other starchy tubers) daily to reduce the risk of developing many major diseases such as CVD, cancer, diabetes and obesity (WHO, 2010).

A systematic review carried out by Ledoux et al. (2011) that synthesised the evidence on fruit and vegetable intake in association with weight change reported a significant association between the consumption of fruit and vegetables with lower weight gain among overweight people in longitudinal studies (Ledoux et al., 2011). In intervention studies an inverse association was found between combined greater consumption of fruit and vegetables and other behaviours, and weight gain in adults. However, the authors suggested more research is needed to confirm this conclusion (Ledoux et al., 2011). In another systematic review, the researchers, Kim, Haines et al. (2003) suggested that increased consumption of fruit and vegetables did not lead to weight loss or reduce the risk of obesity. In contrast, the European Prospective Investigation into Cancer (EPIC), using data from across five countries, analysed the relationship between fruit and vegetable consumption and weight change over time in a total of 89,432 adults (Buijsse et al., 2009). They found that for every 100 grams of fruit and vegetable consumed per day there was an associated reduction in annual weight gain of 14 grams. The current evidence is inconsistent, so the aim of this study is to examine the association between variety and frequency of intake of fruit and vegetables with prospective weight gain in a cohort study of women.

Moreover, the consumption of fruit and vegetables is important, not just as an approach to potentially control weight, but also to improve and promote health and wellbeing. Increasing the consumption of fruit and vegetables is an important strategy for the prevention of some specific types of cancer (World Cancer Research Fund International, 2007). Even though the evidence does not support that total fruit and vegetable consumption for all-cause cancer prevention, it does support the greater consumption of fruit and vegetables for obesity prevention, which is an important risk factor for many cancers (World Cancer Research Fund International, 2007).

1.6 Consequences of overweight and obesity

1.6.1 Health effects of overweight and obesity

Regardless of the reason for weight gain in the various life stages, there are serious concerns with overweight and obesity in regards to health outcomes. There are strong links between obesity and the incidence of both non-communicable diseases (NCDs) or chronic diseases and mortality. Globally, overweight and obesity is the fifth greatest risk factor for death The WHO have estimated the number of people who die annually because of being obese to be 2.8 million (WHO, 2014). In Australia for example, the Australian Bureau of Statistics (ABS) (2004-05) found that overweight or obese people have poorer health than those who are of a healthy weight. Overweight or obese people reported 6% more health complaints than people who were normal or underweight (ABS, 2005).

Obesity is associated with decreased quality of life and reduced life expectancy (Diaz, 2002, Lijing et al., 2006). In addition, it increases the risk of many NCDs, including

CVD, diabetes, hypertension, metabolic syndrome and dyslipidemia (Cameron et al., 2009, Hu, 2003). It can also increase the risk of some cancers such as breast cancer (Sanchez-Villegas et al., 2010, Hu et al., 2000, World Cancer Research Fund International, 2007), cancer of the oesophagus, pancreas, colon and rectum, endometrium, kidney and potentially the gallbladder (World Cancer Research Fund International, 2007). Studies show that obese people have lower levels of High-Density Lipoprotein (HDL) and higher levels of total cholesterol, triglycerides, and apolipoprotein than non-obese people (Lee et al., 2010), which increases their risk of cardiovascular disease. There is also a relationship between body weight, body fat and bone mineral density (BMD), with evidence suggesting that an increase in body fat and waist circumference is related to a decrease in BMD (Greco et al., 2010), and greater risk of bone fractures (Søgaard et al., 2014). One such study looked at 398 patients, aged 44.1±14.2years, with a BMI 35.8±5.8kg/m2, and found a significant inverse correlation between BMI and BMD (Larsson et al., 1984). Obese people are more likely to develop osteoarthritis with a relative risk (RR) of up to 2.45 times that of non-obese individuals (Access Economics, 2008).

Obesity is linked to higher risk of chronic diseases. Adipose tissue plays a role in inflammation by increasing free fatty acids and pro-inflammation chemokines and cytokines including monocyte chemotactic protein (MCP)-1, tumor necrosis factor (TNF)-α, and decreasing the anti-inflammation adipokine. These are found in association with type 2 diabetes (McArdle et al., 2013, Jung & Choi, 2014)

Type 2 diabetes is a significant adverse consequence of overweight and obesity. Nearly 75% of the Australians who have Type 2 diabetes are categorised as overweight or obese (ABS, 2005). Type 2 diabetes occurs when either the body fails to produce enough insulin or when tissues in the body become insulin resistant (Centers for Disease Control and Prevention, 2004). Insulin's ability to function normally is adversely affected by body fat and the pancreas will therefore overproduce insulin to try and regulate blood sugar. Over time, the body is not able to continue to keep producing more and more insulin and to keep the blood sugar at normal levels, and Type 2 diabetes develops. Apart from being part of the cause of Type 2 diabetes, obesity makes the management and treatment of the diabetes difficult by increasing insulin resistance and glucose intolerance, thereby reducing the effectiveness of the drugs for treatment (Centers for Disease Control and Prevention, 2004).

Overweight and obesity are also linked to development of CVD. Evidence shows that overweight and obese people are more likely to develop CVD, including stroke, with a RR up to 1.8 (Krauss et al., 1998, Access Economics, 2008). Higher BMI associated with increased lean body tissues, fat and body surface area can effect cardiac functions in different ways. Heart strain is a result of pumping a higher blood volume around a larger body, and this can lead to hypertension (Kopelman, 2000). Hypertension is common in adults who are overweight or obese. In those who are obese, the incidence of hypertension is approximately three times higher than in those who are non-obese (Kopelman, 2000). The increase in sensitivity of obese people to sodium is one reason for this elevated risk. In addition, greater body weight increases the consumption of oxygen and therefore cardiac output (Kopelman, 2000). Obesity also impacts the lipid levels in the blood. This increase in turn, increases triglyceride levels, which has the effect of decreasing the HDL or good cholesterol (Krauss et al., 1998, Kopelman, 2000). The excess fat due to obesity also causes increases in Low Density Lipoprotein (LDL) or bad cholesterol. A combination of a decrease in HDL and an increase in LDL results in a higher risk of CVD including heart attack or stroke (Krauss et al., 1998). This impairment of blood level of lipids is termed dyslipidemia. Dyslipidemia occurs when LDL cholesterol and triglyceride levels are high and HDL cholesterol concentrations are low. Dyslipidemia is also a primary risk factor for coronary heart disease (Hu et al., 2000).

Obesity is also a causative factor for breathing problems during sleep, a condition known as Obstructive Sleep Apnoea (OSA) (Eckert & Malhotra, 2008). OSA is due to obstruction of the upper respiratory tract when lying horizontally. The excess weight around the face, neck and shoulders compresses the trachea, limiting breathing. OSA is indicated by pauses in breathing during sleep. There are many consequences of OSA such as daytime sleepiness, snoring loudly and insomnia. OSA has been shown to be associated with decreased quality of life (Eckert & Malhotra, 2008).

Obesity can also effect mental and emotional health. The effect of obesity on mental health can be as damaging as the physical effects (Lorefat et al.). Obesity gives rise to a number of psychological problems such as low self-esteem, depression and anxiety (Kolotikin et al., 2001).

Since obesity increases the risk of disability, morbidity and mortality, it also affects quality of life. A review paper by Kolotikin et al. (2001) reports that obesity adversely affects quality of life in many ways including: greater risk of illness; loss of income from inability to work; mobility issues; inability to exercise; and psychological distress (Kolotikin et al., 2001).

Young women with high BMIs face many additional health problems before reaching mid-age. These include decreased fertility, and impaired reproductive function, including altered hormones levels, anovulation, and irregular menstrual cycles. In addition, obesity can also affect the occyte and embryo development and quality (Jungheim et al., 2013, Lane et al.). Women with high BMIs are at increased risk of complications in pregnancy, such as increased risk of gestational hypertension and incidence of caesarean delivery, post-partum haemorrhage and underweight babies (Smith et al., 2008, Jain et al., 2012). There is a body of research that confirms the adverse implications of maternal obesity for offspring. For example, the weight status of women prior to pregnancy can affect the offspring's future weight status. A recent systematic review and meta-analysis revealed that the risk of childhood obesity was three times greater in those who born to women who were obese mothers prior to pregnancy (OR, 1.95; 95% CI, 1.77–2.13; and OR, 3.06; 95% CI, 2.68–3.49), compared with children born to mothers who were at a healthy weight range pre- pregnancy (Yu et al., 2013). While maternal obesity can contribute to small gestation infants as well (Smith et al., 2008, Jain et al., 2012). Therefore, obese young women have an increased risk of developing various chronic diseases which is also the case for their children both in the short and in the long term (WHO, 2013b, World Cancer Research Fund International, 2007, Smith et al., 2008, Kolotikin et al., 2001, Jain et al., 2012, Hu, 2003). These include but are not limited to: Polycystic Ovary Syndrome (PCOS); Type 2 diabetes; CVD; and cancers, especially postmenopausal breast cancer and endometrial cancer (World Cancer Research Fund International, 2007, Hu, 2003). Mortality related to obesity is increased as well (Hu, 2003). Collectively, pre-pregnancy obesity in young women, or excessive gestational weight gain can adversely impact on the health and wellbeing of women themselves and/or their off-spring health, via a number of mechanisms and at different stages (Yu et al., 2013, Robinson et al., 2015, Mamun et al., 2014, Galliano & Bellver, 2013).

Higher BMI at mid-age, and gaining further weight at this time, reduces the chance of healthy survival through to old age (Sun et al., 2009). A USA study conducted by Sun, et al. (2009) on a total of 17,065 women with mean age 50 years at baseline from the Nurses' Health Study, who were followed up to 70 years of age, aimed to assess the relationship between weight status and its impact on healthy survival. The study found that women who were obese (BMI ≥30) during mid-age at baseline and who survived until at least 70 years, had 79% lower odds of healthy survival, meaning they had more health related problems (OR: 0.21, 95% CI: 0.15 to 0.29). The reference group for this study were women who had 18.5≤ BMI ≥22.9, and the health problems were identified as various diseases including, but not limited to diabetes, CVD, Parkinson's disease, impaired physical activity, mental health and cognitive function issues (Sun et al., 2009). Gaining weight at mid-age is also associated with significant increases in the risk of CVD, due to increases in blood pressure and levels of low density lipoprotein and triglycerides (Wing et al., 1991).

Given the relationship between obesity and numerous chronic conditions, it is not surprising that mortality is increased in those who are obese (Kolotikin et al., 2001). Obese women are more likely than non-obese women to experience morbidity and to die prematurely (Hu, 2003). The same is true for men, especially men with excess abdominal adiposity, which is associated with premature mortality due to CVD (Larsson et al., 1984).

1.6.2 Economic effect of overweight and obesity

Obesity not only affects the health status of the individual, but it has adverse economic consequences as well. The costs of obesity to individuals, the health system and to society are extreme. A 2009 report has predicted that from 2020-2025 in the USA, approximately $208 billion will be attributed to lost worker productivity, morbidity and premature death caused by obesity (Lightwood et al., 2009). Furthermore, 1.5 million life-years will be lost, and the total cost of medical care is estimated at $46 billion for this same period (Lightwood et al., 2009). In Australia, a report estimated that the annual total direct cost in 2004-2005 (health care and non-health care) per person increased from $1472 for those of normal weight, to $2788 for those who were obese (Colagiuri et al., 2010). The total financial costs of obesity including the net cost of loss of wellbeing increased from $ 21 to $58 billion between 2005 and 2008. The cost of obesity alone, was $3.8 billion in 2005 and $8.28 billion in 2008 (Access Economics, 2008).

1.7 Conclusion

Clearly from the previous studies and evidence presented, overweight and obesity have many direct and indirect adverse effects on individuals, society and government. Therefore, more studies are needed to establish effective strategies to prevent this worldwide phenomenon and help women to achieve weight stability throughout their lives.

Prevention of weight gain and staying in the healthy weight range is an important strategy to promote health, well-being and to prevent chronic diseases such as diabetes and CVD and some cancers. Thus I focused on conducting two analyses on sub-samples of women who were initially in the healthy weight range and who were followed up for specific time periods. More detail is provided in Chapters 6 and 8

In addition, diet is one of the key components that needs to be addressed in order to resolve this problem. Consuming good levels of fruit and vegetables may be an important strategy to help women avoid excess weight gain during their lifespan. Dietary intake can be measured in different ways, as food components such as nutrients, or as whole diet measured by diet quality indexes or scores. Thus I have conducted my study on diet quality and weight change in women. The next section will provide more details about thesis aims and structure.

1.8 Research aims

The main goal of this thesis is to evaluate the association between diet quality using the ARFS and weight change in Australian women over time. The women included in the analyses within this thesis were from two cohorts of women, mid-aged and young, enrolled in the Australian Longitudinal Study on Women's Health (ALSWH), which is a prospective study that has been running since 1996. The specific objectives of my thesis are:

1. To synthesise and summarise the evidence published on diet quality and weight change in adults longitudinally.

2. To examine the relationship between diet quality as the independent variable and weight change as the dependent variable in Australian women (both young in mid-aged cohorts) from the ALSWH over six years of follow-up.

3. To examine if there is any difference between various diet quality tools in determining the relationship between diet quality and weight change in young Cohort with all BMI groups over a 6 year period.

4. To test the relationship between different diet quality indexes and weight change over a 6 year period in sub-groups of ALSWH women with a healthy weight from the young cohort (2003-2009).

5. To test the relationship between diet quality and incidence of obesity and overweight over a 6 year period in sub-groups of ALSWH women with a healthy weight from the mid-aged cohort (2001-2007).

6. To examine if there is any difference in weight change between those who eat healthier quality diet compared with those who decreased diet quality during nine years of follow-up (2001-2010) for mid-age women.

1.9 Thesis structure

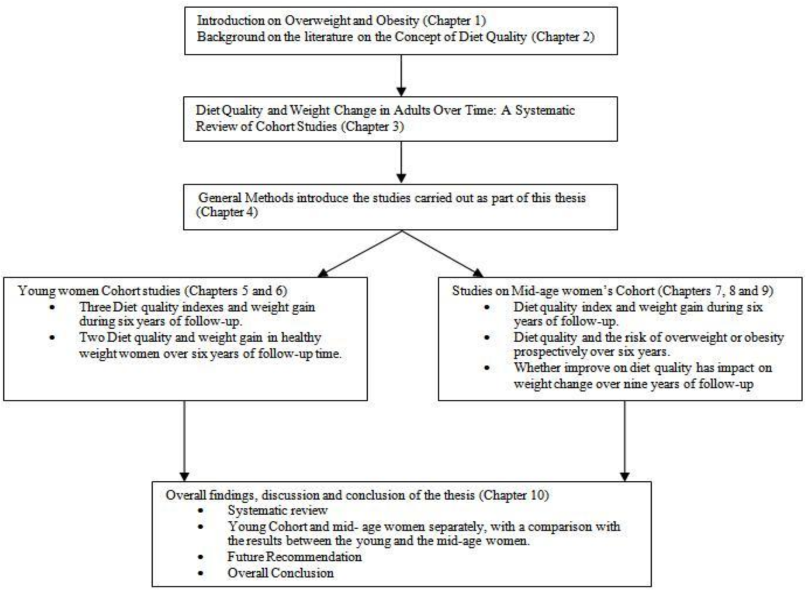
Overview

The structure of the thesis is explained in Figure 1-5 the main aim of this thesis was to examine the association between diet quality and body weight change in women prospectively. Women in this study were those recruited into the ALSWH from two age cohorts (‘mid-age’ and ‘young’ women). The analyses were conducted on both the mid-age and young cohorts to evaluate the associations between diet quality and the risk of overweight and obesity, or absolute weight change at each life-stage, over specific periods of time (Table 1-1).

This thesis contains four main sections including:

- Section 1 - Systematic review of the association between diet quality and weight change in adults over time (Chapter 3);
- Section 2 - Analyses conducted on women in the young Cohort (Chapters 5 and 6);
- Section 3 - Analyses conducted on women in the mid-age Cohort (Chapters 7, 8 and 9); and
- Section 4 - Overall discussion, recommendations and conclusion (Chapter 10).

Figure 1-5: Thesis structure



The findings of the systematic review on the association between diet quality, as measured by indexes, and weight change in adults have been published (Aljadani et al., 2013a, Aljadani et al., 2013c) and are included in Appendices 1 and 2. In addition, I recently updated the systematic review conducted at the start of this PhD research project and it has now been published, in order to re-examine and synthesise the most current and best available evidence on the association between diet quality and weight change in adults over time. This recently updated version is presented in Chapter 3. Following this, the individual analyses conducted in each of the young and mid-age cohorts of women from the ALSWH, are presented in Chapters 5-9. Each one of these chapters has been submitted for publication or has been published.

1.9.1 Section 1: The Systematic Review

This review was conducted to synthesise the best available analyses that had evaluated the effect of dietary patterns on changes in body weight status in adults prospectively in cohort or case-control studies. Three publications were derived from the results of this systematic review, including one paper published in 2013 by the *Joanna Briggs Institute (JBI)* (Aljadani et al., 2013a) as well as a book chapter (Aljadani et al., 2013c). The JBI paper reported the best available evidence on dietary patterns measured by three main methods; factor analyses, cluster analyses, and diet quality indexes, and the relationship with weight change in adults over time. The book chapter synthesised the best available evidence on diet quality and body weight change in adults prospectively. These publications have been included in the thesis as Appendices 1 and 2. Chapter 3 is related to this systematic review and represents the updated search for recent studies published since the first systematic review, examining the association between diet quality and weight change in adults prospectively. An additional six studies were included in the updated review.

1.9.2 Section 2: Young Women

Two papers have been written on the association between diet quality and weight change in young women. More specifically, a paper has been published (Aljadani et al., 2013b) in the *Journal of Obesity* which aimed to assess the associations between dietary patterns quantified by the ARFS, the Australian Diet Quality Index (Au-DQI) and the Fruit and Vegetables Index (FAVI) in young Australian women over six years of follow-up. This paper describes the development and use of both the Au-DQI and the FAVI for the first time. The Au-DQI was created based on Australian Recommendations for adults and was adapted from the five point USA DQI. It contains five nutrient components. The FAVI diet quality tool is a brief diet quality index assessed based on frequency and variety only of fruit and vegetables consumed. This reflects a key message of the Australian Dietary Guidelines, namely more frequent consumption of a wide variety of fruit and vegetables. This paper is reported in the thesis in Chapter 5. Chapter 6 reports on another study conducted on the young women, which aimed to evaluate the association between diet quality (measured by the ARFS and FAVI) and weight gain in healthy weight women (at baseline) during six years of follow-up. It has been submitted for publication to *The Australian and New Zealand Journal of Public Health*.

1.9.3 Section 3: Mid-aged Women

This section represents three papers reporting analyses conducted in the mid aged women, including the published paper in the *Australian and New Zealand Journal of Public Health* (Aljadani et al., 2013d) which examined diet quality and weight change in women during 2003-2009 (Chapter 7). Two further studies were conducted with the mid aged women, including one that examined the risk of becoming overweight or obese for those women who were healthy weight at baseline and with a range in their baseline diet quality, as measured by the ARFS (Chapter 8). The third study examined the relationship between changes in diet quality over time, as measured by the ARFS, and weight change over nine years of follow-up (Chapter 9).

1.9.4 Section 4: Overall Discussion, Conclusion and Recommendations

Chapter 10 contains a discussion of the overall findings from the systematic review (including preliminary and updated searches and different study designs). The findings from the analyses conducted on young and mid aged women are discussed separately. I also compared the findings between the two cohorts, the young cohort and the mid-age cohort. The overall conclusion includes recommendations for future research.

The next chapter (Chapter 2) provides more information about overall diet measurement including diet quality concept. Diet quality is presented in more detail and includes a number of recent reviews on diet quality and health outcomes. In addition, Chapter 2 reports on the most common diet quality indexes or scores, which have been used in the literature review and more than 20 indexes or scores with details of the components of each score and scoring methods are presented I have also reported the differences and similarity in general between diet quality indexes or scores.

Table 1-1: Research aims and thesis chapters

	Research aim	Chapter	Paper title	Participants age group	Extra Criteria for participants inclusions
1	To synthesise and summarise the evidence published on diet quality and weight change in adults.	3	1. The longitudinal association between predefined diet quality and weight gain in adults: a systematic review Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C. E. Collins. **Published** in 2015 in Current reports J	Adults aged 18 years or older	NA
		Appendix 1	2. The association between diet quality and weight change in adults over time: A systematic review of studies with follow up. Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C.E. Collins. **Published** in 2013 in Joanna Briggs library (JBI) Database of Systematic Reviews and Implementation Reports	Adults aged 18 years or older	NA
		Appendix 2	3. The association between diet quality and weight change in adults over time: A systematic review in prospective studies. Authors: H. Aljadani, A. Patterson, D. Sibbritt, and C.E. Collins. **Published** in 2013 as a book chapter	Adults aged 18 years or older	NA
2	To examine the relationship between diet quality as the independent variable and weight change as the dependent variable in young Cohort from the ALSWH over six years of follow-up. To examine if there is any difference between various diet quality tools in determining the relationship between diet quality and weight change in young Cohort over a 6 year period.	5	Diet Quality, Measured by Fruit and Vegetable Intake, Predicts Weight Change in Young Women Authors: H. Aljadani, A. Patterson, D. Sibbritt, M. Hutchesson, M. Jensen, and C.E. Collins. **Published** in Volume 2013 (2013), 10 page in Journal of Obesity	1)Young women from the Australian Longitudinal Study on Women's Health (ALSWH) 2) Mean aged 28 years at baseline,	Two analyses : 1) Those with all TEI reporters. 2) Those with valid TEI. Plus all samples are defined as free-disease samples who reported no medical conditions at both baseline and follow-up such as type 2 diabetes.
3	To test the relationship between different diet quality indexes and weight change over a 6 year period in sub-groups of ALSWH women with a healthy weight from the young cohort (2003-2009)	6	The association between diet quality and the risk of overweight and obesity Authors: H. Aljadani; L. Al-Oboudi; A. Patterson; D. Sibbritt and C.E. Collins. It will submit to The Australian and New Zealand Journal of Public Health	1) Young women, enrolled from the ALSWH 2) Mean aged 28 years at baseline.	An analysis: 1) Those were free-disease women who reported no medical conditions at both baseline and follow-up such as type 2 diabetes. 2) Healthy weight ($18.5 \leq$ BMI <25 kg/m^2) at baseline.

					3) All TEI reporters.
4	To examine the relationship between diet quality as the independent variable and weight change as the dependent variable in mid-aged cohort from the ALSWH over six years of follow-up.	7	The Australian Recommended Food Score did not predict weight gain in mid-age Australian women during six year of follow-up Authors: H. Aljadani; D. Sibbritt; A. Patterson; and C.E. Collins. **Published:** 2013 in Volume 37(4), pages 322-28. Journal: The Australian and New Zealand Journal of Public Health	1) Mid- age women from the ALSWH. 2) Mean age 52 years.	An analysis: 1)Those were free-disease women who reported no medical conditions at both baseline and follow-up such as type 2 diabetes 2) All women with BMI at baseline. 3) All TEI reporters
5	To test the relationship between diet quality and incidence of overweight or obesity over a 6 year period in sub-groups of ALSWH women with a healthy weight from the mid-aged cohort (2001-2007).	8	Diet quality and six year risk of overweight and obesity amongst mid-age Australian women who were initially in the healthy weight range Authors: H. Aljadani; A. Patterson; D. Sibbritt and C.E. Collins Journal: The Health Promotion Journal of Australian (2015).	1) Mid- age women from the ALSWH. 2) Mean age 52 years.	An analysis: 1) Those were free-disease women who reported no medical conditions at both baseline and follow-up such as type 2 diabetes 2) Healthy weight ($18.5 \leq$ BMI <25 kg/m^2) at baseline. 2) Those identified with Valid TEI.
6	To examine if there is any difference in weight change between those who eat healthier diet quality compared with those who decreased diet quality during nine years of follow-up (2001-2010) for mid-age women.	9	Prospective change in diet quality and its relationship with weight change in mid-age women Authors: H. Aljadani; A. Patterson; D. Sibbritt and C.E. Collins. It submitted to the Journal of Public Health.	1) Mid-age women from the ALSWH. 2) Mean age 52 years.	An analyse: 1) a samples of free-disease women who reported no medical conditions at baseline only such as type 2 diabetes 2) All BMI women 3) Those reported valid TEI

Chapter 2 Background Literature

2.1 Overview

This chapter presents a brief introduction to the measurement and methodology used to assess dietary patterns in research studies. These include the theoretical and empirical approaches to measuring overall dietary patterns. The following section focuses on the theoretical or '*a priori*' approach that uses diet quality indexes or scores. Section 2.2.2.1 reports the reviews that have been conducted on the concept of diet quality and health outcomes more broadly. The next section (Section 2.2.2.2) briefly tabulates and reports the scoring methods and the items included in more than 20 indexes or scores. Following on from that is a description of some of the most common indexes that have been used in previous studies, such as the Dietary Quality Index (DQI), the Healthy Eating Index (HEI); the Dietary Guideline Index (DGI) and the Recommended Food Score (RFS). Section 1.8 presents my project outline and research aims, and finally Section 1.9 describes my thesis structure.

2.2 Dietary Patterns Measurement

Previously, many researchers have examined the relationship between single nutrient intakes, or food items, and chronic disease or health outcomes (McCarron & Reusser, 2000). The findings of these studies are important in understanding the function and role of single nutrients or food intakes and the relationship with health outcomes and disease risk, including cardiovascular disease (CVD) (McCarron & Reusser, 2000). However, as humans we consume whole diets and not individual components of food or isolated nutrients, and it is therefore important to understand more about the diet as a whole. Key examples of nutrients and food component interactions include: increased iron absorption in the presence of vitamin C; the association between magnesium and potassium (Hu, 2002); and the role of lactose in calcium and zinc absorption (Abrams et al., 2002). Moreover, the impact of a single nutrient in research can be too small to capture, while the impact of a whole diet which contains many nutrients may be easier to identify and capture (Hu, 2002). Thus, assessing overall food intake and dietary patterns is useful in many circumstances (Waijers et al., 2007, Wirt & Collins, 2009).

Evidence supports the examination of whole diet rather than just nutrients alone in intervention studies (Ursin et al., 1993), as results may be confounded by the various ways in which nutrients may be consumed, or due to specific dietary patterns (Hu, 2002). Additionally, it is crucial in the public health field to recommend dietary patterns, rather than specific nutrients, as people must choose foods to consume, not nutrients (Slattery, 2010). As a result of these issues, and the limitations surrounding studies that have evaluated the effect of single food components or nutrients on chronic diseases, significant attention and interest has developed in the last decade on the measurement of whole diet and its relationship with health outcomes (Hu, 2002, McCarron & Reusser, 2000).

There are two main approaches to measuring overall dietary intake patterns. These are based on theoretically or empirically derived methods. The theoretical approaches are known as 'diet quality indexes or scores' and are based on "*a priori*" decisions, and applying specific scoring methods to a person's dietary intake. These scores are based on prior selection of specific components of nutrients and/or foods combined together or alone; with some containing additional non-diet items (Wirt & Collins, 2009, Kant, 1996). (Section 2.2.2). The second approach to evaluating dietary patterns is an empirically derived "*a posterior*" method. This statistically classifies population-based dietary data into similar consumption patterns aggregated in factor analyses, cluster analyses or using reduced rank regression (Tucker, 2010, Hu, 2002, Togo et al., 2001).

2.2.1 The empirical or 'a posterior' approach to measuring dietary patterns

Briefly, the empirically determined methods or 'a posterior' approach can be used, for example, factor analysis and principal components analysis at the same time, and the dietary patterns derived by this method would be known as 'factor patterns'. The empirically determined methods are a statistical approach that can be used to derive dietary patterns from data collected on food consumed by participants gathered by

Food Frequency Questionnaires (FFQ), 24 hour recall or dietary record within any given study (Tucker, 2010, Hu, 2002, Togo et al., 2001).

Factor analysis creates food patterns (or 'factors') based on inter-correlation between one food item and other food items by giving scores for these items within the dataset. These aggregate food patterns, or factors, are given a score, determined as the sum of the products of the strength of the correlation of each food pattern with the overall intake of an individual. Once the total score for each food pattern is determined, it can then be used in regression models or other statistical tests to examine the association between these food patterns and the outcome of interest in the study. A limitation of factor analysis is that a participant can be classified into more than one food pattern. As such, this may not be the best approach if the goal of the analysis is to assign an individual to a dietary pattern (Tucker, 2010, Hu, 2002).

The second "a posterior" approach is cluster analysis, which is another statistical method that uses pre-existing data on dietary intake to create clusters of food patterns. In this approach, participants are aggregated into clusters based on the similarity between them in terms of food intake characteristics such as the number of food items consumed, the mean weight of foods consumed, or combinations of diet variables with other variables in the dataset, such as biomarkers. This approach is important when the goal of the research is to identify or target a specific group with eating habits that may put them at risk; for example, a group of participants who consumed high levels of alcohol or white bread. However, a limitation of using cluster analysis to identify food patterns is that it has less statistical power in comparison to factor analysis. (Tucker, 2010, Hu, 2002, Togo et al., 2001)

Finally, there is an additional statistical method used more recently, known as Reduced Rank Regression (RRR). The RRR is a new approach to measuring dietary patterns, which is similar to factor analysis, in that it aggregates food components into patterns correlated with a particular outcome (dependent) variable; an example would be a study aimed at creating dietary patterns, derived by the RRR, that are associated with the risk of CVD and to investigate their relationship with arterial stiffness, using six biomarkers of CVD as response variables (Lamichhane et al., 2014). Tucker (2010) has reported that this method needs more validation studies and more research to understand the relationship between the derived food patterns and the outcome of interest.

There are some limitations to the empirical methods used to determine overall dietary patterns. Firstly, these methods do not allow comparison with the current national dietary intake guidelines or recommendations. Secondly, the techniques separate people into groups based upon the available food intake data, without necessarily representing ideal eating patterns or eating behaviours. Further, because the approach can mix food items in varying patterns, it makes it difficult to determine a public health recommendation. Also, each study derives varying patterns based on the available data on diet consumption for the study population only, making it difficult to compare patterns between studies (Tucker, 2010).

2.2.2 The theoretical or 'a priori' approach to measuring dietary patterns

The theoretical approach to measuring dietary patterns is also known as the diet quality index or scores approach. It is defined as a measure of the quality of the whole diet as developed by researchers using accepted nutrition recommendations as the basis. The concept aims to assess the quality of an individual's overall eating pattern using a score or index to assess how closely dietary intake aligns with National Dietary Guidelines and/or recommended nutrient intakes (Wirt & Collins, 2009, Kant, 2004). A common use of diet quality indexes is to predict the risk of developing disease (Kant, 1996). The ability of the existing indexes to predict the risk of morbidity and mortality, including for CVD, has been well documented (Wirt & Collins, 2009). For example, the Dietary Approaches to Stop Hypertension (DASH) diet quality index has been shown to be very useful in predicting high blood pressure (Appel, 2003, Salehi-Abargouei et al., 2013). Another use of these indexes or scores is to identify recommendations to guide those who want to improve diet in order to manage weight or achieve a health goal in intervention studies (Grafenauer et al., 2014). Also, diet quality indexes can be a simple and efficient way to provide a broad assessment of the quality of diet (Fransen & Ocké, 2008). This approach is important in epidemiological and public health research because it enables the measurement of overall food intake and allows synthesis of complex dietary patterns against National Dietary Guidelines and recommendations.

The concept of measuring diet quality also has some limitations. It is based on current food and nutrient recommendations which may not necessarily be ideal for the population under study, leading to a reduction in the power of the study to detect the real association of interest (Tucker, 2010). Diet quality indexes in general need to be developed for a specific population and country. While some indexes can be adapted and applied to other populations, researchers need to consider differences in local food supply, eating patterns and differences in dietary recommendations from one country to another (Collins et al., 2015). On the positive side, studies that examine diet quality indexes may lead to new knowledge about the accuracy of the current dietary recommendations, and result in improvements to these in the future. Also, many of the studies on diet quality are based on cohort studies with large numbers of participants (Wirfält et al., 2013).

2.2.2.1 Diet Quality Reviews

Over time, diet quality indexes have received significant research attention and are now commonly used to evaluate overall dietary intake in epidemiological nutrition studies. There are now many reviews detailing the available diet quality indexes (Wirt & Collins, 2009, Waijers et al., 2007, Arvaniti & Panagiotakos, 2008). Most of these reviews have involved adults, with only limited research involving children (Lazarou & Newby, 2011, Marshall et al., 2014).

These reviews help to improve the understanding of the available diet quality index methods, the techniques around how the tools are constructed and validated, and conclusions about their ability to predict health outcomes, morbidity and mortality. In addition, these reviews highlight the differences between the indexes, as some indexes are designed to target dietary patterns associated with risk of specific disease, while others are based on alignment with country specific National Dietary Guidelines or WHO recommended food intakes.

The first attempt at reviewing the available evidence on diet quality indexes was conducted by Kant in 1996 (Kant, 1996). Kant reported that the first tool to define a healthy diet was constructed by Burke during the years 1938 to 1943 (Burke, 1943), and was called the 'Dietary Rating'. This tool compared dietary intakes with the Food and Nutrition Board recommendations for nutrient intakes at that time (Kant, 1996). Kant identified the differences between the diet quality index components and structure, and categorised the approaches used into three main groups: 1) indexes based on food groups only; 2) indexes based on nutrients only; and 3) indexes based on both food and nutrient components (Kant, 1996). There have been other more recent reviews that have summarised the current diet quality indexes or scores across different age groups. Table 2-1 details the reviews of diet quality indexes in adults.

In 2001, two reviews were published on diet quality indexes. One focussed only on studies that evaluated diet quality indexes and cancer risk, in order to try and propose an index useful in predicting the risk of breast cancer in cohort and case-control studies (Gerber, 2001). The objective of the second review was to synthesise the evidence on diet quality and body weight status in observational studies (Togo et al., 2001).

In the second review by (Togo et al., 2001), the authors searched Medline for journal articles published from 1996 to February 2001 and included studies that measured dietary patterns using more than one method, including the diet quality index approach in cross-sectional analyses. However, the review focussed on the indexes or scores based on food, or foods combined with nutrient adequacy, and excluded studies that evaluated the association between diet quality indexes or scores based on nutrient intakes only. This review only included a study if it recruited adults as the majority of study participants. A total of 12 cross-sectional studies, that evaluated the association between diet quality indexes and body weight were included, with the participants' ages ranging from 2 to 91 years of age. Some of the indexes used were the Recommended Food Score (RFS), Healthy Eating Index (HEI), Dietary Diversity Score (DDV), and the Energy-Dense Nutrient-Poor food score (EDNP). Half of the studies (n=6) reported significant inverse associations between diet quality indexes and Body Mass Index (BMI) or obesity prevalence (Togo et al., 2001). These studies assessed dietary patterns using different indexes including the DDV; Fat intake score (FIS); HEI and others. The authors recommended studies needed to apply more sophisticated statistical approaches to examine diet quality and weight (Togo et al., 2001).

In 2004 Kant published a second review, identifying the available indexes at that time. This systematic review aimed to report on studies that assessed dietary intake based on "*a priori*" and "*a posterior*" methods in relation to diet quality or dietary patterns and health outcomes. Medline was searched for this systematic review and included studies published between 1995 and 2004. The review included 32 studies and these were grouped in the following way: 1) dietary variety scores (9 studies); 2) indexes based on nutrients and/or food items (18 studies) and 3) Mediterranean dietary scores (MDS) (5 studies). Within these 32 studies, about 20 basic indexes were used and these included, but were not limited to the Diet Score, the DQI, the HEI, the RFS and various versions of the MDS. Modified versions of these scores were also used, such as the Mediterranean Diet Quality Index (MDQI); the Diet quality Index-Revised (DQI-R); the Healthful Diet Indicator (HDI) and the Food Variety Score (FVS). The overall conclusion was that having a higher diet quality was associated with a lower risk of developing CVD, and lower overall risk of mortality.

Waijers et al. published another review in 2007 (Waijers et al., 2007). This used the PubMed database, and included studies published before 2005. A total of 39 studies, that had used 20 different indexes, were included in the review. These indexes were grouped under four common index types that incorporate both food groups and nutrient intakes: 1) the DQI, 2) HEI, 3) MDS and 4) HDI. However, as this review did not include studies that measured diet quality based on food groups or diet variety only, such as the RFS by Kant and Thompson (1997), it missed an important type of diet quality index. Furthermore, the focus of this review was to critique the methodology and to identify the differences and limitations between the indexes or scores. The index components were discussed in detail with their benefits of use and units of measurement, in order to establish recommendations for composition of a new holistic index. The recommendations for the composition of a new diet quality index from this review were: 1) to include two macronutrients (e.g total fat and carbohydrate or protein) in the index; 2) to consider t*rans* fatty acids as an index component and to include single types of fatty acids, such as Saturated Fatty Acids (SFA), rather than fatty acid ratios; 3) fruit and vegetables should be treated as two separate groups; 4) to consider the benefits and effects of refined products versus whole grain when constructing the diet quality index; 5) the unit of measurement for items included in the index should be considered. The authors of this review describe the cut-off values and scoring methods used in the identified diet quality indexes and whether a point was awarded if the individual's consumption met a specific value, or zero if otherwise. The review also suggested that total energy intake (TEI) be considered when establishing an index, and whether the score is to be adjusted for TEI or not. The authors found that diet quality indexes may be associated with health outcomes (Waijers et al., 2007).

A comprehensive review of diet quality indexes and health outcomes conducted by Wirt and Collins in 2009 aimed to describe the methods of diet quality indexes or scores and their relationship with health outcomes and mortality, and to assess this across a range of study designs. This review identified 25 diet indexes or scores used within 28 studies. The search time frame was 2004-07 and it included studies from the two reviews previously published by Kant in 1996 and 2004. Studies were included if they met the following inclusion criteria: 1) study design: longitudinal/cohort, case-control or cross-sectional studies; 2) adult participants; 3) language: English language only; 4) the exposure: use of any diet quality index (food indexes/scores). Studies were excluded from the review if they met any of the following criteria: 1) not written in English; 2) animal studies; 3) participants were children or included pregnant women; 4) study design was an intervention or Randomized Control Trial (RCT); 5) research was published before 2004 (except papers from either Kant reviews); and 6) dietary patterns were assessed by "a posterior" method from participants consumption data. The indexes or scores outlined in this review included, but were not limited to: the HEI, the Healthy Eating Indicator, the Healthy Food Index (HFI), the RFS, the DQI, the Diet Quality Score (DQS), the MDS and the Food Diversity Score (FDS). The majority of the included studies were cohort studies (n=20) and the remaining were either cross-sectional (n=5) or case-control (n=3) studies. The cohort studies aimed to assess the relationship between indexes and morbidity or mortality, while the cross-sectional analyses were mainly validation studies of the indexes with biomarkers. The case-control studies were established to compare the ability of some diet quality approaches to predict the risk of morbidity and mortality. Overall, higher diet quality was found to be associated with lower risk of overall and specific disease morbidity and mortality including CVD and cancer.

A more recent review was published in 2013, with the objective of developing a fifth version of the Nordic Nutrition Recommendation (NNR) (Wirfält et al., 2013). This review sought to report and summarise the findings of the previous systematic and narrative reviews that compared dietary patterns, including diet quality indexes, with health outcomes. This review by Wirfält and colleagues (Wirfält et al., 2013) concluded that optimal diet quality was associated with lower risk of developing chronic disease and lower mortality in adults. Specifically, dietary intakes high in vegetables, fruits, nuts, whole grain cereals, fish, low fat milk and milk products, and low in nutrient poor and processed foods (such as processed meat, refined cereal and sweetened foods) was associated with higher intakes of nutrients, including minerals, vitamins, beneficial fatty acids, anti-oxidants, phenol compounds and phytoestrogens, as well as with lower risk of morbidity. However, the authors recommended that further high quality studies were needed (Wirfält et al., 2013).

While this section reported most of the reviews that have been done on diet quality indexes or scores, the following section 2.2.2.2 details most of the common instruments used to assess the diet quality. Table 2-2 presents the details of scoring methods and components of some of the existing diet quality indexes or scores.

Table 2-1: Diet Quality Indexes Reviews

	Author and year of publication	Aim and review type	Outcome	Diet quality indexes or scores selected	Search databases	Search period
1	Gerber (2001)	A qualitative review: 1) To capture the studies that estimated the relationship between diet quality indexes and breast cancer prospectively. 2) To propose an index to assess diet and breast cancer risk in case-control and observation studies.	RFS is associated with reduced risk of breast cancer. HEI did not predict cancer risk. Proposed a new index - the M-DQI based on MED and AHA.	Two indexes: • The Recommended Food Score (RFS) • The Healthy Eating Index (HEI)	NA	NA
2	Togo, et al. (2001)	A systematic review: To synthesise the evidence on dietary patterns and body weight in cross-sectional studies.	Inverse association between diet quality indexes (mostly focused on food variety) and weight status.	The indexes were: • RFS • Diet Diversity score (DDS) • Variety of Sweets • Variety of Vegetables • Variety Ratio between Variety of Vegetables and Variety of Sweets • Fat Intake Score • A food score called (Type A Food), that included 8 food groups: pasta, cereal and rice, starchy vegetables, bread, desserts and sank chips and others • A food score called (Type B Food), that included 3 groups such as milk, meat and eggs. • HEI • Energy-Dense and Nutrient-Poor food score (EDNP).	Medline	NA
3	Kant (2004)	A systematic review: To synthesise the existing literature on the relationship between dietary	Mortality and development of CVD were inversely related to diet quality but with a modest effect size.	Included in these indexes: • Food Group Score • Various versions of the Mediterranean Diet Score (MDS) • Diet Score • Diet Quality	Medline	1995 to 2004

		patterns and health outcomes.		• Diet Quality Score (DQS) • Overall and Food Group Diversity • Dietary Approaches to Stop Hypertension Score (DASH) • Alternative Healthy Eating Index (AHEI) • Not Recommended Food Score (NRF) • Dietary Guideline Index (DGI) • Healthy Food index (HFI) • HEI • Healthful Diet Indictor (HDI) • Chinese Diet quality Index (Ch-DQI) • Dietary Variety score for recommended food (DVRS)		
4	Schulze & Hoffmann, (2006)	A Narrative review: To examine relationship between dietary patterns and CVD/ stroke.	Diet indexes can be a useful tool to predict the risk of CVD and stroke.	The indexes included: • HEI • AHEI • RFS • MDS	PubMed	
5	Waijers, et al. (2007)	A narrative review: To review the methods and composition of available diet quality scores in the literature at that time. Also to report the differences and limitations of the scores.	This approach of measuring overall diet did not predict the risk of morbidity or mortality better than single nutrients did.	20 indexes, reported under four main index types: • HEI • Diet Quality Index (DQI) • HDI • MDS However, this review did not include diet quality indexes based on food variety such as Dietary Variety score (DVS) and RFS.	PubMed	To September 2005
6	Arvaniti & Panagiotakos, (2008)	A narrative review: To critique and review the common diet quality indexes.	The growing interest of diet quality indexes and its association with health outcomes is important and essential.	23 indexes included: • HEI and the Canadian version of the HEI(C-HEI) • AHEI • DQI and the revised version of the DQI (DQI-R) • Diet Quality Index-International (DQI-I) • DVS • The Naturally Nutrient Rich Score (NNRS) • DVSR • The Food Variety Score (FVS) and the Dietary Diversity score (DDS) • RFS • HFI	NA	NA

				• HDI • DGI • Various versions of the MDS including but not limited to the Mediterranean Diet Quality Index (MDQI).		
7	Fransen & Ocke, (2008)	A narrative review To synthesise the evidence on the association between diet quality and biomarkers or nutrient adequacy.	The interest in proposing and using a variety of diet quality indexes is growing around the world, mainly in Australia and Europe, not just the USA. Diet quality indexes have been shown to be a good measure for nutrient adequacy especially for a-carotene, b-carotene, vitamin C, vitamin B6, Ca, folic acid, Fe and Mg.	Many new indexes identified such as: • Australian version of the HEI (Au-HEI) • Australian version of the DGI (Au-DGI) • French National Nutrition and Health Program Score • DQI in Denmark. • The Recommended Compliances Index based on Healthy Eating from the WHO. **Some other indexes proposed to prevent disease such as** • DASH score • Heart Disease Prevention Eating Index **And there are indexes based on food variety:** • such as DVS	NA	NA
9	Buckland, et al. (2008)	A systematic review: To synthesise the available evidence on the association between MED and obesity in RCT and cohort studies.	The evidence was inconsistent but the majority of the studies (n=13 studies) suggest that the MES plays a significant role in reducing the risk of overweight and obesity. Also, studies should use clear definitions of MED.	Versions of the MDS selected in 3 cohort, 7 cross-sectional and 11 intervention studies and classified in to three groups based on: • Score contains two groups of positive or negative components • Score standardized components • Score contains a ratio of components	A search done in both English and Spanish language in MEDLINE; NCBI, Bethesda, MD, USA.	NA
10	Roman-Vinas, et al. (2009)	A systematic review: To select the studies and indexes used to validate the index with the intake of adequate nutrients in adults.	Diet quality indexes are valid instruments to evaluate intake adequacy for certain micronutrients. The correlation between nutrients with the indexes varies depending on the index that is used.	Only four indexes used: • DQI-R • Food Variety Score (FVS) • DDS • HEI	PubMed	up to April 2008
11	Wirt & Collins, (2009)	A review: To identify the available diet quality indexes at the time and assess their correlation with health outcomes. Also to	Diet quality predicts the risk of morbidity and mortality, especially CVD.	25 indexes including but not limited to: • HEI • AHEI • DQI and DQI-R • Various version of MDS • DGI	Medline, Cochrane, EMBASE, ProQuest, CINAHL and Scopus to select the studies included in Kant reviews in 2004	2004 to 2007 and included studies identified by reviews done by

		report the indexes methodology and to assess the study designs.		• HDI • DQS • Healthy Food and Nutrients Index (HFNI) • RFS • NRFS		Kant 1996 and 2004.
12	Edefonti, et al. (2009)	A qualitative review: To review the evidence on dietary patterns and breast cancer	There is need to ongoing research in diet quality and breast cancer, using valid indexes and good study design.	Four studies, used the following indexes: • RFS • HEI • AHEI • Alternative Mediterranean Diet Score (aMDS) • DQI-R • C-HEI • First Course Diversity • Second Courses Diversity • Vegetables Diversity • Desert Diversity.	PubMed	Up to April 2008
13	Kant (2010)	A narrative review: To synthesise the evidence that examined dietary patterns and nutrition quality, morbidity and mortality.	The prospective studies found that the healthiest dietary patterns can be predictors of lower risk of all cause of death and CVD but inconsistent in cancer.	Six main indexes identified including: • DQI • RFS • NRFS • MES and some versions • Recommended Food and Behaviour Score (RFBS) • Dietary Behaviour Score (DBS)	PubMed For morbidity and mortality, only the cohort studies with at least 5000 participants and follow-up 4 yrs or more and disease-free. Also only RCTs with the same minimum follow-up as above were included	From 2003 to 2009
14	Sofia, et al. (2010)	A systematic review: To update a previous review and meta-analysis that included studies testing the relationship between MDS and health outcomes in cohort studies.	Higher MDS was associated with a significant reduction of overall mortality, CVD, cancer incidence and neurodegenerative diseases and mortality of CVD and cancer.	10 additional studies than the previous review, which identified various versions of the MDS only.	MEDLINE (from 1966 to June 2010), EMBASE (1980 to June 2010, Web of Science, The Cochrane Library (2010) and Google Scholar.	Up to 2010
15	Miller, et al. (2010)	A narrative review: To synthesise the data for studies that examined the association between diet quality scores or	It appears that the risk of colorectal cancer can be affected or prevented by a diet high in plant food (e.g. vegetables and fruit), low in processed food (e.g.	Six indexes included: • RFS • The USA Department of Agriculture Food Guide Recommendations (USA DA FG) • DASH	Cochrane, PubMEd, Web of science. The inclusion criteria were: Dietary patterns including but not limited to diet quality indexes.	Up to January 2009

		indexes based on food, and the risk of colorectal cancer in case-control or cohort studies only.	processed meat), and low in animal fat.	• HEI-2005 • AHEI • MDS	Colorectal cancer. Any publication date.	
16	Randi, et al. (2010)	A narrative review: To synthesise the data from studies on the risk of colorectal cancer effected by dietary patterns in epidemiology studies.	Higher diet quality score measured by the RFS, MED and HEI-2005 was associated with lower risk of colorectal cancer, while DRS and LSS were associated with greater risk.	11 indexes including: • HEI-2005 • MED • RFS • Dietary Risk Score (DRS) • Total Diversity • Life summary score (LSS) • Adult life diet risk score (ALDRS) • The USA Food Guide pyramid score • DASH • AHEI • Oxidative balance Score (OBS)	PubMed	Up to July 2009
17	Hsiao, et al. (2011)	A narrative review: To select the studies that tested the relationship between diet indexes and body weight in adults aged 60 or younger.	Results were inconsistent.	Diet quality indexes identified from four cross-sectional studies that included: • MES • DQR • Healthy Diet Score (HDS)	Pub-Med of the USA National Library of Medicine.	Up to November 2010
18	Barbresko, et al. (2013)	A systematic review: To identify studies that examined diet quality indexes and inflammation biomarkers.	The results were inconsistent but the intervention studies support that the MES can be a good predictor for lower inflammation.	8 main indexes included from 17 intervention and cross-sectional studies. These indexes are: • MED and its variations • HEI • AHEI • RFS • DQI and DQI-R • Comprehensive Healthy Dietary pattern with 47 food groups • Simplified Healthy Dietary patters (HDP) with 6 food groups • Dietary diversity scores for recommended foods (DDS-R).	Pub-Med, Web of Science and EMBASE	January 2000 to January 2012.

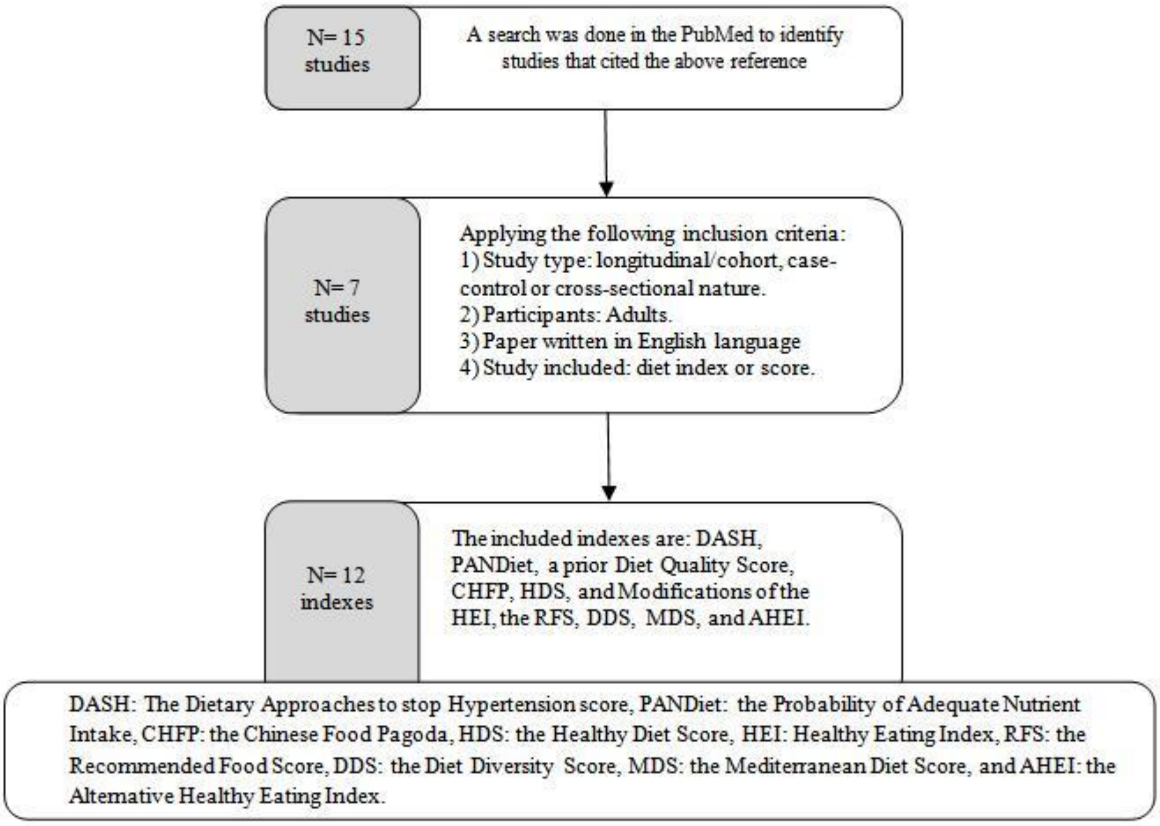
2.2.2.2 Diet quality indexes

Table 2-2 is a summary of most of the existing diet quality indexes. I have adapted Table 1 from the Wirt and Collins review (2009). A search was conducted in PubMed to identify studies that cited the review by Wirt and Collins, in order to update the table. Fifteen studies were found that cited the review. The same inclusion criteria used by Wirt and Collins were used to identify studies for this update. These included: 1) studies that were longitudinal, case control, or cross sectional; 2) participants were adults and 3) the dependent variable was any diet quality index or score. From these 15 studies, only seven studies met the inclusion criteria with 13 indexes added to Table 2-2. Figure 2-1 shows the selection process for studies. The additional indexes include: DASH, Probability of Adequate Nutrient Intake (PANDiet), a prior Diet Quality Score, Chinese Food Pagoda (CHFP), Healthy Diet Score (HDS), Modifications of the HEI, the RFS, Diet Diversity Score (DDS), MDS, and Alternative Healthy Eating Index.

Collectively, from the reviews tabulated (Table 2-1) and (Table 2-2), it can be seen that there is strong and growing interest in applying diet quality indexes for measuring overall dietary patterns and for assessing the quality of food consumed by individuals in public health and epidemiological research, with limited use in intervention studies (Petrogianni et al., 2013). Although the interest in composing diet quality indexes initially started in the USA, considerable work has now been done in other industrialised countries, including Europe (McNaughton et al., 2012), Canada (Fitzgerald et al., 2002) and Australia (Collins et al., 2008, McNaughton et al., 2008). However, there are a very limited numbers of papers published from developing countries such as Iran (Asghari et al., 2012) and China (Asghari et al., 2012). Most of these studies recruited adults or the elderly, with very limited studies conducted in pregnant women (Fransen & Ocké, 2008) or children (Marshall et al., 2014).

The currently available diet quality indexes do vary in many aspects. The greatest differences surround the basis or components of the indexes. Some contain only food items, such as the RFS (Collins et al., 2008, Collins et al., 2011, Kant & Thompson, 1997), which contains foods or food groups including fruit, vegetables, whole grains, lean meat or alternatives, and low fat dairy. Other indexes include components that focus on nutrients only, such as the DQI, which was developed for Canadian populations (Fitzgerald et al., 2002) and is composed of 17 nutrient items including macronutrients and micronutrients such as vitamin A.

Figure 2-1: The methods of selection for diet indexes to update the table of diet quality indexes described in Wirt & Collins (2009)



Some other indexes contain combinations of both food and nutrient components, such as the HEI, which contains ten components, including: variety in the diet, four nutrients (total fat; SFA; cholesterol; and sodium) and five food groups (grain; vegetables; fruit; meat; and milk) (Hann et al., 2001). There are also some indexes that use a ratio between variables, such as the Alternative Healthy Eating Index (AHEI) used by McCullough (McCullough et al., 2002). It contains the ratio of white to red meat, and the ratio between Polyunsaturated Fatty Acids (PUFA) and Saturated Fatty Acids (SFA). Still other indexes include non-diet components such as physical activity in the index, for example the 15-point French Programme National Nutrition Santé-Guideline score (15-point PNNS-GS) used by Assmann, et al., (2014).

While the currently available diet quality indexes do vary, they are quite similar in some aspects. For example, there are some common components across the existing diet quality indexes, including but not limited to total fat, SFA, alcohol, fruit and vegetables, dairy, cereal or whole-grains (Waijers et al., 2007). However, these components are often measured differently across the indexes. For example, micronutrients are measured as milligrams or micrograms, or as the percentage of the available recommendation, or target dietary allowances. For instance the DQS (Fitzgerald et al., 2002) contains 17 nutrients including vitamin C which is measured in milligrams, while an index called Dietary Quality (Murphy et al., 1996) that contains eight nutrients including vitamin C, measures it as the percentage of Recommended Dietary allowance (RDA). In some indexes fruit and vegetables are expressed in grams (Waijers et al., 2007), while in other indexes such as the DQI-R (Fung et al., 2006) it is by servings per week or per day.

Differences between the diet quality scores also exist in terms of the cut-off values and scoring methods applied. For example, the Mediterranean Diet Patterns (MDP) score uses the median for component intakes by gender as a base, and then allocates one point if the individual consumption for the positive (or negative) component was greater (or lower) than the median, and zero if it was otherwise. In other indexes, such as the HEI by Hann et al. (2001) researchers assign proportional values based on criteria consistent with the National Dietary Guidelines or the recommendations for adequate nutrient intakes for their population of interest. For the HEI, the highest score is 10 points per component, and this indicates optimal adherence with the recommendations, while a score of zero indicates complete non-adherence with each component and therefore the poorest dietary intake. If the person of interest consumed 100% of the recommendation for fruit, they would achieve 10 points for this component, which is the highest score. Proportional points between 10 and zero are applied for those who consume less than the recommendation. For example, a person who consumed 30% of the recommended amount for fruit would score 3 points for the fruit.

Another scoring method, which is dichotomous, assigns participants one point if consumption is consistent with criteria values provided by the researchers from the appropriate national recommendations, or zero if consumption is otherwise. This method is used in the RFS (Collins et al., 2008) and the DQS (Fitzgerald et al., 2002). Some indexes, such as the Framingham Nutritional Risk Score (FNRS) (Kimokoti et al., 2010), and an index called 'a priori diet quality score' (Oude Griep et al., 2013) rank participants into groups (quintiles) according to their consumption of different component parts, and each participant is assigned a positive or negative mark for each index item. More specifically, the a priori diet quality score included three groups with different numbers of components. These groups are as follows: 1) the beneficial group that contains 20 items including fruit, vegetable, fish, low fat diary green vegetables and others; 2) the adverse group that contains 13 items such as butter fried foods, fried potatoes, grains, dessert, organ meat and others; and 3) the neutral group, that included 13 items such as fruit juice, lean red meat, eggs and others. The 20 items among the beneficial food group give a score of 0 points (lower quintile) up to 4 points (top quintile), while for the adverse group scored 4 points (lower quintile) to zero points (top quintile), and for those who were non-consumers and for the neutral foods they were scored as zero points. All the points are then summed, which gives 132 points as a maximum for this index, indicating the healthiest diet intake. The highest scores in most of the indexes such the RFS or HEI indicate greater compliance with the recommendations, while a few such as the DQI (Gerber et al., 2000) adapted for Mediterranean populations is a reverse score. That is, those with zero points consumed the healthiest diet.

One very significant factor in the scoring of diet quality indexes is the weighting of each component within the overall index score. For many indexes, such as the HEI, investigators have used equal weightings (10 points) for each component, while in a few indexes (e.g. the CHFP) (Yu et al., 2014) varying weights have been applied to each component. The CHFP contains 10 components and the scores range from zero (worst diet) to 45 (healthiest diet) points. Each component is scored from five, four or three points down to zero according to recommended values. More specifically, five points (top score) are given to those who comply with the recommendation for the following components (grains, vegetables, fruit, dairy, fats and oils, beans and salt). Four points is the maximum for the meat and poultry component and three points for the eggs, fish and shrimp components. A score of zero applies to those who did not meet criteria values at all, and an intermediate intake scores proportionally.

Since the interest in using the concept of diet quality in public health and epidemiology research has increased significantly in the last decade, it has led to some researchers proposing an index that can be used internationally. The Diet Quality Index-International (DQI-I) is an example of such a score. The methodology of this score is presented in the next section.

2.2.2.2.1 The Diet Quality Index-International (DQI-I)

The DQI-I is composed of four main components with different numbers of items within each. These are: 1) diet variety (scored 0 to 20 points); 2) adequacy of intake of three food groups (vegetables, fruits, and grains) and five nutrients (protein, fibre, iron, calcium and vitamin C) (scored 0-40 points in total); 3) moderation of intake for four nutrients (total fat, SFA, cholesterol and sodium) and for empty energy/nutrient-poor foods (scored from 30 down to zero points); and 4) overall balance (0-10 points in total). The concept of empty energy/nutrient-poor foods in the third component of this index is defined by the following equation: (level of a nutrient in a specific amount of the food/recommended amount of the nutrient) ÷ (Energy content of the same amount of the food/ recommended TEI for the person). The value for each nutrient, for example vitamin C, is calculated separately. If the value for this particular nutrient, such as vitamin C, is greater than one, the food item is considered as a nutrient-dense food. While if the value for a food item is less than 1, then the food item is defined as nutrient-poor food. The fourth component of the DQI-I is overall balance (0-10 points in total) which is determined by two components including 1) the ratio of TEI from carbohydrate: protein: fat, which is scored from 0 to 6 points, and 2) the ratio of fatty acids (PUFA): Monounsaturated fatty acids (MUFA) : SFA, scored from 0 to 4 points. The DQI-I total score has a range from zero to a maximum of 100 points (Kim et al., 2003).

The DQI-I is the only diet quality score developed specifically to enable international comparisons. Other examples of some of the common diet quality indexes, that are used within specific countries and have been developed to reflect adherence to their own specific national dietary guidelines are listed and described briefly below. These include the DQI, HEI, AHEI, MDS and RFS. Under each score I have reported most of the common modified versions.

Table 2-2: An updated of review by Wirt and Collins (2009) on diet quality indexes and health outcome

Studies that have used the diet quality tools of interest	Dietary method	Index	Objective	Components of the score	Scoring method
A) Indexes based on food and nutrient components					
1)The Healthy Eating Index (HEI)					
1)Hann, et al. (2001) Weinstein, et al. (2004) Fung, et al. (2006) 2) McCullough, et al. (2000a) McCullough, et al. (2000b)	24hr recall, 2 day food record 2) FFQ	1) Healthy Eating Index (HEI)	Single, summary measure of diet quality based on nutrients and foods. Assesses adherence to USA Food Guide Pyramid and Dietary Guidelines for Americans	10 items: 1) Grain (serve/d). 2) Vegetables (serve/d). 3) Fruit (serve/d). 4) Meat (serve/d). 5) Milk (serve/d). 6) Total fat (%TEI). 7) Saturated fat (%TEI). 8) Cholesterol (mg/d). 9) Sodium (mg/d). 10) Variety in diet (variety of foods /3d).	Each item contributes 0-10 points. Score range 0 (worst) to 100 (best). A person scores 10 points (top points) if meet the 100% of the recommendation of that particular item, and zero points if a person did not consume it. The scoring ranks consumption between highest and lowest proportionally, based on % consumption. For example if a person consumed 30% of the recommendations, the person will score 3 points. The scoring cut-off points are based on different values depending on the specific age and sex recommendations. Variety in diet scores 10 points if consume certain numbers of foods during 3 days ($\geq$ 24, < 9 food items), and each item should be consumed at least ½ serve.
Griep, et al. (2013) Lavoie, et al. (2013)	3-day food records	2) Healthy Eating Index adapted for Canadian population (C-HEI)	The 1997 Canada's Food Guide for Healthy Eating and Dietary Guidelines.	9 items: 1) Grains (serve/d). 2) Vegetables and fruit (serve/d). 3) Dairy (serve/d). 4) Meat and alternatives (serve/d). 5) Total fat (%TEI). 6) Saturated fat (%TEI). 7) Cholesterol (mg/d). 8) Sodium (mg/d). 9) Diet variety (serve/d).	Each item scored (zero to 10) points, except vegetables and fruit, scored 0 to 20 points. Top score is 100 = the healthiest diet intake; zero = poorest diet. The scoring cut-off points are based on age & sex recommendations. Diet variety scores the top points (10) if consume at least $\geq$ a total of 4 serving of four food groups (grain, dairy, meat, and fruit and vegetables).
2) Alternative Healthy Eating Index (AHEI)					
McCullough, et al. (2002) Fung, et al. (2006)	FFQ (~130 item)	1) Alternative Healthy Eating Index (AHEI)	Assesses whether AHEI predicts disease risk better than HEI. In contrast to HEI it acknowledges benefits of unsaturated oils, distinguishes quality within food groups, and excludes	9 components: 1) Vegetables (serve/d). 2) Fruit (serve/d). 3) Nuts and soy protein (serve/d). 4) Ratio of white to red meat. 5) Cereal fibre (g/d).	AHEI range is: 2.5 to 87.5 points; 8components have possible scores (0-10) points where 10 is the healthiest and zero the worst. Consumption in between is scored proportionally. The final component is scored as either 2.5 points for non-users of multivitamins or 7.5 for multivitamin users

			potato/ potato products.	6) Trans fat (%TEI). 7) Ratio of polyunsaturated fat to saturated fat. 8) Duration of multivitamin use. 9) Alcohol (drink/d)	
Yu, et al. (2014)	2 Semi-quantitative FFQs used with 81 and77 items.	2)AHEI (adapted for Chinese populations)	It based on the AHEI-2010	8 items: 1) Vegetables (serve/d). 2) Fruit (serve/d). 3) Nuts and legumes (serve/d). 4) Red/processed meat (serve/d). 5) EPA and DHA (mg/d). 6) PUFA (%TEI). 7) Sodium. 8) Alcohol (drinks/d).	AHEI-2010 total score is 80. It was adjusted for TEI, using density method and standardized to 2,000 kcal. The scoring ranks consumption between highest and lowest consumption proportionally. The highest score (10) is awarded for meeting 100% of the recommendations and zero for no consumption. For red/processed meat (serves/d) if consumption is ≥ 1.5 (serves/day) the score is zero and 10 points are given for non-consumers. Sodium intake is ranked into deciles and those in the lowest group get the highest score (10), and those in the lowset group get zero.
3) Healthy Diet Indictor (HDI)					
Huijbregts, et al. (1997) Huijbregts, et al. (1998) Knoops, et al. (2006)	Diet history	1) Healthy Diet Indicator (HDI)	Based on WHO dietary recommendations for preventing chronic disease.	9 items: 1) Saturated fat (%TEI). 2) Polyunsaturated fat (%TEI). 3) Protein (%TEI). 4) Complex carbohydrates (%TEI). 5) Dietary fibre (g/d). 6) Legumes/nuts and seeds (g/d). 7) Fruit and vegetables (g/d). 8) Mono- & disaccharides (%TEI). 9) Cholesterol (mg/d).	Each component scored either one or zero points, with 1 indicating being within recommendations and 0 being outside recommendations. HDI = sum of variables with range from 0-9 (9 as healthiest value).
4) Healthy Diet Score (HDS)					
McNaugton, et al. (2012)	4-day weighed food record	1)Healthy Diet Score for British population	Developed from the Healthy Diet Indicator developed by Huijbregts (1997) (1997) and the British dietary recommendations.	12 items: 1) Saturated fat (%TEI). 2) Polyunsaturated fat (%TEI). 3) Protein (%TEI). 4) Total carbohydrate (%TEI). 5) Fibre (g/d). 6) Fruit and vegetables (g/d). 7) Pulses and nuts (g/d). 8) Total non-milk extrinsic sugar (%TEI).	Index score range from zero to 12 points. 12 indicates the healthiest diet. Each item scored zero (if exceed or < recommendations) and 1 point if met the recommendations.

				9) Cholesterol intake (mg/d). 10) Fish (g/d). 11) Red meat and products (g/d). 12) Calcium (mg/d).	
5) Healthy Food and Nutrients Index (HFNI)					
Bazelmans, et al. (2006)	One day food record	1)Healthy Food and Nutrient Index (HFNI)	Based on dietary guidelines issued by the National Nutrition Council Belgium.	9 items: 1) Saturated fat (%TEI). 2) Monounsaturated fat (%TEI). 3) Polyunsaturated fat (%TEI). 4) Protein (%TEI). 5) Fibre (g/d). 6) Carbohydrates (%TEI). 7) Cholesterol (mg/d). 8) Fruit and vegetables (serve/d). 9) Beta-Carotene (quartiles).	8 items based on dietary guidelines, with the 9^{th} item as Beta-carotene expressed in quartiles. Each item scores 1 point for consumption within recommendations and zero if otherwise. Score range 0-9, with higher score indicating adherence to recommendations.
6) Diet quality index (DQI) and Diet quality index-Revised (DQI-R)					
Seymour, et al. (2003)	24 hr recall and 2 day food record	1) Diet Quality Index (DQI)	Measures quality of diet that can reflect the risk of diet related chronic disease. Based on the National Research Council Diet and Health recommendations.	8 items: 1) Total fat (%TEI). 2) Saturated fat (%TEI). 3) Cholesterol (mg/d). 4) Protein (%RDI). 5) Calcium (%DRI) 6) Sodium (mg/d). 7) Vegetables and fruit (serve/d). 8) Grains (serve/d).	Each items scores either 0 (meets recommendation), 1 (recommendation almost met), or 2 (recommendation not met). Maximums DQI is0-16 points with 0 indicates healthiest diet.
Fung, et al. (2006) Newby, et al. (2003a)	24 hr recall FFQ (131 items)	2) DQI-Revised (DQI-R)	DQI revised designed to reflect current dietary guidelines, incorporating dietary moderation and variety, and improved methods of estimating food serves.	10 items: 1) Grains (serve/d). 2) Vegetables (serve/d). 3) Fruits (serve/d). 4) Total fat (% TEI). 5) Saturated fat (% TEI). 6) Cholesterol (mg/d). 7) Iron (%DRI). 8) Calcium (%DRI). 9) Diet diversity. 10) Diet moderation.	Each item scored from 0 to 10 points, with a maximum score of 100. In contrast to DQI, higher scores indicate adherence to dietary guidance. Fruit and vegetables are separated according to Pyramid recommendations; includes iron intake; excludes protein intake; and scores dietary moderation and diversity. Moderation component includes added sugar, discretionary fat, sodium, and alcohol. Diet diversity contains 4 main food groups (1) grains, 2) vegetables, 3) fruit, 4) meat and dairy), each of these groups contains various numbers of items. Grains, vegetables, meat and dairy with 7items for each, while fruit has 3 items. Each item scored 1 point if ≥ ¼ of daily serve consumed and

					zero points if not. All points are summed across item and divided by total number of item in that group, then multiplied by 2.5. The top score is 2.5 points for each group with a total of 10 points for all the 4 groups. Then 10 points are assigned for diet diversity if total points for all 4 groups ≥ 6, and 5 points if ≥ 3 and <6, and zero if <3. Diet moderation items are added sugar, discretionary fat, sodium, and alcohol. Each gets a top score of 2.5 points, with 10 points awarded if total points from the previous items are ≥ 7, five points for ≥4 and <7, and zero if <4.
Gerber, et al. (2000)	FFQ (162 items)	3) DQI	Measures quality of diet in a Mediterranean population	7 items: 1) Total fat (%TEI). 2) Saturated fat (%TEI). 3) Cholesterol (mg/d). 4) Olive oil (ml/d). 5) Fish (g/d). 6) Cereals (g/d). 7) Vegetables and Fruit (g/d).	Similar to original DQI but modified for Mediterranean population by including olive oil and fish instead of protein group and omitting calcium and sodium intake. Each item scores either a zero (meets recommendation), 1 point (recommendation almost met), or 2 point (recommendation not met). Score range is 0-14; a score of 0 indicates an excellent diet.
7) Dietary Approaches to stop hypertension score (DASH) score					
Yu, et al. (2014)	2 Semi-quantitative FFQs used with 81 and77 items.	1) Dietary Approaches to stop hypertension score (DASH) score	Adopted the DASH.	7 components: 1) Vegetables (g/d). 2) Fruits (g/d). 3) Dairy (g/d). 4) Meat, poultry, fish and eggs (g/week). 5) Nuts, legumes and seed (g/week). 6) Fat and oil (g/d). 7) Sodium intake (mg/d).	Each component weighted equally and contributes 10 points as the top score with a total score of 70. The highest score means the healthiest diet. Adjusted for TEI, using density method and standardized to 2,000 kcal.
8) Dietary Guidelines Index (DGI)					
Harnack, et al. (2002)	FFQ (127 item).	1)Dietary Guidelines Index (DGI)	Measures compliance with 5th edition of Dietary Guidelines for Americans.	9 items: 1) Aim for healthy body weight. 2) Be active every day. 3) Build healthy base. 4) Chose variety of grains. 5) Chose variety of fruit and vegetables. 6) Chose diet sensibly. 7) Moderate sodium intake. 8) Moderate sugar intake.	Each item scored from zero to a maximum of 2 points, with a range of 0-18 points. 18 indicates full compliance with guidelines and 0 being non-compliant. Includes non-diet related recommendations, e.g. Aim for healthy body weight: those with BMI< 25 kg/m^2 receive two points, and those overweight (BMI 25 to 29.9) get one point and zero for obese (BMI ≥30kg/m^2). Build healthy base: using Food Guide Pyramid

				9) Moderate alcohol drink.	serve recommendations for grains, vegetables, fruit, milk and meat. The maximum point of 0.4 points is awarded for meeting the recommended serves/d for each group. Chose diet sensibly: contains scoring for total fat, saturated fat, cholesterol intake, moderate sugar and sodium intakes. Moderate alcohol intake scored according to specific criteria.
B) Diet quality indexes or scores based on food					
1) The Diet quality Score (DQS)					
Toft, et al. (2006)	FFQ (48 item validated by a 198 item)	1)Diet Quality Score (DQS)	A crude index of overall quality of diet based on previous indexes of overall diet quality, as well as Danish Dietary Guidelines (minimum 600g vegetables/fruit each day, minimum 200g fish per week, and low fat intake (total fat- <30% TEI, saturated fat- <10% TEI).	4 items: 1) Vegetables (serve/d). 2) Fruit (serve/d). 3) Fish (g/d). 4) Fat (the use).	This DQS has score range from zero to 12. The highest score indicates the healthiest diet. Each item has a score range from zero to 3 points.
2) The Programme National Nutrition Santé Guideline Score (PNNS-GS)					
Assmann, et al.(2014)	One 24h dietary record with validated photographs of > 250 foods shown in three different portion sizes.	1)The Programme National Nutrition Santé Guideline Score (PNNS-GS)	French Food serving recommendations, French recommended dietary allowances and Recommendations of the Programme National Nutrition Santé.	13 items: 1) Fruit and vegetables (serve/d). 2) Bread, cereal, potatoes and legumes (serve/d). 3) Whole grain food (serve/d). 4) Milk and dairy products (serve/d). 5) Meat, poultry seafood and eggs (serve/d). 6) Seafood (serve/week). 7) Added fat. 8) Vegetables added fat (the use). 9) Sweetened foods (%TEI). 10) Beverages non-alcoholic (ml/d). 11) Alcohol (drinks/d). 12) Salt (g/d). 13) Physical activity (at least 30 min of brisk walking/d).	Each item scores one if met the recommendation or zero if not, except three items. These are 1) Fruit and vegetables, with two points as the maximum, 2) salt and 3) physical activity with 1.5 points as top score. This index has a score range from 0 to 15 points, with 15 indicating the healthiest diet.
3) Healthy Food Index (HFI)					

Osler, at el. (2001) Osler et al. 2002(2002)	FFQ (28 items)	1) Health Food Index (HFI)	Based on previous diet quality indexes and recommendations for a healthy diet (Kant 1996). Assesses whether food intake patterns defined *a priori* on basis of food recommendations and *a posterior* by factor analysis, using mortality as the outcome.	4 items: 1) Margarine, butter or lard (use/d). 2) Boiled or raw vegetables (serve/d). 3) Coarse rye or white bread (serve/d). 4) Fruit (serve/d).	This index has a score range from 0 to 4 points. The maximum four points indicates better diet quality. Each of the HFI items receive 1 point if meet the recommendation and zero if otherwise.
4) Recommended Food Score (RFS)					
Kant, et al. (2000) McCullough, et al. (2002) Mai, et al. (2005)	FFQ	1)Recommended Food Score (RFS)	Based on consumption of foods recommended in USA dietary guidance.	23 core food items included under these sub-scales: Fruit/ Vegetables/ Whole grains/ Lean meat or alternate/ Low fat dairy. For all food items the cut-off was one point if ≥1serve/week.	The RFS has a score range from zero to 23. Each food item included has a possible score of one if consumed at least once/week, or zero if not consumed. The score of 1 means meeting the recommendation.
Michels and Wolk, (2002) Fung, et al. (2006)	FFQ	2)Recommended Food Score (RFS)	Based on 'healthy' foods (consumption of foods from the FFQ list consistent with the American national dietary guidelines).	17 items included under these sub-scales: Fruit/ Vegetables/ Fish/Low fat dairy. For all food items the cut-off was ≥ one serve/week.	Foods consumed 1-3 times a month score 1 point (maximum of 17). Score range 0-17 with 17 being the best score. Differs slightly from previous RFS with poultry, potato and juices excluded.
McNaughton, et al. (2012)	4-day weighed food record	3)The RFS British population and the RFS-Median	Adapted from the USA RFS by Kant for use with 24-h recall data -RFS scoring method adapted from the MDS.	29 items with the following sub-scales: Wholemeal bread and grains (3 items)/ Semi or skim milk (2 items)/ Protein e.g. chicken or turkey (4 items)/ Vegetables (11 items)/ Fruit (6 items) / Nuts and seeds (1item)/ Drinks (2 items). All food and drinks measured by g/d.	The 24-h recall data was used to score intakes if they consumed specific items that comprise this index: One point (maximum) is scored if consume >15g or >30g for the non-beverages and beverages respectively daily, otherwise scored zero points. For the RFS-Median, sex-specific median of the items intake was used to assess the participants and one point awarded for those who consume more than the median, otherwise score zero points.
Collins, et al. (2011)	FFQ-	4) The Aus-RFS (ARFS) by Collins.	Modelled on the USA RFS by Kant.	7 sub-scales containing a total of 74 items. The subscales are: 1) Vegetables (serve/week). 2) Fruit (serve/week). 3) Protein (serve/week). 4) Grain (serve/week). 5) Dairy (ml/d). 6) Fat (use).	ARFS score range from 0-74. One point awarded for each item reported as being consumed at least once a week. The maximum ARFS score is 74, meaning the healthiest diet.

				7) Alcohol (drinks/d).	
5)Not Recommended Food Score (NRFS)					
Michels and Wolk, (2002)	FFQ	1)Not Recommended Food Score (NRFS)	Based on 'unhealthy' foods (consumption of foods not recommended by current dietary guidance).	This included some 'unhealthy' foods items such as: 1) Processed meat and products such as bacon, sausage, liver. 2) Chips. 3) Butter. 4) Cheese high in saturated fat. 5) White bread.	Foods consumed 1-3 times a month score 1 point (maximum of 21). Score range 0-21 with 21 best.
6)Total and specific food group diversity					
Fernandez, et al. (1996) Fernandez, et al. (2000)	FFQ (29 item) FFQ (79 item)	1)Total and specific food group diversity	Assesses variety of food intake.	5 food groups with different items: 1) Vegetables group including: potatoes, cabbages and Cruciferous veg. (serve/week). 2) Fruit group including: apples, citrus fruits (serve/week). 3) Meat and fish group including: beef and veal (serve/week). 4) Carbohydrate group including: pasta or rice, bread (serve/week). 5) Other group including: cheese, milk, and eggs (serve/week).	Based on total number of foods consumed at least once a week. Diversity score among the 5 food groups includes: 1) dairy; 2) bread and cereals; 3) meat; 4) vegetables; 5) fruit. Quartiles of "total diversity and specific food group diversity", formed based on distribution of controls including age and sex. Highest quartile indicates more diversity in the diet.
Slattery, et al. (1997)	Diet history	2)Total and specific food group diversity, and diet composition	Assesses variety of food intake and composition of diet (proportion of food categories).	6 groups: 1) Meat, fish, poultry, eggs. 2) Fruits. 3) Vegetables. 4) Whole grains. 5) Refined grains. 6) Dairy foods.	Diet diversity defined by number of unique foods reported in past year, in addition to diversity within six food groups. Composition defined by estimated proportion of total food items reported in each food group, as well as ratio of plant to animal products. Gender specific quintiles were produced for diet diversity and composition in the control group. Did not specify calculation of score.
7) Dietary Diversity Score (DDS)					
Bezerra and Sichieri, (2011)	List of 27 food items.	1)Dietary diversity score (DDS)	It assesses the purchase of a variety healthful food in Brazil.	23 "healthy" food items only, including but not limited to: potatoes, carrots and pumpkin, manioc and other roots and tubers, coconuts, nuts, tomatoes, lettuce, other vegetables, bananas, oranges.	If these are purchased they will score one if not then zero points applied. This DDS has range score from zero to 23.
8) a *priori* diet quality score					
Oude Griep, (2013)	Diet history.	1) a priori diet	a *priori* diet quality score	3 groups that contain different numbers	It is scored based on ranking each participant after

Myer, et al. (2013)		quality score	based on health effects hypothesis.	of components. 1) Beneficial groups includes (n=20) fruit, vegetables, fish, low fat dairy, green vegetables and other. 2) Adverse (n=13) for example butter fried foods, fried potatoes, grain dessert, organ meat and other. 3) Neutral (n=13) such as fruit juice, lean red meat, eggs and other.	classifying them into quintiles. 20 beneficial food group items, a score 0 to 4, with 4 to zero points for the adverse group. Non-consumers awarded zero points. A maximum of 132 points, indicates the healthiest diet intake
7) Chinese Food Pagoda (CHFP)					
Yu, et al. (2014)	2 Semi-quantitative FFQs used with 81 and77 items.	1)Chinese Food Pagoda CHFP	Based on the recommendations in the Food Pagoda and an adaptation of the USA HEI 2005.	10 components: 1) Grains (g/d). 2) Vegetables (g/d). 3) Fruits (g/d). 4) Dairy (g/d). 5) Beans (g/d). 6) Meat and poultry (g/d). 7) Fats and oils (g/d). 8) Salt (g/d). 9) Eggs (g/d) 10) Fish and shrimp (g/d).	Each component scored from five down to zero points, except 1) fish and shrimp and 2) eggs (each score 3 down to zero), and meat and poultry (score 4 to zero). The highest score complying with recommendations and lowest not meeting recommendations. The intermediate intake scored proportionally. The CHFP score range is from zero to 45 points, adjusted for TEI, using the density method and standardized to 2,000 kcal.
C)Diet quality indexes or scores based on nutrients only					
1) Diet quality Score (DQS)					
Fitzgerald, et al. (2002)	24 hr recall	1)Diet Quality Score (DQS))	Uses estimated average requirement recommendations of USA Dietary Reference Intakes (2000) to define compliance.	17 components: 1) Carbohydrate (% Kcal). 2) Total fat (% kcal). 3) Saturated fat (% kcal). 4) Protein (g/kg body weight). 5) Vitamin A (µg). 6) Vitamin C (mg). 7) Vitamin E (mg α-tocopherol). 8) Thiamine (mg). 9) Riboflavine (mg). 10) Niacin (mg). 11) Vitamin B-6 (mg). 12) Vitamin B-12 (µg). 13) Phosphors (mg). 14) Magnesium (mg). 15) Iron (mg). 16) Zinc (mg).	This DQS is scored based on age and gender specific recommendations. 1 point awarded for recommendation being met and 0 if not met. Score range is 0-17, with 17 indicating highest compliance. Dietary supplements were excluded.

				17) Selenium (µg).	
Murphy et al. (1996)	24hr recall	2)Dietary Quality	Assesses diet quality (targets 2/3 of 1989 American Recommended Dietary Allowance) and association with survival. Nutrient based.	11 components: 1) Iron (mg/d). 2) Protein (g/kg). 3) Calcium (mg/d). 4) Vitamin A(µg/d). 5) Vitamin C (mg/d). 6) Thiamine (mg/d). 7) Riboflavin (mg/d). 8) Preformed Niacin (mg/d). 9) TEI (kcal/d). 10) Quantity and variety of food serving (serve/d). 11) Regular supplement use.	In this score: consumers classify into two groups either poor diet group or no poor diet. Based on number of nutrient intakes that fall below 67% of the 1989 RDA. When ≥5 nutrients below 67% of RDA diet was classed as poor quality. For quantity and variety of food serving if subject consumed < 6 food type it considered as poor diet intake.
Verger (2012)	3 x 24-hour recalls	3)Probability of Adequate Nutrient Intake (PANDiet)	Based on national nutritional recommendations for French and USA adults.	24 items: 1) Protein (g/kg body weight). 2) Carbohydrate (%TEI). 3) Fibre (g/d). 4) Total fat (%TEI). 5) Saturated and polyunsaturated fatty acids (%TEI). 6) Cholesterol (mg/d). 7) Thiamine (mg/d). 8) Riboflavin (mg/d). 9) Niacin (mg/d). 10) Folate (µg/d). 11-17) Vitamins A (µg /d), B-6 (mg/d), B-12 (µg /d), C (mg/d), D (µg/d) and E (mg α-tocopherol/d). 18) Calcium (mg/d). 19) Magnesium (mg/kg). 20) Zinc (mg/d). 21) Phosphorus (mg/d). 22) Potassium (mg/d). 23) Iron (mg/d). 24) Sodium (mg/d).	Scoring method based on the probabilistic approach developed by the Institute of Medicine. Scoring considered the numbers of days of dietary data, with the highest score awarded if met the nutrient recommendations. The score range is from zero to 100, that indicates a healthier diet.
2) Adherence to Mediterranean Dietary Score (MDS)					
Trichopoulou, et al. (1995)	Semi-quantitative FFQ (19	The original Mediterranean Diet Score (MDS)	Assesses overall diet pattern and survival based on MDP.	8 components: 1) High monounsaturated to saturated fat ratio (g/d).	Cut-off points were used for each component based on median values for each sex, with adjustment for EI in kcal. 1 point for each component met, with a score

	items)			2) High legume consumption (g/d). 3) High vegetable consumption. 4) High fruit consumption (g/d). 5) High cereal consumption (g/d). 6) Moderate ethanol consumption (g/d). 7) Low milk/dairy consumption (g/d). 8) Low meat and meat product consumption (g/d).	range of 0-8. Higher scores indicate better diet.
McNaughton, et al. (2012)	4-day weighed record	The British MDS	MDP score	10 items: 1) Vegetables (g/d). 2) Legumes (g/d). 3) Fruit (g/d). 4) Nuts (g/d). 5) Cereals (g/d). 6) Fish and seafood (g/d). 7) The ratio of Monounsaturated to saturated fat. 8) Dairy products (g/d). 9) Meat and products (g/d). 10) Alcohol (g/d).	Uses sex-specific median as cut points for all index components, except alcohol. For the beneficial groups including vegetables, legumes, fruit and nuts, cereal, fish and seafood and the ratio of Monounsaturated to saturated fat, one point is scored for consumption above the median, while for dairy and meat groups if consumption is less than the median one point is scored, otherwise zero. For Alcohol; if a women consume >5g or >25g/d of ethanol, or (>10; >50g/d) of ethanol for men, they score one point and zero otherwise.
Trichopoulou, et al. (2003) Lagiou, et al. (2006)	FFQ (150 items)	MDS	Assesses overall diet pattern based on MDP.	9 components: 1) High monounsaturated to saturated fat ratio. 2) High legume consumption (g/d). 3) High vegetable consumption (g/d). 4) High fruit consumption (g/d). 5) High cereal consumption (g/d). 6) Moderate ethanol consumption (g/d). 7) Low milk/dairy consumption (g/d). 8) Low meat and its products consumption (g/d). 9) Nut and fish (g/d).	Similar to original MDS, with nuts and fish added as spate group making a total of 9 components. Beneficial components (legumes, fruit/nuts, vegetables, cereals, and fish) receive score of 1 if above the sex-specific median cut-off, and 0 if below. For detrimental components (dairy, meat and poultry) a score of 1 received if below median and 0 if above. For ethanol component, 1 point received for men who consume 10-50g per day, and women who consume 5-25g per day. The last component is the ratio of monounsaturated fat to saturated fat. Score range is 0-9 with 9 indicating maximal adherence to traditional Mediterranean diet.
Osler & Schroll, (1997)	3 day food record and frequency checklist.	MDS	Assesses association between a Mediterranean diet score and survival in an elderly Danish population; and diet score and biochemical dietary measures	7 items: 1) High monounsaturated to saturated fat ratio. 2) High consumption of vegetables and legumes (g/d). 3) High fruit consumption (g/d). 4) High cereal consumption (g/d).	The scoring methods are similar to previous MDS. Score range 0-7 with 7 indicating better diet.

				5) Moderate ethanol consumption g/d). 6) Low milk/dairy consumption (g/d). 7) Low meat/meat product consumption (g/d).	
Knoops, et al. (2006)	Diet history	MDS	Assesses overall diet pattern based on traditional Mediterranean diet.	9 components similar to the original MDS, but the legumes group was replaced with legumes/nuts/seeds, the vegetable group replaced with vegetable and potatoes, and the meat and meat products group replaced with meat and poultry. Fish was also added as a new group.	The scoring methods are similar to original MDS. Range score from 0-9 with 9 indicating a higher quality diet.
Knoops, et al. (2006)	Diet history	Mediterranean Adequacy Index	Assesses how close food intake meets reference dietary patterns. This version slightly from the original.	2 main groups: 1) Mediterranean foods include cereals, legumes, vegetables, fruit, potatoes, fish, monounsaturated fat and wine. 2) Non- Mediterranean foods include milk and its products, meat and poultry, eggs, sugar and saturated fat. Original version used vegetable oil instead of monounsaturated, and animal fats and margarine instead of saturated fat	The sum of Mediterranean food groups divided by sum of non-Mediterranean food groups. In the original version food groups are expressed as percentage of total daily intake of energy. This version is adjusted to daily intakes of men and women.
Fung, et al. (2006)	FFQ 116 items	Alternative Mediterranean Diet Score (aMDS)	Assesses overall diet pattern based on MDP.	9 groups: 1) Vegetables (g/d). 2) Legumes (g/d). 3) Dairy (g/d). 4) Cereals (g/d). 5) Meat and meat products (g/d). 6) Fish (g/d). 7) Alcohol (g/d). 8) Monounsaturated: saturated fat ratio. 9) Fruits and nuts (g/d).	Variation of original MDS. Components modified: potato products excluded from vegetable group, fruits and nuts separated into 2 groups, dairy group eliminated, includes whole-grain products only, includes only red and processed meats for the meat group, and assigns 1 point for alcohol intake consumption (<15 and >5g/d). Scoring system as MDS. The score range is 0-9 with 9 indicating better diet.

2.2.2.2.2 The Diet Quality Index

The Diet Quality Index (DQI) was developed in 1994 to evaluate the risk of chronic disease in a group of 5,484 American adults. The DQI has a range from zero to 16 points and assesses consistency of eating patterns with the 1989 National Academy of Sciences publication Diet and Health (Patterson et al., 1994). Lower scores reflect greater adherence to the Diet and Health recommendations and indicate a more healthy diet while the highest scores reflect the poorest dietary intake (Patterson et al., 1994).

There are some recent studies that have used the original DQI (Table 2-2). For example, the study conducted by Seymour et al. in 2003 (Seymour et al., 2003). This version of the DQI had a range from zero to 16 points and contained eight items, including six nutrients, together with two food groups. These components were: 1) total fat intake (≤30%TEI); 2) SFA intake (<10%TEI); 3) cholesterol intake (<300mg/day); 4) moderate intake of protein (lower than twice the RDA); 5) adequate calcium intake (RDI levels); 6) intake of sodium (≤2,400mg/d); 7) a combination of vegetables and fruits (≥5serve/day); and 8) grains including breads, cereals, and legumes (≥6serve/day). Each person scored zero for a component if they met 100% of the recommendation, one point if the person almost met the recommendation, and two points if the person exceeded or was significantly below the recommendation. Also each item was weighted equally to the overall score. For example, a person scored zero if they consumed ≥5 servings (met the recommendation) of fruit and vegetables, score one point if they consumed 3 to 4 servings (almost met the recommendation) and zero if they consumed none to two servings (decreased) of fruit and vegetables. A person scored zero if the intake of fat is ≤30% of TEI (met the recommendation), one point if total fat intake is >30–40% of TEI (almost met the recommendation) or two if the total intake of fat is >40% of TEI (exceeded).

In 1999, five years after the construction of the original DQI, Haines and others (Haines et al., 1999) created the DQI-R. The DQI-R is based on the USA Food Guide pyramid and the Recommended Dietary Allowances and the Dietary Guidelines for Adults. The differences in the DQI-R compared with the DQI are in the scoring ranges, cut-off points and the included components. The DQI-R included iron, dietary diversity and moderation, as well as separating the vegetables and fruit into two groups. The DQI-R had a scoring range from 0-100 points, and included 10 components: (total fat (≤30% of TEI); SFA (≤10%TEI); cholesterol intake (<300mg/d); fruit (2-4serving/d); vegetables (3-5serving/d); grains (6-11serving/d); iron (%RDA); calcium (%AL); dietary variety; and moderate intake of certain foods. The dietary variety component was based on four main food groups including: 1) grains (7 items); 2) meat/dairy products (7 items); 3) vegetables (7 items); and 4) fruits (2 items). The tenth component of the DQI-R is moderate intake of sodium, sugar, fat and alcohol. Each component in the index is scored 0, 5 or 10 points. Ten points are given if a person meets all of the recommendations within this component, indicating the optimal diet quality, five points for those who achieve 30% of the recommendations within the component and zero points if they meet less than 30% of the recommendations within the component.

There is also a five point DQI, which was designed to evaluate adherence to the fourth edition of the Dietary Guidelines for Americans (1995). Each participant achieved one point for each of the following nutrients: total fat <30%kcal; SFA <10%kcal; cholesterol <300mg/d; sodium <2400mg/d; and carbohydrate >50%kcal (Quatromoni et al., 2006).

In addition, some researchers have sought to adapt the original DQI for Mediterranean populations by adding fish instead of protein and olive oil as a separate group, omitting the sodium and calcium intake components. Thus this Mediterranean version of the DQI contains seven components, with a maximum 14 points, that includes total fat, SFA, cholesterol, olive oil, fish, grains and vegetables and fruits (Gerber et al., 2000). For more detail refer to Table 2-2.

Furthermore, an Australian DQI (Au-DQI) (AIHW, 2007, Smith et al., 1998) has been developed for the Australian population. The Au-DQI has seven components with a maximum of 60 points. The components are: fruit; vegetables; low fat dairy; trim meat; healthy choice; dietary variety; and lower consumption of high SFA nutrient poor foods. The healthy foods are defined as core healthy foods such as fruits, vegetables, whole grains, lean meats or meat alternatives, and low-fat dairy. The idea of these healthy food choice diet quality scores is based on the approach described in the USA

RFS developed by Kant (2000), and because the RFS was found to be associated with lower mortality. This score was based on the 1998 Australian Guide to Healthy Eating (Smith et al., 1998). The Au-DQI applied a binary scoring method. Each component, except for low fat dairy and trim meat, was allocated 10 points, while these two had a maximum of five points, or zero points for not meeting recommendations. A person achieved the highest score if they consumed the recommended amount, while points for the consumption of high fat nutrient poor foods were inverse; meaning those who consumed none were awarded 10, while zero was applied to those who consumed any of the high fat foods (AIHW, 2007).

There is a more recent Australian version of the DQI called the Aussie-DQI, based on the Dietary Guidelines for Australian Adults (NHMRC, 2003) and are in line with the Australian National Health Priority Areas (ANHPA) (AIHW, 2011). This Aussie-DQI has 11 components, including: five food groups (Fruit, vegetables, grains, dairy products, and meat and alternatives); and moderate alcohol consumption; percentage of TEI from sugar; and SFA; salt or sodium intake; processed meat; and diet variety. Each component contributes equally to the overall score with maximum of ten points, except for diet variety, which has a maximum of 20 points (Zarrin et al., 2013). Diet variety is defined as variety of four groups (vegetable, fruit, whole grains and fish), with each group contributing a top score of five points if meeting a specific number of serves/day. For example, a person was awarded five points if they consumed ≥ 3 types of vegetables daily and zero if otherwise.

2.2.2.2.3 The Healthy Eating Index

The Healthy Eating Index (HEI) was proposed to assess compliance with the Dietary Guidelines for Americans (1990) and the USA Department of Agriculture Food Guide Pyramid (1992). The HEI contains ten components that include: adequacy of intake of five food groups (grains, vegetables, fruit, dairy and meat); four nutrient based components; and dietary variety. These nutrients include: the percentage of TEI from total fat; the percentage from SFA; and the intake of dietary cholesterol and sodium, measured in milligrams. All of the components contribute equally to the overall index. Each one yields a score from zero to 10 with consumption in between scored proportionally. For example, if a person consumes 30% of the daily serving recommendation for fruit, they will score three points on that component. The HEI has a score from zero to a maximum of 100 points. A score of 100 points indicates optimal diet quality and full adherence to the recommendations (Kennedy et al., 1995).

This index was modified to create the HEI-2005 by adding the new components of whole fruit; dark-green and orange vegetables and legumes; and "discretionary calories", which is the percentage of energy from Solid Fat, Alcoholic beverages, Added Sugar (SoFAAS). (Guenther et al., 2007, Guenther et al., 2008). As a result the HEI-2005 contains 12 components of: 1) total vegetables; 2) dark-green and orange vegetables and legumes; 3) total fruits; 4) whole fruits; 5) total grains; 6) whole grains; 7) dairy; 8) meats and beans; 9) oils (moderation of the intake); 10) SFA; 11) sodium; and 12) " discretionary calories " or "the energy from the SoFAAS". In the HEI-2005 its components are weighted differently in the overall index score. Each of the following items scores a maximum of five points: total fruit, whole fruit, total vegetables, dark-green and orange vegetables and legumes, total grains and whole grains. The TEI from SoFAAS is scored from zero to 20 points, a person is awarded 20 points if the percentage of the TEI from the SoFAA is ≤ 20%, while they will get zero point if ≥ 50% of TEI. The rest of the HEI-2005 components score a maximum of 10 points. This gives the index a total of 100 points, with a higher score meaning more optimal diet quality (Guenther et al., 2008).

The HEI was further modified to develop the HEI-2010. In this version, total grains were omitted, while green vegetables and beans were added in place of the dark-green and orange vegetables and legumes group. Components assessing moderate intakes in the HEI-2010 are refined grains, sodium and empty calories, while in the HEI-2005 version it were sodium, SFA and TEI from SoFAAS. Thus, the components for the HEI-2010 are: total fruit, whole fruit, total vegetables, greens vegetables and beans, whole grains, dairy, total protein foods, seafood and plant proteins and fatty acids (ratio of poly- and MUFA to SFA). The scoring is similar to the HEI-2005, some components for example, the "total fruit" and the "whole fruit" scoring a maximum of five points each. The remaining items which are not common to the HEI-2005 are scored out of a maximum of 10, except for moderation of intake of empty calories which scores a maximum of 20 points (Guenther et al., 2013).

George et al. (2014) examined the ability of selected diet quality indexes to predict mortality and included the HEI-2010. This study was a longitudinal analysis carried out in 63,805 American women and evaluated the risk of all-cause mortality in relation to diet quality as measured by four dietary quality indexes including: HEI-2010, AHEI-2010, (Alternate Mediterranean Diet) aMED and DASH. An FFQ was used to assess usual dietary intake and the participants were followed for 12.9 years. It found that higher scores on all of the indexes was associated with lower risk of all-cause mortality (George et al., 2014).

While developed in the USA, the HEI has been adapted and modified for application in other populations. For example, the Canadian-Healthy Eating Index (C-HEI) was adapted from the HEI-2005. This C-HEI contains nine items including grains, vegetables and fruit, dairy, meat and alternatives, total fat, SFA, cholesterol and dietary variety (Lavoie et al., 2013). The scoring method is shown in Table 2-2. The C-HEI shows an inverse association with body weight status (Lavoie et al., 2013). A recent study of 13,536 Canadian adults was designed to estimate the relationship between dietary patterns (assessed by the HEI and DQI independently) and BMI in a cross-sectional analysis. It found that every one unit higher score on the DQI was associated with a significantly lower 0.053kg/m^2 BMI, and every one unit increment increase in the HEI was associated with a lower BMI of 0.095kg/m^2 in those with high BMI or obesity with mean BMI= 33kg/m^2 but not in those with low BMI or overweight with mean BMI=22kg/m^2. The association between diet quality across the indexes and weight (BMI) was stronger in women than in men. Specifically, an increment of one unit increase in DQI and HEI was associated with lower BMIs of 0.073kg/m^2 ($p=0.028$) and 0.12kg/m^2 ($p=0.009$) respectively in women. While one unit increase in HEI was associated with lower BMI in men (0.06kg/m^2 ,$p=0.030$), the DQI was not significantly associated with BMI in men (Sundararajan et al., 2014).

The HEI has also been adapted for use in Australian populations. The Au-HEI aligns with the Dietary Guidelines for Australian Adults (NHMRC, 2003) and the Australian

Guide to Healthy Eating (Smith et al., 1998). This index contains seven items, including diet variety, healthy choice, fruit, vegetables, dairy, meat and SFA intake. Healthy choices included the consumption of healthy core foods derived from an FFQ and Short Dietary Questions (SDQ) and healthy eating behaviours, including consuming low fat milk and trimming fat off meat. The components of the Au-HEI are scored out of 10, except for meat and dairy, which have a maximum score of five. Thus this index is scored from zero to 60 points. The highest score represents the optimal diet quality, reflecting greater adherence to the Australian Dietary Guidelines for Adults (AIHW, 2007).

2.2.2.2.4 The Alternative Healthy Eating Index

The Alternative Healthy Eating Index (AHEI) was developed as a method to predict the risk of some chronic diseases, based on the HEI and the USA Dietary Guidelines for Adults. The AHEI contains nine items including: vegetables; fruit; nuts and soy protein; ratio of white to red meat; cereal fibre; trans fat; ratio of PUFA to SFA; alcohol; and vitamin supplements. Each component, except the use of vitamin supplements, is awarded a score from zero to ten proportionally, based on meeting criterion values for recommendations. For vitamin supplement users 7.5 points are added, while those who do not use supplements get 2.5 points added. This AHEI has a range of scores from 2.5 to 87.5 points, with the highest score indicating healthier dietary intakes. This index was shown to have an inverse association with the risk of chronic disease in both men and women respectively (RR: 95% CI; 0.80; 0.71, 0.91;0.89; 0.82, 0.96) (McCullough et al., 2002). In China, the AHEI has recently been adapted. This Chinese version comprises eight components with each component contributing equally to the overall score with 10 points. These components are: vegetables, fruit, nuts and legumes, red/processed meat, long chain omega3 fatty acids (Eicosa-Pentaenoic Acid (EPA) and Docosa-Hexaenoic Acid (DHA)), PUFA, sodium and moderate alcohol (Yu et al., 2014). For more detail refer to Table 2-2.

2.2.2.2.5 The Dietary Guideline Index

Another diet quality index that has been developed based on the Dietary Guidelines for Americans (2000) and other national recommendations, including as the National

Research Council's Committee on Diet and Health (1989) and Food Guide Pyramid (1992), is the Dietary Guideline Index (DGI). The DGI has eight components, each of which contributes equally to the overall score. Each component is scored from zero to two. The participants are ranked into tertiles based on each component and those in the top tertile are assigned two points, while those in the lowest tertile get zero points, and those in the middle tertile score one point. The first component is for healthy body weight, and those who are in the healthy weight range (BMI >25kg/m^2) are awarded the highest score (two points), while those defined as overweight get one point and obese participants get zero. The other components are: being active daily; building a healthy base by consuming the recommended amounts of the core food groups; choosing a variety of grains and whole grains; variety of fruit and vegetable intakes; choosing diet sensibly (meaning that foods that are low in SFA and cholesterol and moderate intake of total fat are chosen); having moderate intakes of sodium, sugar from food and beverages; and alcohol (Harnack et al., 2002).

In Australia, McNaughton and colleagues (2008) have proposed an index called the Dietary Guidelines Index (DGI); consistent with the Australian Dietary Guidelines and the Australian Guide to Healthy Eating (Smith et al., 1998). This index contains 15 components consistent with the guidelines. For example, one aim of the Australian Dietary Guidelines is to promote the enjoyment of a wide variety of nutritious foods. In the Australian DGI, this is interpreted as consuming core foods from each of the five food groups at least once a week and would assign individuals the highest score for this component. Each component contributes equally to the overall score, with 150 points the maximum, indicating optimal diet quality. The DGI components are: diet variety; adequacy of intake of fruit; vegetables and legumes; cereal; dairy; meat and alternatives; fluid; 'extras' foods; the proportion of whole meal; the ratio of whole grain bread to the total bread; the proportion of lean meats relative to total meat. In addition to moderate intake in the following components of the DGI: total fat and SFA; alcoholic beverages; salt intake; and added sugar from beverages (McNaughton et al., 2008).

2.2.2.2.6 The Mediterranean Diet Pattern scores

In general, the traditional Mediterranean Diet Pattern (MDP) includes regular consumption of vegetables, fruit, legumes, cereals, nuts, fish and foods rich in olive oil, as well as a low intake of foods high in SFA, dairy products, meat and poultry (Trichopoulou et al., 2003). The original MDS is based on adherence to the MDP (Trichopoulou et al., 1995). The MDS contains eight components, six food items, one alcohol item, and the ratio of MUFA to SFA. A participant is either awarded one or zero points for each component based on cut-offs of sex-specific median intakes in the study group. The lowest score indicates the individual is not meeting the MDS and the highest score of eight points indicates the greatest adherence to the MDS.

Many others have revised and modified the original MDS. For example, the Mediterranean Diet Score as used in the paper by Beunza et al. (2010) considered the intake of nine food items rather than six, which were classified into: 1) positive components (vegetables, fruit, nuts, legumes, cereals, moderate alcohol and fish); and 2) negative components (meat and poultry, dairy products) (Beunza et al., 2010). The score assigned to each component was based on both the nature of the food component and the quantity of that food consumed in relation to the median value for all subjects under consideration (Willett et al., 1995). A score of zero was assigned to a positive component if the individual's consumption was less than the gender-specific median consumption (Simopoulos & Visioli, 2007). A score of one was awarded if the food item was positive and consumption was greater than the gender-specific median. The opposite procedure was followed in the case of negative components. A score of zero was awarded if the consumption was greater than the gender-specific median, and one if consumption of the negative component was less than the relevant median (Simopoulos & Visioli, 2007, Beunza et al., 2010).

Another example of the MDS, the one used by Sanchez-Villegas et al. (2006), was defined 'a priori' and considered the intake of 10 food items. These foods were classified into two groups: 1) beneficial food items which included cereals, vegetables, fruits, legumes, fish, nuts, olive oil and moderate red wine; and 2) detrimental food items which included meat, meat products and whole fat dairy products (Sanchez-Villegas et al., 2006). The total score range was from 10 to 30 points. To compute the score for each participant, a rank system was applied to each component. Firstly each item was classified into tertiles and scored from 1 to 3 from the lowest to the highest tertile for beneficial food items, and then 1 to 3 from the highest to lowest tertile for detrimental food components. The 10 component scores were summed for each participant. Thus a maximum of 30 points reflects the highest MDS and the greatest adherence to MDP, while a score of 10 points reflects the lowest adherence (Sanchez-Villegas et al., 2006).

Mendez et al. (2006), used another version of the MDS which they based on dietary intake data from a diet history rather than an FFQ. This process generated a list of approximately 600 food items, considerably more than is included in most FFQs. This version of the MDS score is similar to the one used by Beunza et al. (2010), and classified food items into: 1) beneficial foods including fish, vegetables, fruits, legumes, cereals and the ratio of MUFA to SFA; and 2) detrimental food items, including moderate alcohol intake and meat. Milk and dairy products were not considered in this index. A score of zero was assigned to a component if it was beneficial and if the individual's consumption was less than the gender-specific median consumption of that particular food for all individuals in the study. The opposite procedure was followed in the case of detrimental foods, with a score of zero awarded if consumption was more than the gender-specific median and a score of one given if consumption was less than the relevant median (Mendez et al., 2006).

Romaguera et al. (2009), used a revised Mediterranean dietary pattern to devise a Relative Mediterranean Diet Score (rMed). This rMed differs from the original MDS and comprises nine nutritional components which characterize MDP. Components like vegetables, legumes, fruit, nuts, cereals, seafood and fish, moderate alcohol consumption and olive oil are rated as beneficial foods, while meat and meat products and dairy products are rated as detrimental. All food items in this score are expressed in units as grams/1000 kcal. Each component in this index is scored as tertiles, except for alcohol and olive oil. Scores of 0, 1 and 2 were awarded from the lowest to the highest tertile for the beneficial food items. The detrimental components of meat/ meat products and dairy were given 0, 1 or 2 from the highest to the lowest tertile. Thus higher intakes of beneficial foods and lower intakes of detrimental foods contributed more to the score, reflecting greater adherence to MDP. For olive oil, a score of zero was awarded to non-consumers, 1 to those with consumption below the median level and 2 to those with consumption greater than or equal to the median. Regarding alcohol, a score of 2 was given to those with moderate alcohol consumption, ranging from 10 to <50g/d for men and 5 to <25g/d for women. Consumption outside of this range for alcohol scored zero. The rMed score ranged from 0 (lowest adherence to MDP) to 18 (highest adherence to MDP). Further evaluation classified the score 0-6 as low adherence, 7-10 as medium and 11-18 as high adherence to MDP (Romaguera et al., 2009).

2.2.2.2.7 The Recommended Food Score

This Recommended Food Score (RFS) was developed in the USA by Kant & colleagues (2000), and was designed to be consistent with the key message of the Dietary Guidelines of consuming a variety of fruit, vegetables, whole grains, lean meat and low fat milk. The RFS (Kant et al., 2000, Fung et al., 2006) depends on the food list in the underlying FFQ. In order to minimize the measurement error effect caused by varying volumes or portion sizes of food consumed, the RFS applies a scoring system independent of amount. A consumer is assigned one point if they consume an item once or more per a week, or zero if otherwise. The scores for all items are then summed to give a maximum score of 49 (Fung et al., 2006) or 23 (Kant et al., 2000) depending on the numbers of items in the FFQ, (optimal diet quality) down to zero (poorest diet quality) (Kant et al., 2000, Fung et al., 2006). Higher scores on the RFS have shown a link with lower risk in many studies. For example, a longitudinal analysis conducted by Kant et al. (2000) on the association between RFS and all-cause mortality in 42,254 women (mean aged 61.1 yrs), recruited from the Breast Cancer Detection Demonstration Project cohort study, showed a significant negative relationship (p value for trend <0.001 and RR=0.69 (95%CI: 0.61 to 0.78) for the fourth quartile compared with first quartile) (Kant et al., 2000). In another analysis which examined the association between RFS score and cancer (all types) mortality only in the same population, there was also a strong relationship over 9.5 yrs (median) of follow-up (RR=0.74; p-value for trend <0.001) (Mai et al., 2005).

Another similar finding with the RFS and all-cause mortality was observed in Europe. The study was carried out on 40,837 men, aged from 45 to 79 years, followed-up from 1998 and 2005. They found that higher RFS (defined as ≥28 points) was negatively associated with risk of mortality compared with lower RFS (defined as ≤20 points); (HR=0.81; 95% CI: 0.71–0.91; p-value for trend<0.0001) (Kaluza et al., 2007).

The RFS has also been shown to be associated with some biomarkers. For instance in the USA Kant et al. (2005) examined data from 8,719 adults aged ≥20 years from the third National Health and Nutrition Examination Survey for links with three separate diet quality indexes [HEI, RFS and Dietary Diversity Score for recommended foods (DDS-R)] and serum concentrations of biomarkers for both dietary intake and disease risk, and for obesity risk. They found that better scores on all three diet quality indexes were associated with higher levels of serum concentrations of vitamin C, E, folate, and all carotenoids (p≤0.00001), except lycopene. There were significant associations with lower BMI changes, serum homocysteine, C-reactive protein, plasma glucose, and haemoglobin A1C (p<0.05). In addition, both the RFS and DDS-R were associated with lower risk of blood pressure and cholesterol levels (p≤0.03). Thus the RFS is a valid index for measuring diet quality (Kant & Graubard, 2005).

Another recent study, conducted by Kim et al. (2011), used the RFS to assess the association between the quality of diet and oxidative stress biomarkers in a group of 976 Korean adults (mean age 51 years) enrolled in the Biomarker Monitoring for Environmental Health Study. The RFS was adapted from Kant et al. (2000), for the Korean population with a possible score from zero to 47 points. The RFS contains 46 food items worth 46 points; including but not limited to whole grains, fruit and vegetables; and an additional point awarded for consuming meals three times/day on a regular basis. Data was collected using a 106 food item FFQ (Kim et al., 2011) by interviews with the participants, and the urinary Malondialdehyde (MDA) and 8-hydroxy-2-deoxyguanosine (8-OHdg) were measured to assess oxidative stress. The multiple linear regression model was adjusted for sex and age, and found that higher diet quality scores on the adapted RFS were significantly inversely associated with oxidative stress biomarkers,(β=-0.01; p value=0.03). On average, the RFS score was 19.8±10.6/47 for men and women together, but when the scores were stratified by sex it was found that mean diet quality score was higher in women (22.7±10.3) than in men (16.6±10). In addition, the study demonstrated that those who fell into the upper quartile according to their scores on the RFS consumed significantly greater amounts of antioxidants including vitamins A, C and E, zinc and folate and other nutrients such as calcium and protein, compared with those in the lower quartile of the RFS (Kim et al., 2011). The RFS has also been adapted for other populations besides the USA and Korea, such as Europe, the UK and Australia.

2.2.2.2.8 The Australian Recommended Food Score

In Australia, the Australian Recommended Food Score (ARFS) was adapted by Collins et al. in (2008) from the USA original RFS, which was developed by Kant & Thompson (1997) for American adults.

The maximum score on the ARFS is 74, with the score ranging between 0 and 74, with higher scores representing better diet quality. Healthy food items consumed once a week or more are awarded one point, otherwise zero is applied. The foods are classified into seven sub-scales with varying maximum points allocated as follows: vegetables (21 points); fruit (13 points); protein foods (14 points); grains (13 points); low fat dairy (seven points); fats (one point); and alcoholic beverages (two points). One point is also awarded for each of the following: a minimum of two serves of fruit daily; and a minimum of 4 serves of vegetables daily. For alcohol consumption, a maximum of two points are awarded: one point for frequency of consumption of wine, beer, liqueurs, spirits, fortified wine or spirits up to 4 days a week; and the second point is for quantity usually consumed on one occasion (1-2 drinks only, when alcohol was consumed). For those not consuming any alcohol, no marks are awarded, due to the ‘U-shaped’ association between health status and alcohol intake (Collins et al., 2008).

The ARFS is a brief tool that aligns with the Australian Dietary Guidelines for adults (NHMRC, 2003). Its scoring is based on the frequency of consumption of healthy food items. Scores range from zero to 74 for mid-aged women or 72 for young women. The two scores differ between mid-aged and young women because alcohol consumption, which is high in young Australian women, is considered a health risk for this age group because it is not recommended for conception life-stage. Not adding points for alcohol consumption for the young women from the ALSWH is consistent with other work done using both the ARFS and ALSWH data (Hure et al., 2009).

The ARFS has been previously validated in both the young and mid-aged cohorts of the ALSWH (Collins et al., 2008, Collins et al., 2015, Hure et al., 2009). The first validation study (Collins et al., 2008) compared nutrient intakes from the full FFQ by quintiles of ARFS, in the mid-aged cohort of women from the ALSWH (n= 9,895). This indicated that a higher ARFS was associated with higher intakes of micronutrients and a lower percentage of energy as total and SFA ($p<0.0001$). This indicates that this scoring method, which is based on consumption of foods that align with the Australian Dietary Guidelines, is also associated with a more optimal macro and micronutrient profile.

The second study, conducted by Hure et al. (2009), on 7,486 young women aged 25 to 30 years from ALSWH aimed to examine the dietary intake measured by ARFS by pregnancy status, including women who were pregnant, trying to conceive, had a baby in the last year or 'other'. The study found that on average those who were pregnant or had a baby and 'other' had similar diet quality scores with Mean (SD) score of 30 (4) and 29 (1) score, respectively. Carbohydrate, fibre, sugar, protein, PUFA, calcium, iron, zinc, B-carotene, folate, thiamine, riboflavin, niacin, vitamin C, vitamin E and vitamin K intakes all increased as ARFS quintiles increased. Total fat, SFA, MUFA and retinol intakes decreased with increasing ARFS quintiles. The most recent validation study (Collins et al., 2015) was conducted in 31 men and 65 women, with an age range from 30 to 75 years, who were enrolled in the Family Diet Quality Study. In this validation study, data for diet, and the ARFS, were derived from a valid self-reported 120-item semi-quantitative FFQ. The results indicated that the ARFS was highly correlated with nutrient intakes. The overall interclass correlation coefficient (r) for the ARFS and FFQ nutrients were 0.87 (95% CI: 0.83, 0.90), 0.85 (95% CI: 0.80, 0.89), respectively. ARFS was correlated with FFQ nutrient intakes, especially fibre, vitamin A, beta-carotene and vitamin C (r=0.53; 95% CI: 0.37, 0.67), and with mineral intakes, especially calcium, magnesium and potassium (r=0.32; 95% CI: 0.23, 0.40). Thus the ARFS is a valid measure of overall dietary quality.

Thus the ARFS is reflective of overall nutrient intake in Australian women (Collins et al., 2008, Hure et al., 2009), and the work of Kant has identified from the National Health and Nutrition Examination Survey of >8000 adults, that higher scores for the Recommended Food Score (on which the Australian version is modelled), predicted both serum concentration of nutrients and biomarkers for disease risk (Kant & Graubard, 2005). In addition, a previous review examining both diet quality and food variety, measured using diet quality indexes, found that they are able to predict both overall morbidity and mortality (Wirt & Collins, 2009).

The greatest limitation of the ARFS scoring method in the context of this thesis is that it is based on the frequency of healthy food items usually consumed only, and does not factor in portion size or unhealthy items. The data from the semi-quantitative FFQ, on which the ARFS is derived, uses a standard portion size (Hodge et al., 2000b). The aim of this project however, was not to test the relationship between portion size and weight change. It was to investigate the relationship between diet quality, and specifically a variety of healthy foods eaten as measured by the ARFS, and weight change over time. Another major consideration is that the ARFS does not capture consumption of nutrient-poor food items, which may be important predictors in the relationship between diet quality and weight change. However, previous research using the ARFS has shown that higher scores are associated with 'more optimal' nutrient profiles, including lower intakes of less desirable nutrients such as total and SFA and sodium (Collins et al., 2008), suggesting that more frequent intake of nutrient dense foods is more important in terms of optimising diet quality.

Moreover, we selected the ARFS specifically as we are seeking to examine whether a tool that could potentially be used for self-evaluation can be useful in predicting weight change, and could therefore be applied in time and resource limited settings, and calculated without the need to wait for a health professional evaluation.

The first step was to evaluate and summarise the available evidence in this area. Hence I have done a systematic review of the association between dietary patterns in general, including diet quality, in adults in the context of cohort studies (Chapter 3). This chapter provides information about diet quality indexes, including the scoring methods, which were identified in the systematic review.

Chapter 3 Systematic Review (Section 1)

This is an article published in 2015

Authors: Aljadani, Patterson, Sibbritt, and Collins

Title: Diet quality and weight change in adults over time: A systematic review of cohort studies

Journal: Current Nutrition Reports in 11 January 2015.

This work was an update for the first systematic review published (Appendix one and two).

These are:

1) The paper with title "The association between dietary patterns and weight change in adults over time: a systematic review of studies with follow up." (Appendix One)

Authors: Aljadani, Patterson, Sibbritt, and Collins

Journal: JBI Database of Systematic Reviews and Implementation.

2) The book chapter title: "The association between diet quality and weight change in adults over time: a systematic review of prospective cohort studies". (Appendix two)

Authors: Aljadani, Patterson, Sibbritt, and Collins

Book information's: Diet quality- an evidence approach. New York: Springer, in: VICTOR R PREEDY, L. L. A. V. P.

Also part of this work presented as poster presentations in different local and international conferences as follow:

- The Annual Meeting of the Australia and New Zealand Obesity Society (ANZOS) in 2011. Adelaide, Australia.
- The International Conference on Diet and Activity Methods (ICDAM) in 2012. Rome, Italy.
- The International Congress of Dietetics (ICD) in 2012. Sydney Australia.

The Work presented in the manuscript was competed with collaboration with the co-authors (Appendix 5**)**

3.1 Overview

There is no previous systematic review on the evidence on the relationship between the concept of diet quality and change in body weight status in adults longitudinally. At the time (2010) when I conducted my review, only one systematic review identified (Togo et al., 2001). This focused on cross-sectional studies, while my review in cohort studies. My review was published in 2013, as two papers and as a book chapter. By the time that the subsequent studies in my research project had been conducted, other studies had been published. Consequently, I updated my review in 2014 to include these further studies. The updated review presents in this chapter.

3.2 Abstract

This systematic review examines the relationship between diet quality and weight gain in adults over time and is an update of our previous review of the same topic. The goal was to synthesise the best available current evidence on diet quality and weight change within longitudinal analyses. The inclusion criteria were case-control or cohort studies, adults aged ≥18 years. The independent variable was diet quality indexes and the dependent variable was any measurement of body weight. The current systematic review identified 16 studies, published between 1970 and 2014. Of these, eight were published since the last review. The findings of these recent studies confirm the results of our previous review. That is, that higher diet quality is associated with relatively lower prospective weight gain, and a lower risk of becoming overweight or obese, compared with those who have poor diet quality. Across the 16 studies it appears that the diet quality indexes based on foods alone, or food and nutrient components, are more predictive of weight change. However, further research is needed to confirm this. Additionally, high quality analyses are needed that assess change in diet quality over time.

3.3 Introduction

There is great interest in measuring overall diet intake using tools that reflect usual eating patterns, rather than focusing on single nutrients, and to evaluate the relationship with various health outcomes in cohort studies (McCarron & Reusser, 2000, Hu, 2002, Wirt & Collins, 2009). This stems from the acknowledgement of the limitations of single nutrient methods. One of these weaknesses is that people do not consume isolated nutrients; they consume a variety of foods and the resultant mix of nutrients interacts within the body in ways in which we do not fully understand. Additionally, it is preferable to recommend a dietary pattern to the public than to make recommendations on individual nutrients (Wirt & Collins, 2009, McCarron & Reusser, 2000, Hu, 2002, Slattery, 2010). One method for measuring dietary patterns is using "a priori" diet quality index or score that complies with a country's National Dietary Guidelines. For example, the Healthy Eating Index (HEI), indexes associated with lower risk of chronic disease, such as the Dietary Approaches to Stop Hypertension diet score (DASH score), or scoring methods that align with Mediterranean Dietary Patterns (MDP) (Waijers et al., 2007, Appel, 2003, Wirt & Collins, 2009).

Obesity and weight gain are risk factors for adverse health outcomes. Obesity prevalence has been increasing rapidly around the world (WHO, 2013a)••. The older epidemiological literature on the relationship between diet and weight change is heterogeneous, particularly in cross-sectional analyses (Togo et al., 2001). In 2011, we reviewed the best available evidence on the association between dietary patterns and weight change in adults over time (Aljadani et al., 2013a, Aljadani et al., 2013c). At that time limited analyses (n=8) had been conducted that examined the diet quality indexes in relation to body weight change, with considerable inconsistencies across methodologies and results. Although the evidence was limited and significant heterogeneity was found, we concluded that higher diet quality scores, that reflected greater alignment with national dietary guidelines, were associated with lower weight gain. Hence, the focus of this systematic review is to update the results of our previous review. In this current update we will capture the most recent studies on diet quality and prospective weight changes in adults, tabulate the data and discuss the results of the included studies. Hence the aim is to summarise the best available evidence on the association between diet quality, using any pre-defined diet quality indexes or scores, and body weight change in adults over time.

3.4 Methods

The criteria for including studies in this review were the same as our previous review (Aljadani et al., 2013a, Aljadani et al., 2013c). Study designs included cohort or case control studies. The participants had to be adults aged ≥18 years. The dietary intake could be assessed by any method, but had to include a pre-defined diet quality or variety index or score. Weight change could be measured by different methods including weight (kg), Body Mass Index (BMI) (kg/m^2), waist circumference (WC), or % body fat.

Medline, Cinahl, Embase and Scopus were searched for additional papers published since the 2011 review. The search was therefore for literature reviews and original research papers published between 2011 and February 2014. Keywords used included diet quality, diet index, diet score, weight gain, BMI, obesity, adults, cohort, case-control, prospective. The quality of the included studies was assessed by two independent reviewers using standardised critical appraisal instruments from the Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI, Appendix 1). This tool assessed representativeness of the sample; that the study assessed participants at the same follow-up time; identification of confounding factors; the objective of the outcome; the follow up period; description of withdrawals; measurement of the outcome; and the statistical analysis used.

3.5 Results

Figure3-1 summarises the combined number of studies identified and subsequently included in the review for 2011 and 2014. From 3136 citations identified by the initial and updated search, a total of 16 studies were included in this review.

Figure3-1: Flowchart of studies included in a systematic review of the relationship between diet quality and weight change in adults over time:

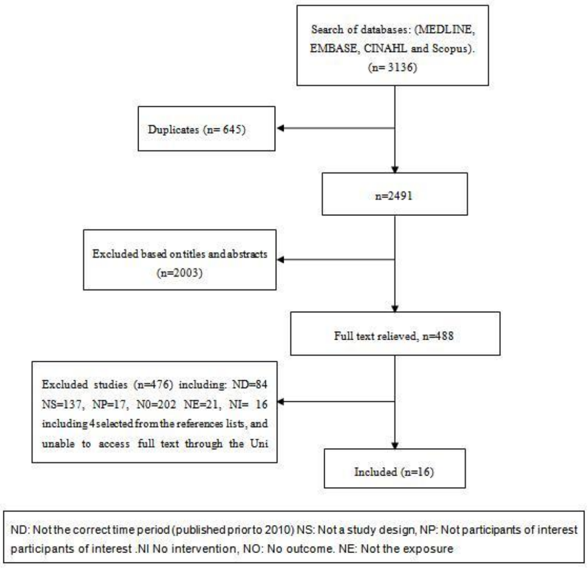


Table 3-1 summarises the characteristics of the included studies, such as demographic characteristics, study aim, the follow-up period and participant retention. Table 3-2 describes the dietary intake methods and diet quality indexes used, the main weight change variables and the results.

3.5.1 Methodological quality

Table 3-3 summarises the methodological quality of included studies as assessed by the JBI-MAStARI tool. The studies were generally of good quality and 12 of the 16 included had low risk of bias, meaning that they met at least 6 out of eight of the criteria. The included studies used appropriate statistical tests, identifying the main confounders in the analysis and followed the participants over a significant period of time (one year or more).

3.5.2 Results of the review

3.5.2.1 Diet quality indexes

The sixteen studies included in the review used various methods to measure dietary intake, diet quality and body weight outcomes. Among these studies, five studies used different versions of the scoring methods that align with the MDP (Beunza et al., 2010, Mendez et al., 2006, Romaguera et al., 2010, Sanchez-Villegas et al., 2006, Yannakoulia et al., 2009); two studies (Kimokoti et al., 2010, Wolongevicz et al., 2010) used the Framingham Nutritional Risk Score (FNRS), two used the Australian Recommended Food Score (ARFS) (Aljadani et al., 2013d, Aljadani et al., 2013b), one used the USA five point scale of diet quality index (DQI) (Quatromoni et al., 2006), one used the Aus-DQI (Aljadani et al., 2013b)••, one used the Australian Dietary guideline index (DGI) (Arabshahi et al., 2012), one used the Healthy Diet Score (HDS) (Forget et al., 2013), one used the 100-point Diet Quality Index (2005 DQI) (Zamora et al., 2010) and one used the Fruit and Vegetables index (FAVI) (Aljadani et al., 2013b).

Regarding the variety of indexes used to measure the quality of diet, four studies (Lassale et al., 2012, Boggs et al., 2013, Asghari et al., 2012, Beunza et al., 2010) used at least two indexes to measure the quality of dietary intake. Asghari et al. (2012) for example, used three indexes in an Iranian population, including; Mediterranean Diet Scale (MDS), Healthy Eating Index-2005 (HEI-2005) and Diet Quality Index-International (DQI-I). Another example of using more than one index is the study conducted by Lassale et al. (2012). It used six different tools to assess the quality of dietary intake, including the 15-point French Programme National Nutrition Santé-Guideline score (15-point PNNS-GS), the American DGI, DQI-I, MDS, the relative Mediterranean Diet Score (rMED) and the Mediterranean Style Dietary Pattern Score (MSDPS).

3.5.2.2 The main outcome of the studies

In the previous review we found that the studies reported the relationship between diet quality and weight status over varying time periods. For example Quatromoni, et al. (2006) examined the relationship over eight years; Kimokoti, et al. (2010) over 16 years; and Mendez, et al. (2006) at 3.3 years of follow-up. In addition, the way weight was reported varied, with some studies reporting the development of overweight or obesity during the follow-up period (Yannakoulia et al., 2009, Wolongevicz et al., 2010, Romaguera et al., 2010), while others reported the change in body weight annually (Beunza et al., 2010, Sanchez-Villegas et al., 2006).

Two studies (Quatromoni et al., 2006, Beunza et al., 2010) found that those who reported higher dietary quality scores, as measured by DQI, had lower weight gained over time, compared with those who had lower diet quality scores (in the lowest quintile). Wolongevicz, et al. (2010) found that those with the lowest diet quality scores were more likely to develop overweight or obesity during follow-up compared to those with higher or 'healthy' diet quality index scores. In contrast, two studies (Yannakoulia et al., 2009, Kimokoti et al., 2010) found that there was no relationship between diet quality and any change in weight status during follow-up.

Sanchez-Villegas et al. (2006), used six different versions of the MDS index. They found that higher diet quality, as assessed using four versions of the MDS, were associated with lower weight gain over time. However this was not the case for the other two versions. Romaguera, et al. (2010) found that for participants who were overweight at baseline, the risk of becoming obese at follow-up was greater if their diet quality was also poor. However, they found no relationship with the development of overweight amongst those who were in the healthy weight range at baseline. (Romaguera et al., 2010)

The eight additional studies included in the updated review had varying conclusions. Arabshahi et al. (2012) examined diet quality by the DGI and measured changes in BMI and waist circumference during 15 years of follow-up in Australian men and women. Findings differed by gender, with no association between diet quality score and change in weight or BMI in women. However, in men there was a significant association between diet quality and change in BMI. In the fully adjusted model, those who achieved the highest DGI scores (fourth quartile), had a significantly lower annual BMI increase (mean= 0.05 kg/m^2 with 95% CI: (0.00, 0.09) compared to those with poor dietary intake (first quartile) (mean= 0.11kg/m^2, with 95% CI: (0.06, 0.16). This model was adjusted for baseline age, education, smoking status, alcohol consumption, physical activity and baseline WC.

Asghari et al. (2012), used three diet quality indexes, the MDS, HEI-2005 and DQI-I, to evaluate the association between change in diet quality, and changes in BMI during 6.7 years of follow-up. They found that higher HEI-2005 scores were associated with statistically significant lower BMI (-0.022±SE 0.011) over the follow-up period (p value =0.043). However, neither the MDS nor DQI-I were associated with changes in BMI in this groups of adults ($p > 0.05$).

Boggs, et al. (2013)•• estimated the Hazard Risk (HR) for developing obesity from 1995 to 2011 in relation to baseline diet quality, as evaluated using two diet quality indexes, the AHEI-2010 and the DASH. The study recruited 19,885 African American women aged 21-39 years. Overall, there was no relationship between baseline diet quality and weight changes during the follow-up. However, among a sub-analysis considering the initial BMI and changes in diet quality scores at two points (1995 and 2001), different results appeared. They found that those who were of normal weight at baseline (BMI: 18.5- 24.9 kg/m^2) and maintained a higher diet quality score during follow-up, had significantly lower risk of developing obesity compared with those who had a lower diet quality score over time. The HRs, when comparing the highest to the lowest quintiles of AHEI-2010 and DASH respectively, were 0.76 (CI 95%:0.58, 0.98) and 0.68 (95% CI: 0.53, 0.88). However, among women who were overweight at baseline, there was no relationship between diet quality and obesity risk.

Forget, et al. (2013) reported on a study of 196 young adults, that evaluated the association between the HDS and changes in BMI over four years. The study found that those with a poor diet quality score (HDS= zero to one/ 5 point) gained a significantly greater (0.70kg/m^2) amount of weight during the follow-up period, compared to those with the healthiest or intermediate diet quality scores (HDS ≥ two points).

Lassale, et al. (2012)•• conducted a study of 3,151 adults who were followed for 13 years in order to evaluate the association between six different diet quality indexes; the 15 point PNNS-GS, DQI-I, DGI, MDS, rMED and MSDPS, and weight change status. When examining results by gender, it was found that there was no association between any of the diet quality indexes and weight change in women (n=1471). By contrast, in men (n= 1680), there was a statistically significant inverse association between all diet quality index scores, except for the MSDPS, and weight change and the risk of obesity. More specifically, a higher dietary index score of one standard deviation resulted in a lower weight gain during the follow up period, ranging from β= 0.40 (95% CI; -0.71 to -0.1) for PNNS-GS, to β= 0.87 (95%CI -1.15 to -0.58) for rMED. The risk of becoming obese was strongly reduced for men in the top quartile compared to the bottom quartile with: OR= 0.20, CI 95%; 0.10, 0.42 for the DGI. OR= 0.45, CI 95%; 0.26, 0.79 for the PNNS-GS and OR= 0.45, CI 95%; 0.27, 0.76 the MDS.

Zamora, et al. (2010)•• enrolled 4,913 adults (Caucasians and African Americans) aged 18-30 years in order to investigate the association between the 2005 DQI and the risk of gaining ≥10 kg during 20 years of follow-up. There was a variation in the results by race but not by gender. For the Caucasian participants with BMI <25 at the start of the study, there was a significant inverse association between diet quality score and the risk of gaining ≥10 kg over the follow-up period. Each 10 point increase in DQI (DQI had a maximum 100 points), was associated with a 10% lower risk of gaining ≥10 kg of weight during 20 years. While amongst African American obese participants, it was found that those with healthiest diet were gaining significantly greater weight. Each 10 points of DQI was associated with a 15% higher risk of gaining 10 kg or more during the same follow-up period.

Aljadani, et al. (2013b)•• assessed the relationship between diet quality, as measured by the ARFS, Aus-DQI and FAVI, and weight gain in young Australian women over six years. In a sub-analysis of those who reported plausible total energy intake (TEI), it was found that the top tertiles of the ARFS and FAVI only were associated significantly with lower weight gain in these women. The results for the ARFS and FAVI were respectively $\beta = -1.6$ kg (95% CI: −2.67 to −0.56), $P = 0.003$ and $\beta = -1.6$ kg (95% CI: −2.4 to −0.3) $P = 0.01$.

In a second study by Aljadani, et al. (2013d) it was demonstrated in 7,155 women aged 48 to 56 years that the ARFS score had no relationship with weight change at six years of follow-up. In multivariate Linear regression analysis, there was still no relationship between diet quality measured by the ARFS and weight gain over six years (β=0.016 and p=0.08).

3.6 Discussion

The main aim of this systematic review was to synthesise the best available evidence on the relationship between dietary patterns and weight change in adults in longitudinal analyses. Overall, the findings of the recent eight studies confirm our previous conclusions that optimal diet quality, characterised by higher index scores that reflect greater alignment with national dietary guidelines, is associated with lower body weight gain in adults over follow-up periods at least one year. Across these studies it was found that those who achieved higher diet quality scores had relatively lower weight gains measured by BMI (kg/m$^{2)}$ in the range of 0.06 to 0.022 kg/m^2, compared to those with the poorest diet quality scores. Furthermore, the findings of the recent studies highlight the fact that the majority of adults were gaining weight over time, even when they had eating patterns that met the national dietary guidelines. Across the included studies it has been reported that adults had BMI increases of between 0.3 to 1.73 kg/m^2 on average, during four to 15 years of follow-up. The studies also found that the majority of participants had a poor diet quality on average. In addition, the results varied depending on the index components, and it may be that indexes based on food alone or food combined with nutrient intakes are a better predictor of weight changes than those indexes based on nutrient intakes only. There were also differences in the ability of diet quality indexes to predict weight change depending on gender. It appears that the relationship is stronger for men than for women.

From this updated review it is apparent that there has been increased research interest in capturing overall diet quality by proposing and adapting various diet quality indexes and investigating associations with secondary health outcomes. The eight new studies demonstrate that a variety of diet quality indexes have been used, including the Aus-DGI, DGI, ARFS, DQI-I,PNNS-GS, various versions of MDP scores, HDS, AHEI and others. In contrast, our previous review to 2011 found that only three indexes had been used in the eight studies, and included FRNS, the five point DQI and various versions of indexes measuring the adherences to the MDP. This emphasizes the growing interest in using and developing diet quality indexes in epidemiology and public health research to predict weight gain.

Once again it was found that these studies were heterogeneous, not only in the diet quality instruments that have been used to quantify dietary patterns, but also in the way that body weight change or weight status was reported. In addition, both the follow-up periods and approach to the statistical analyses varied. For example, some studies found different results by gender (Lassale et al., 2012, Arabshahi et al., 2012), with higher diet quality associated with lower weight gain in men but not in women (Lassale et al., 2012, Arabshahi et al., 2012). It is still uncertain whether diet quality plays a more important role in weight change in men compared with women. In the study by Lassale et al. (2012)••, the percentage of overweight men was higher than for women (47 vs 20%). This could impact the status of weight at the end of the study, as well as the fact that they did not take into account the changes in eating behaviour over the 13 years of follow-up. There may also be unknown confounders, which could affect both diet and weight in women. Most studies examined only measured diet quality at baseline, and thus eating behaviour changes over the follow up period and its influence on weight, have often not been assessed.

Among other studies, results varied based on participants' initial BMI (Boggs et al., 2013) or race (Zamora et al., 2010)••. For example, an analysis (Boggs et al., 2013) conducted on women only, found those who were of normal weight at the start of the study, and who maintained higher diet quality scores from the start and throughout the follow-up period, had a significantly lower risk of becoming obese (BMI ≥30 kg/m^2). Although the same study found no relationship with diet quality for those who were overweight at the beginning of the study (Boggs et al., 2013). Another study (Zamora et al., 2010)•• found higher diet quality scores were associated with lower risk of weight gain in Caucasian American adults, but not amongst African American adults.

Furthermore, when interpreting findings, the instrument used to quantify dietary patterns must be taken into account. Some of the indexes are designed to capture very specific dietary patterns like the MDP scores, while others such as FNRS, DQI may have been designed to look at relationships with chronic disease morbidity and/or mortality. Weight gain is a precursor to these, so you would not expect it to necessarily follow that the indexes predict rate of weight gain prospectively. For instance, in a longitudinal study of the relationship of diet quality measured by three indexes including the MDS, HEI-2005 and DQI-I in 467 adults, the only one that was significantly associated with changes in body weight during 6.7 years of follow-up was the HEI-2005. This relationship was not consistent for the MDS or DQI-I (Asghari et al., 2012). The study carried out in France also found inconsistent results across the indexes used, however weight change in men was predicted by five out of six indexes (Lassale et al., 2012)••. The ideal way to draw a straightforward conclusion across the studies is by comparing the studies that used the same diet quality indexes or at least contain similar components or sub-scales.

There are two studies (Kimokoti et al., 2010, Wolongevicz et al., 2010) that used the FNRS with the objective of evaluating its association with weight change status in both men and women (Kimokoti et al., 2010) or women only, who were of healthy weight at the start of the study (Wolongevicz et al., 2010) and then followed them over 16 years. The study conducted by Kimokoti et al. (2010), found no relationship between the FRNS score and weight change in adults, while the study by Wolongevics et al. (2010), found a statistically significant inverse association between FRNS and the risk of becoming overweight or obese in women. If we consider important confounders, such as weight at baseline, which was adjusted for in the study conducted by Kimokoti et al. (2010) but not in the other study, it may help to explain the significant association in the second study by Wolongevics. The impact of initial BMI also needs to be considered. While one study enrolled all participants of any BMI (Kimokoti et al., 2010), the other enrolled only women with healthy BMI at baseline (Wolongevicz et al., 2010).

There are two analyses (Aljadani et al., 2013b, Quatromoni et al., 2006) using the five-point DQI. These found inconsistent results for weight gain in both men and women (Quatromoni et al., 2006) or women only (Aljadani et al., 2013b) over at least 6 years. These studies did not measure the changes in dietary patterns. This review identified only four analyses that used diet quality indexes based on nutrients only, the DQI and FRNS. From the negative results of these studies (Quatromoni et al., 2006, Aljadani et al., 2013b, Kimokoti et al., 2010, Wolongevicz et al., 2010) we conclude that these indexes may have less predictive ability compared to other indexes in terms of prospective weight change.

Seven studies (Lassale et al., 2012, Asghari et al., 2012, Beunza et al., 2010, Mendez et al., 2006, Romaguera et al., 2010, Sanchez-Villegas et al., 2006, Yannakoulia et al., 2009) used various versions of the MDP score, but all had the same aim of reflecting greater adherence to Mediterranean eating patterns and had similar components or subscales. Eight versions of the MDP indexes found a significant association between greater MDP scores and lower weight gain in adults, while three others, the MSDPS (Beunza et al., 2010, Lassale et al., 2012), MDS (Asghari et al., 2012) and the MDS-Panagiotakos (Sanchez-Villegas et al., 2006), found no relationship with weight gain over time. Thus we conclude that higher diet quality reflected by greater adherence to a Mediterranean eating pattern, characterised by a diet rich in vegetables, fruit, nuts, legumes, fish, cereal, and olive oil, predicts lower prospective weight gain in adults. However, it is questionable whether it is appropriate to use these tools outside the relevant European populations. All the studies that have identified this relationship with MDP score and weight change were located in Europe, except for one recent study carried out in Iran, which found no relationship of adherence to the MDP and weight changes in Iranian populations (Asghari et al., 2012).

There were two analyses that used the DQI-I (Asghari et al., 2012, Lassale et al., 2012) and these had inconsistent results. The study carried out in Iran (Asghari et al., 2012) found no relationship between diet quality and body weight status change, while the other (Lassale et al., 2012) carried out in France found that the DQI-I was significantly inversely associated with weight change in men but not in women.

In two other analyses, the American DGI was used in France and the Aus DGI in Australia (Arabshahi et al., 2012, Lassale et al., 2012). These two studies found consistent conclusions that the highest score of the DGI was associated with significantly lower weight gain in men, but not in women.

Other studies found that AHEI-2010 (Boggs et al., 2013), HEI (Asghari et al., 2012), HDS (Forget et al., 2013), DASH (Boggs et al., 2013), and 15 point PNNS-GS (Lassale et al., 2012)••, were associated with lower body weight gain in adults. It is important to mention that these indexes are based on both nutrients and food components. In addition, some have additional components related to non-dietary factors, such as physical activity in the 15 point PNNS-GS used by Lassale, et al. (2012)•• that may affect the results.

The only two indexes based solely on food components or subscales were the ARFS (Aljadani et al., 2013d, Aljadani et al., 2013b) and the FAVI (Aljadani et al., 2013b). In one of these studies an association between higher quality diet and lower weight gain was found in young women at six years follow up. However another study (Aljadani et al., 2013d) conducted on mid-aged women, also followed for six years, found that the ARFS was not associated with lower weight gain. In both of these studies no adjustment was made for changes in dietary patterns throughout the follow-up period.

Unfortunately, there is a gap in the current research regarding the relationship between changes in dietary patterns over time, and how these changes relate to change in weight for both men and women. It may be changes in diet that are most important in determining weight gain over time, rather than a baseline diet quality score. From this review at least five studies (Arabshahi et al., 2012, Asghari et al., 2012, Boggs et al., 2013, Sanchez-Villegas et al., 2006, Quatromoni et al., 2006) have measured changes in diet quality over time, yet they used varied methods and it is difficult to compare results, so further research is needed in this area. For example the studies done by Arabshahi et al., Asghari et al. and Boggs et al. had significant differences in the method used to estimate the association between diet quality and weight changes over time (Arabshahi et al., 2012, Asghari et al., 2012, Boggs et al., 2013), and reported inconsistent results. Boggs et al. (2013), found a significant association for those who were of normal weight at the start of the cohort and maintained their higher diet quality scores, and a lower risk of developing obesity, but not for those who were already overweight at baseline. However Asghari et al. (2012), found no relationship between diet quality score, except for the HEI-2005, and weight change over time.

Arabshahi et al. (2012), found no association between diet quality change and weight change over time in women, but there was an association in men. Also, the impact for those who increased their diet quality scores over time on weight changes is not certain, due to insufficient numbers in this group. The study by Boggs et al. (2013), found in their overall analysis, without measuring changes in diet quality, that there was no relationship between diet quality and weight change. However, when they considered the changes in diet quality over time, they found that in those who maintained their diet quality score and who were of a healthy weight at the start of the study, that there was an inverse association between diet quality and the risk of obesity. Thus, further studies that factor in change in diet quality over time into analyses are needed.

3.7 Conclusion

In conclusion, from these 16 studies, diet quality indexes or scores appear to be good measures of overall dietary patterns and can be useful tools for predicting weight changes over time. In adults, an optimal diet rich in vegetables, fruit, whole grains and cereals, low fat dairy and low total fat and saturated fat is associated with a reduced risk of gaining weight over time. It also suggests that baseline diet quality can be a strong predictor of prospective weight changes in men, but is less reliable in women. However, additional studies that examine the impact of initial body weight at baseline and which consider the other important confounders, such as change in diet quality, are needed. This will help to develop more robust conclusions in the future.

In addition, the findings of this review suggest that diet quality indexes based on either food and nutrient intakes, or food items alone are likely to be better predictors of weight change over time than indexes based on nutrient intakes alone. This is an important point to consider as in terms of public health recommendations, guidelines should be centred on food patterns rather than nutrient intakes.

Conflict of Interest

The authors do not have any conflict of interests to declare.

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Table 3-1: Characteristics of the included studies

	First author & publication year	Study design & cohort's name	Subjects	Country	Length of a study	Retention	Purpose
				A) Diet quality indexes#			
1	Aljadani et al. (2013d)	The Australian Longitudinal Study on Women's Health (ALSWH)	F=7155, Age 48-56	Australia	6 years	No = 588	To measure the effect of weight changes during six years of follow-up with baseline ARFS.
2	Aljadani et al. (2013b)	The ALSWH	F=8239, Age 27.6±1.5	Australia	6 years	No= 881	Assessed the relationship between tertiles of diet quality measured by the ARFS, FAVI and Aus-DQI and changes in weight over the period from 2003 to 2009.
3	Arabshahi et al. (2012)	Nambour Skin Cancer Study	F, M=2399, Age 25-75	Australia	15 years	Not reported	To investigate the relationship between food based dietary index and change in BMI and WC.
4	Asghari et al. (2012)	Tehran Lipid and Glucose Study	F, M=708, Age >19yrs	Iran	6.7 years	66%	To evaluate the association of diet quality indices with BMI and WC after 6.7 years.
5	Beunza et al. (2010)	The Seguimiento Universidad de Navarra (SUN) cohort.	F, M=10.376 Mean age 38	Spain.	Mean 5.7±2.2 years	>90% (for first 24 mo)	The correlation between MDSs and weight gain over time.
6	Boggs et al. (2013)	Black Women's Health Study	F=19885, Age 21-39	America	6 years	Not reported	Assess diet quality in relation to the incidence of obesity.
7	Forget et al. (2013)	Cohort study (no name specified)	F, M=196, Age 20.5±3.0	Canada	4 years	Unclear (74-90%)	Assess ideal Healthy Diet Score and its association with weight status over 4 years.
8	Kimokoti et al. (2010)	Framingham Offspring/Spouse (FOS) study.	F, M=1515 Age ≥30	USA	16 years	67%	Evaluate how diet quality compares with demographic, anthropometric, biological, clinical, and other lifestyle factors in predicting weight change in our participants; and impact of these factors, including smoking status, on the association between diet quality and weight change.
9	Lassale et al. (2012)	SU.VI.MAX study	F, M=3151 Age 45-60 at baseline	France	13 years	Not reported	1) Assess association between dietary scores and 13 year weight change 2) Assess the 13 year risk of becoming obese in non-obese participants (at baseline) and the association with dietary scores.
10	Mendez et al. (2006)	The European Prospective Investigation into Cancer and Nutrition (EPIC)-Spain.	F=27827 Age 29-65	Spain.	Mean 3.3 years.	95%	To examine whether adherence with MDP is associated with obesity incidence for 3 years of follow up.
11	Quatromoni et al. (2006)	FOS study.	M,F=2245 Age 49-56	USA	8 years	58%	The relationship between 8-year weight change among FOS participants and adherence to the fourth edition of the Dietary Guidelines measured using DQI.

12	Romaguera et al. (2010)	The European Prospective Investigation into Cancer and Nutrition–Physical Activity, Nutrition, Alcohol Consumption, Cessation of Smoking, Eating Out of Home, and Obesity (EPIC-PANACEA) project.	F, M=373,803 Age 25-70	Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Spain, Sweden, and UK.	Median 5 yreas.	Unclear	The association between adherence to MDP and weight change and incidence of overweight or obesity.
13	Sanchez-Villegas et al. (2006)	The Seguimiento Universidad de Navarra (SUN) cohort.	F, M=6319 Mean age 34-40yrs	Spain.	28 mo	90%	The association between adherence to the MDP and weight or BMI change.
14	Wolongevicz et al. (2010)	FOS Study.	F=590 aged 25-71	USA	16 yrs	100%	The relationship between diet quality and the development of overweight or obesity in women over 16 years in healthy, normal-weight (BMI, 25 kg/m2) women.
15	Yannakoulia et al. (2009)	The ATTICA study that is a health and nutrition survey that is being carried out in the province of Attica.	M, F=3031 Aged >18yrs.	Greek	5 yrs	Not reported	To investigate potential effect of several socio-demographic and lifestyle habits on the incidence of obesity in a sample of CVD-free with normal and overweight adults at baseline during five years of follow-up.
16	Zamora et al., (2010)	Coronary Artery Risk Development in Young Adults (CARDIA)	M, F =4913, 18-30yrs	America	20 years	72%	Examine association between diet quality and the 20 yr risk of weight gain

#The Diet Quality indexes data adapted and updated from: 1) Aljadani H, Patterson A, Sibbritt D, Collins CE. The association between diet quality and weight change in adults over time: A systematic review of prospective cohort studies. (In: *Diet quality: an evidence-based approach*. Editor Victor Preedy. King's College London. *In Press* January 2012 (Aljadani et al., 2013c); 2) and Aljadani H, Patterson A, Sibbritt D, Collins CE. The association between dietary patterns and weight change in adults over time: a systematic review of studies with follow up. The Joanna Briggs Institute's Database of Systematic Reviews and Implementation Reports. 2013;11 (Aljadani et al., 2013a).

Table 3-2: Dietary intake methods and weight outcomes

	Author & year	Dietary intake method	Diet quality tool /How the score is derived using the diet quality tool	Weight outcome	Results
			A)Diet quality indexes#		
1	Aljadani et al. (2013d)	The Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2) FFQ.	ARFS contains seven main groups with different sub-scales. Vegetables Fruit Protein Grain Dairy Fat Alcohol	CWt	The ARFS shows no relationship with weight changes in this group of women. P>0.05
2	Aljadani et al. (2013b)	(DQESv2) FFQ.	The ARFS as described above. The FAVI is contains two sub-scales with top points 333 down to zero: The fruit sub-scale, which contains 13 items, The vegetable sub-scale which contains 24 items Consumption frequency of all fruit and vegetable items was scored using the full range of the FFQ Likert scale from zero to nine, with "never" scored as zero and "≥3 times per day" scored as nine points. The Aus-DQI:A person gives one point for each of: total fat <35% kJ saturated fat ≤7% kJ carbohydrate ≥45% kJ Sodium <2300 mg/d	CWt	The ARFS and FAVI were significantly associated with lower weight gain in the sub-sample of the plausible TEI young age women in the fully adjusted model. Those who achievied the highest score in FAVI (the top tertile) gained the lowest weight compared with last tertiles (=−1.6, CI: −2.4 to −0.3, *P*=0.01). Also those who were in the top tertile of ARFS gained less weight than those who were in the last tertile (=−1. 6kg (95% CI: −2.67 to −0.56), *P*=0.003).
3	Arabshahi et al. (2012)	1992 & 1996 – 129 item FFQ. In 2007 – 151 item FFQ.	DGI, consists of 11 items and each scored from zero to ten points which included the following; Vegetables and legumes Fruit Total cereals Meat and alternatives Total dairy Diet variety	CBMI, CWc	1) Men with a higher DGI score gained less BMI and Wc over time. Those in the highest quartile of DGI (86.4 to 122.9 scores) had the lowest gain in BMI compared with those in the lowest quartile with scores 22.2 to 62.3 point of DGI, (0.05v, 0.11kg/m2/year, with 95% CI: (0.00, 0.09) and (0.06, 0.16); p=0.01) and in Wc (0.04v, 0.26cm/year, p=0.04). 2) In women, the DGI score was not associated with any change in anthropometric measures.

			Saturated fat Alcoholic beverages Added sugars Extra foods Proportion of lean meat relative to total meat		
4.	Asghari et al. (2012)	2 x 24hr recall, at approx. 10 day interval.	HEI-2005 developed by Guenther, et al. (2008) but omitting alcohol and simplified the scoring of sodium DQI-I, four aspects of healthy diet including variety, adequacy, moderation and balance MDS proposed by Trichopoulou (2003) but with alcohol item removed and divided the grain into whole grains and refined grain. Processed meat and red meat were into one group. Polyunsaturated fatty acids (PUFAS) was substituted for monounsaturated fatty acids.	CBMI, CWc	1) The change of HEI-2005 associated with lower BMI during the follow-up period. (-0.022± standard error 0.011) with p=0.043. 2) The change of MDS, and DQI-I were not associated with changes in BMI and WC.
5	Beunza et al. (2010)	FFQ with 136 food item.	MDS. There are nine food items: The amount intake of these food are for M and F respectively: (1) Vegetables 550 and 500 (g/d) (2) Fruit and nuts 360 and 360(g/d) (3) Legumes 9 and 7(g/d) (4) Cereals, bread and potatoes 180 and 140(g/d) (5) Ratio of monounsaturated fatty acids to saturated fatty acids 1.7 and 1.7(g/d) (6) Moderate alcohol (10-15g alcohol /d) for M and 50-25g for F. (7) Fish 24 and 19 (g/d) (8) Meat and poultry120 and 90 (g/d) (9) Dairy products 200 and 190(g/m) A maximum of 9 points total from the last components.	1) Annual CWt 2) Incidence of wt gain (≥3 or ≥5kg during the first 2 or 4 years of follow up.	1) Participants in the highest tertile of MDS had the lowest average yearly wt gain relative to lowest tertile of MDS -.059kg/y; 95% CI: (-0.111, -0.008 kg/y). 2) There were significant inverse association between all MDS and wt change OR for incident of wt gain for highest tertile relative to lowest tertile: OR; CI 95% (2 yr) for: ≥3kg: 0.8(07, 0.9) OR: CI 95% (2 yr) for: ≥5kg. 0.76; CI:0.62-0.92 OR; CI 95% (4 yr) for: ≥3kg: : 0.80; CI:0.71-0.91 OR: CI 95% (4yr) for: ≥5kg. : 0.76; CI:0.64-0.9 3) Those in the highest tertile of MDS were less likely to have absolute wt gain relative to those in the lowest tertile.
6	Boggs et al. (2013)	Self-administered modified version of the Block-National Cancer Institute FFQ	AHEI-2010, 11 food and nutrient items, each scored 0 – 10 where 10 shows compliance to dietary recommendations. Vegetables Fruits Whole grains Nuts and legumes Long chain (omega 3) fatty acids (EPA + DHA) and PUFAS Sugar-sweetened beverages and fruit juice Red and processed meats Trans fat Sodium Alcohol DASH contains eight item with maximum 80 points:	CWt, Incidence of obesity.	1) Overall analysis, it found no relationship between AHEI-2010 and DASH during the follow-up period. 2) In analysis which measured the diet quality scores at two occasions and considered the initial BMI, it found consistently higher quality diet scores were inversely associated with obesity incidence among women with a normal BMI (18.5–24.9kg/m^2) at baseline. When comparing highest with lowest quintiles of AHEI-2010 in this group the HR = 0.76 (CI 95%: 0.58, 0.98) vs 0.68 (CI: 0.53, 0.88). 3) No significant association for women who were overweight (BMI 25-29.9kg/m^2) at baseline. HR 0.85 (CI 95%: 0.67, 1.07).

			Fruits and fruit juice Vegetables Nuts and legumes Whole grain Low fat dairy Sodium Red and processed meat Sweet sugar beverages		
7	Forget et al. (2013)	3 day food dairy (2 weekdays, 1 weekend day)	Healthy Diet Score (HDS), 5 components ≥4.5C F/V per week ≥2 serves fish/week ≥3 serves fibre rich whole grains/day <2300mg sodium/day ≤36oz sugar sweetened beverages/ week	CBMI	Participants with a poor HDS (0-1/5) at baseline were more likely to gain more weight by 0.70 kg/m^2 over the 4 years compared with intermediate or ideal scores (p = 0.03).
8	Kimokoti et al. (2010)	3 day estimated food records	Framingham Nutritional Risk Score (FNRS19-nutrients: (1) Total energy(kJ) (2) Protein (% energy) (3) Total fat (% energy) (4) Monounsaturated fat (% energy) (5) Saturated fat (%energy) (6) Alcohol (% energy) (7) Cholesterol (mg/4184kJ) (8) Sodium (mg/4184kJ) (9) Carbohydrate (%energy) (10) Polyunsaturated fat (% energy) (11) Fiber (g/4184kJ) (12) Calcium (mg/4184kJ) (13) Selenium (ug/4184kJ) (14) Vitamin C (g/4184kJ) (15) Vitamin B-6 (g/4184kJ) (16) Vitamin B-12 (ug/4184kJ) (17) Vitamin E (g/4184kJ) (18) Folate (ug/4184kJ) (19) Beta-carotene (ug/4184kJ).	CWt	FNRS was not associated with weight gain in both M and F; p= 0.16 and p=0.61 respectively. F who were former smokers and who were in the lowest tertile of FRNS gained an additional 5.2kg compared with former smokers who were in the highest tertile of FNRS; P for trend=0.03. FNRS was not a predictor for wt gain either in M or F.
9	Lassale et al. (2012)	24hr recall	15 – point PNNS-GS with top 15 points. Eight items are related to food servings including fruits, vegetables, starchy food, whole grain, dairy products, meat, seafood, added fat and vegetables fat. Four related to moderation in consumption, including sweet, salt, water and soda, alcohol. Additional one point to physical activity. Negative	CWt, BMI	1) In men (n= 1680), there was a statistically significant inverse association between all diet quality index scores, except for the MSDPS, and weight change and the risk of obesity. More specifically, a higher dietary index score of one standard deviation resulted in a lower weight gain during the follow up

			points deducted for excessive consumption of salt, sweets and when energy intake exceeds the needed energy level by more than 5%. DQI-I adapted for French populations from DQI-I developed by Kim (2003) with 4 components (variety, adequacy, moderation and balance) DGAI, range 0-20 and divided into 2 sets of components (11 food including dark green vegetables, orange vegetables, and all grains) and 9 healthy choices for example consuming >50% of grains as whole grains) MDS developed by Trichopoulou with range 0-9, based on 9 components (intake of grains, veg, fruit and nuts, milk and dairy, meat, legumes, alcohol, fish ratio of monounsaturated fatty acids to saturated fat. The rMED, 0 – 18 and based on the same components as MDS except MUFA and saturated fat ratio is replaced with olive oil consumption. MSDPS, 13 components, whole grain, cereals, fruit, veg, dairy, wine, fish, poultry, olives, legumes, nuts, potatoes, eggs, sweets, meats and olive oil.		period, ranging from: 0.40 (95% CI; -0.71 to -0.1) for PNNS-GS, to 0.87 (95%CI -1.15 to -0.58) for rMED. 2) The risk of becoming obese was strongly reduced for men in the top quartile compared to the bottom quartile with: OR= 0.20, CI 95%; 0.10, 0.42 for the DGAI. OR= 0.45, CI 95%; 0.26, 0.79 for the PNNS-GS and OR= 0.45, CI 95%; 0.27, 0.76 the MDS. 3) In women, there was no association between dietary scores and obesity risk.
10	Mendez et al. (2006)	Diet history with >600 items	MDS. A maximum of 8 points derived from the following components: (1) Fish (g/MJ) (2) Vegetables (g/MJ) (3) Fruits and nuts (g/MJ) (4) Legumes (g/MJ) (5) Cereals (g/MJ) (6) The ratio of monounsaturated saturated fat(g/MJ) (7) Moderate ethanol intakes, defined as 5–25 g/d for women and 10–50 g/d for men. (8) Meat (g/MJ)	CWt in mean of follow-up 3.3 years	1) Participants in the highest MDS were less likely to be obese among overweight subjects. OR; (95% CI) of becoming obese for F and M respectively. 0.69, (0.54–0.89) 0.68, (0.53–0.89). 2) High MD adherence was not associated with overweight incidence in women or men. OR; (95% CI) of becoming overweight for F and M respectively. 0.99(0.78, 1.25). 1.11 (0.81-1.52).
11	Quatromoni et al. (2006)	3 day estimated food records	Diet quality index (DQI) 5-point DQI to assess adherence to key US dietary recommendations. One DQI point was contributed for each of five nutrients if (1) Total fat (<30%kcal) (2) Saturated fat (<10%kcal) (3) Carbohydrate (>50%kcal)] (4) Cholesterol (<300mg/d) (5) Sodium (<2400mg/d) DQI scores ranged from 0 to 5	CWt in 8 years	1) Participants in the highest DQI quintile gain less wt over 8 years; (P for trend <0.01). The mean ± SD of wt gain in F in the highest DQI quintile was 3.3±17.4 Ib compared with 8.0±13.0 Ib gained in those within the lowest DQI quintile. The mean ± SD of wt gain in M in the highest DQI quintile was 2.7±10.1 Ib compared with 5.1±13.3 Ib those in the lowest DQI quintile. 2)There is significant inverse association between the mean of DQI score for all participant and weight change in both adults; p =0.025 and p=0.008 respectively for M and F.
12	Romaguera et	FFQ	A revised MDS (rMDS). There is 11 component of this score as	CWt and	1) Those in the highest tertile of rMDS had less wt gain -0.16 kg

	al. (2010)		follow: (1) Vegetables, (2) Legumes (3) Fruit and nuts, (4) Cereals (5) Fish and seafood (6) Olive oil, (7) Moderate alcohol consumption (8) Meat and meat products (9) Dairy products Each part measured by g/1000kcal to express ED	Incidence of overweight	(CI 95%: -0.24, -0.07) and -0.04kg (-0.07, -0.02) for the combined results. 2) Overall results showed that a 2-point increased in the rMDS was associated with becoming overweight; OR (CI 95%) = 0.97 (0.95, 0.99)
13	Sanchez-Villegas et al. (2006)	FFQ with 136 food item	MDS. A maximum of 30 points total from the components: (1) Cereals (g/d) (2) Vegetables (g/d) (3) Fruits (g/d) (4) Legumes (g/d) (5) Fish (g/d) (6) Nuts (g/d) (7) Olive oil (g/d) (8) Moderate red wine consumption (g/d) (9) Meat and meat products (g/d) (10) Whole-fat dairy products (g/d).	1) Annual CWt and CBMI	1) The highest quartile of MDS gained less weight (0.65kg)(0.0.59, 0.8) compared with those in the lowest quartile P for trend 0.291 2) Participants at the highest quartile of MDS gained smaller in BMI 0.23 (0.12, 0.33) compared with those in lowest quartile of MDS. P for trend 0.279.
14	Wolongevicz et al. (2010)	3 day dietary record	Framingham Nutritional Risk Score (FNRS) 19-nutrients: (1) Total energy (kj) (2) Protein (%energy) (3) Total fat (%energy) (4) Monounsaturated fat (%energy) (5) Saturated fat (%energy) (6) Alcohol (%energy) (7) Cholesterol (mg/4184) (8) Sodium (mg/4184kj) (9) Carbohydrate (%energy) (10) Polyunsaturated fat (%energy) (11) Fiber (g4184kj) (12) Calcium (mg/4184kj) (13) Selenium (ug/4184kj) (14) Vitamin C (g/4184kj) (15) Vitamin B-6 (g/4184kj) (16) Vitamin B-12 (ug/4184kj) (17) Vitamin E (g/4184kj) (18) Folate (ug/4184kj) (19) Beta-carotene (ug/4184kj).	Incidence of overweight or obesity; BMI $\geq 25 km/m^2$.	FNRS was associated with incidence of overweight or obesity (p for trend =0.009). Women with lower diet quality were significantly more likely to become overweight or obese; OR: 1.76; CI: 95 %(1.16–2.69) times compared with those with highest diet quality. Higher; FNRS was associated with a reduce the risk of being overweight or obese.
15	Yannakoulia et al. (2009)	EPIC-Greece questionnaire, a validated semi-	MDS ranged from 0 to 55 based on M patterns pyramid. The patterns are consistence with: a) Daily consumption of non-refined cereals and products (like whole	Developing obesity	MDS was no related to the risk of developing obesity during the following-up period for those who were normal weight or over weight at baseline.

		quantitiave FFQ	grain bread, pasta, rice, etc., 8servings/day), vegetables (2–3servings/day), fruits (4–6servings/day), olive oil (in daily cooking as the main added lipid) and non fat or low-fat dairy products (like cheese, yoghurt, and milk, 1–2 servings/day), (b) Weekly consumption of potatoes (4–5servings/week), fish (4–5servings/week), olives, pulses and nuts (>4servings/week) and more rare poultry (1–3servings/week), eggs and sweets (1–3servings/week) and c) Monthly consumption of red meat and meat products (4–5 servings/month). d) Moderate consumption of wine (1–2wineglasses/day), which usually accompanies meals. e) Milk consumption is moderate, while of cheese and yogurt consumption is high. (Panagiotakos et al., 2006)		OR: 0.98, (95%:CI: 0.95, 1.03), p=0.51
16	Zamora et al. (2010)	Diet history	2005 DQI, 10 components with zero to 100 points: 3 addressed total fat, saturated fat and cholesterol 4 quantified adequate intake of reduced fat dairy, fruit, veg and grain. 3 addressed variety of intake, reducing consumption of energy dense, nutrient poor foods and sodium	CWt, BMI	1) For the Caucasian participants with BMI <25 at the start of the study, there was a significant inverse association between diet quality score and the risk of gaining ≥10 kg over the follow-up period. Each 10 point increased in DQI, associated with 10% lower risk of gaining ≥10 kg of weight during 20 years. 2) While amongst African American obese participants, it found that those with healthiest diet were gaining significant greater weight. Increased 10 points of DQI associated with a 15% higher risk of gaining 10 kg or more during the same follow-up period.

Wt: weight, CWt changes in weight during follow-up, CWc: changes in waist circumferences during follow-up, EI energy intake, BMI body mass index, FFQ food frequency questionnaire, ED energy density, PA physical activity

#The Diet Quality indexes data adapted and updated from: 1) Aljadani H, Patterson A, Sibbritt D, Collins CE. The association between diet quality and weight change in adults over time: A systematic review of prospective cohort studies. (In: *Diet quality: an evidence-based approach*. Editor Victor Preedy. King’s College London. *In Press* January 2012(Aljadani et al., 2013c); and 2) Aljadani H, Patterson A, Sibbritt D, Collins CE. The association between dietary patterns and weight change in adults over time: a systematic review of studies with follow up. The Joanna Briggs Institute's Database of Systematic Reviews and Implementation Reports. 2013;11 (Aljadani et al., 2013a).

Table 3-3: Quality assessment of included studies

	Authors	Is the sample representative of patients in the population as a whole?	Was everyone assessed at the same follow-up time?	Are the confounding factors identified and strategies to deal with them stated?	Are outcome assessed using objective criteria?	Was follow up carried out over a sufficient time period?	Were the people who withdrew described and included in the analysis?	Were the outcomes measured in reliable way?	Was appropriate statistical analysis used?	Ranking
					A)Diet quality indexes					
1	Aljadani et al. (2013d)	Y	Y	Y	N	Y	Y	Y	Y	7Y 1N
2	Aljadani et al. (2013b)	Y	Y	Y	N	Y	Y	Y	Y	7Y I N
3	Arabshahi et al. (2012)	Y	Y	Y	Y	Y	N	Y	Y	7Y 1N
4	Asghari et al. (2012)	Y	Y	Y	Y	Y	N	Y	Y	7Y 1 N
5	Beunza et al. (2010)	N	N	Y	N	Y	U	Y	Y	4Y 2N IU
6	Boggs et al. (2013)	Y	Y	Y	N	Y	N	N	Y	5Y 3N
7	Forget et al. (2013)	Y	Y	U	Y	Y	U	Y	Y	6Y 2U
8	Kimokoti et al. (2010)	U	Y	Y	Y	Y	U	Y	Y	6Y 2U
9	Lassale et al. (2012)	Y	Y	Y	Y	Y	N	U	Y	6Y I N 1 U
10	Mendez et al. (2006)	Y	Y	Y	N	Y	U	Y	Y	6Y 1N 1U
11	Quatromoni et al. (2006)	U	Y	Y	Y	Y	U	Y	Y	6Y 2U
12	Romaguera et al. (2010)	N	N	Y	N	Y	U	N	Y	3Y 4N 1U
13	Sanchez-Villegas et al. (2006)	N	Y	Y	N	Y	U	Y	Y	5Y 2N 1U
14	Wolongevicz et al. (2010)	U	Y	Y	Y	Y	U	Y	Y	6Y 2U
15	Yannakoulia et al. (2009)	Y	Y	Y	Y	Y	Y	Y	Y	8Y
16	Zamora et al. (2010)	Y	Y	Y	Y	Y	U	Y	Y	7Y 1U

N: no, Y: yes, U: unclear.

#The Diet Quality indexes data adapted and updated and Aljadani H, Patterson A, Sibbritt D, Collins CE. The association between dietary patterns and weight change in adults over time: a systematic review of studies with follow up. The Joanna Briggs Institute's Database of Systematic Reviews and Implementation Reports. 2013;11(Aljadani et al., 2013a).

Appendix 1: The JBI_MSTARA

Assessment for : Example - (2010)

Type: Primary
User:
Design: Comparable Cohort / Case Control Studies

	Criteria	Yes	No	Unclear
1)	Is sample representative of patients in the population as a whole?	○	○	○
2)	Are the patients at a similar point in the course of their condition/illness?	○	○	○
3)	Has bias been minimised in relation to selection of cases and of controls?	○	○	○
4)	Are confounding factors identified and strategies to deal with them stated?	○	○	○
5)	Are outcomes assessed using objective criteria?	○	○	○
6)	Was follow up carried out over a sufficient time period?	○	○	○
7)	Were the outcomes of people who withdrew described and included in the analysis?	○	○	○
8)	Were outcomes measured in a reliable way?	○	○	○
9)	Was appropriate statistical analysis used?	○	○	○

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Chapter 4 Overall Methods

4.1 Overview

The following chapter describes methods relevant to all studies conducted within this body of work. In particular, it presents the aims of the projects, study participants, and a snapshot of the ALSWH. This chapter also reports the general approach to statistical analyses used and a brief summary of each study conducted as part of my thesis.

4.1.1 Aim

The aims of this thesis are:

- To examine the relationship between diet quality as the independent variable and weight change as the dependent variable in Australian women (both young and mid-aged cohorts) from the Australian Longitudinal Study on Women's Health (ALSWH) over six years of follow-up.
- To identify any difference between various diet quality tools in determining the relationship between diet quality and weight change in the young cohort over a 6 year period.
- To test the relationship between different diet quality indexes and weight change over a 6 year period in sub-groups of ALSWH women with a healthy weight from the young cohort (2003-2009).
- To test the relationship between diet quality and incidence of overweight or obesity over a 6 year period in a sub-group of ALSWH women with a healthy weight from the mid-aged cohort (2001-2007).
- To identify any difference in weight change between those who eat a healthy diet compared with those whose diet quality decreased during nine years of follow-up (2001-2010) for mid-age women.

4.1.2 Study Sample and the Australian Longitudinal Study on Women's Health (ALSWH)

My study used data from women enrolled in the Australian Longitudinal Study on Women's Health (ALSWH). The ALSWH (Brown et al., 1996) was established in 1996 (baseline) and aimed to follow-up women for at least 20 years. The study recruited over 40,000 female participants in three cohorts, based on age; these were young women (18-22 years at baseline), mid-aged women (45-49 years at baseline) and older women (70-74 years at baseline). The over-arching aim of the ALSWH cohort study is to examine the social, psychological and physical predictors of a range of mental health, well-being and health outcomes and the use of health services over time. The National Health Insurance database (Medicare) was used as the sampling frame to recruit women because it is the most up to date and complete dataset for permanent residents in Australia. Participants were randomly selected from the Medicare database, and there was oversampling among women in rural and remote areas, who were recruited at double the rate of the other women. The reason for this was so that researchers could capture the variations related to health of women who lived in rural and remote areas, despite the small numbers as compared to the numbers of women living in urban areas. Identifying information was not available from Medicare for the researchers as women were randomly selected and sent invitations to participate via mail. Only once the invitations had been accepted and the women had signed consent to provide personal details, did the research team have access to identifiable data. The response rate for the first baseline survey was higher in mid-aged women (54%), than in the young women (41-42%), and the older women had the lowest response rate (37-40%). These women have been contacted via mail at intervals of 2-4 years during 19 years of follow-up. The participants of ALSWH have previously been shown to be representative of the Australian population of women in the same age groups (ALSWH, 2015).

The Australian Longitudinal Study of Women's Health has become a well-known cohort study internationally. Researchers from different disciplines (medicine, nutrition, public health, biostatistics, social sciences, and epidemiology) from both the

University of Newcastle and the University of Queensland have worked collaboratively to establish these cohorts, follow-up participants and promote the study. Their efforts have provided excellent opportunities, not just for expert researchers, but also for post-graduate students and early career researchers and PhD candidates from different disciplines nationally and internationally, as in my case, to learn and to conduct studies which contribute valuable knowledge and evidence to the Australian government who fund ALSWH and to the published literature. The ALSWH website (www.alswh.org.au/) provides more detailed information about the papers and abstracts published over the last 2 decades. The contribution of the studies conducted on the ALSWH have been classified by Lee and colleagues (Lee et al., 2005) into four major research areas :1) NCDs; 2) the use of Health services; 3) social factors and 4) methods, such as validation of elder abuse measures. The results of these studies assist in promoting issues related to women's health, both physical and mental. They also assist in promoting health policy and practice in health service usage.

The questionnaires used by ALSWH are self-reported and cover five major themes: 1) Time use; 2) Health, weight and exercise; 3) Violence against women; 4) Life stages and key events; and 5) Use of and satisfaction with health care services. The questionnaires are constructed in different formats, some with Yes/No answers and others with various likert scales and range of response categories, and the final question on all surveys provides an open space for women to add further information that they believe may be relevant. The baseline questionnaire was 24 pages in length with different numbers of questions, depending on the cohort. The first young cohort survey consisted of 94 questions with 252 items; the mid-aged survey included 100 questions with 285 items; while 80 questions with 260 items was used for the older cohort. All of the questionnaires that have been developed for the ALSWH can be found online on the official ALSWH website (www.alswh.org.au/).

Dietary data was collected from participants in Survey 3 for both the young and mid-aged cohorts of the ALSWH. The questionnaires for these surveys contained a separate section on usual eating habits over the previous 12 months. A specific food frequency questionnaire (FFQ) the Dietary Questionnaire for Epidemiological Studies Version 2

(DQESv2), developed by the Cancer Council of Victoria, was used for this purpose (Appendix 3). The DQESv2 has been previously validated in young women (Hodge et al., 2000b) and assesses intake of 74 food items and 6 alcoholic beverage types, over the past year. Usual consumption frequency of each food item is indicated on a 10-point Likert scale, ranging from 'never' up to 'three or more per day'. Additional questions assess the total number of daily serves of fruit, vegetables, bread, dairy products, eggs, fat spreads and sugar, as well as the type of bread, dairy products and fat spreads used. Nutrient intakes were computed using the food composition database of Australian foods (Australian Government, 2013b) and software developed by the Cancer Council of Victoria. The DQESv2 data from Survey 3 for both cohorts (young and mid-age) were used to calculate the Australian Recommended Food Score (ARFS - Appendix 4) for all of the analyses described in this thesis. Survey 6 for mid-age women contain only the ARFS not the DQESv2.

4.1.3 Ethics approval

The ALSWH received ethics approval from the Human Research Ethics Committees of the University of Newcastle and the University of Queensland, prior to commencing in 1996. Researchers who are granted permission to utilise the data collected during this study are covered under the original ethics application.

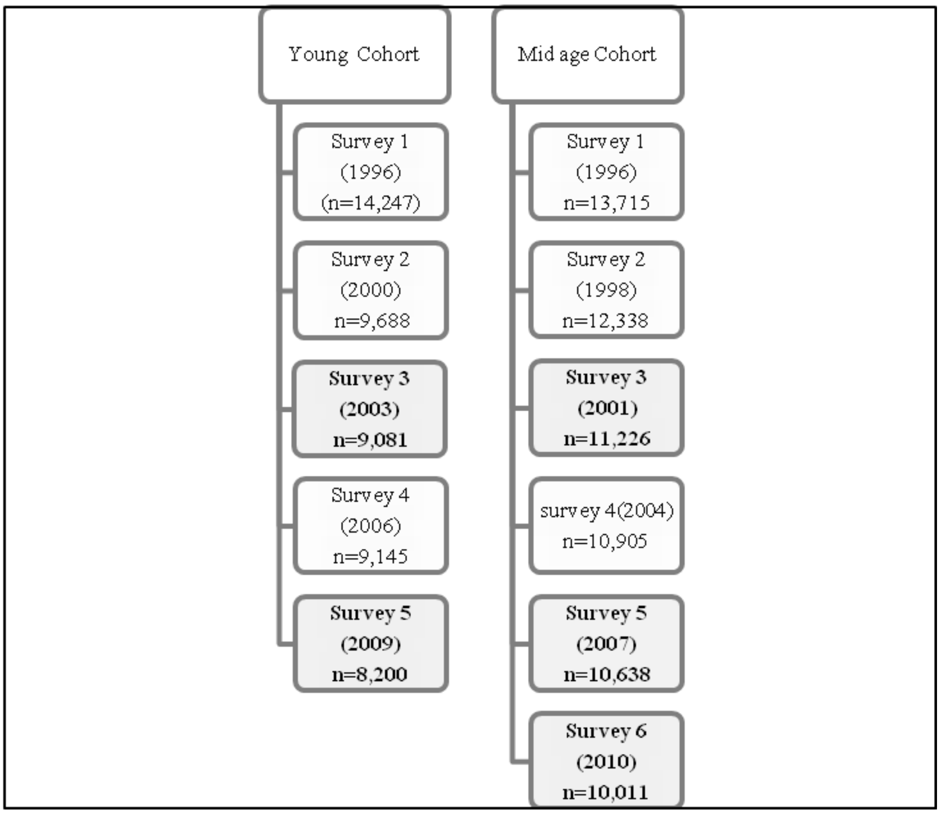
4.1.4 Data acquisition

ALSWH data is available for use by any researchers with approval of the study plan in an expression of interest (EOI). An EOI for my PhD work was submitted with the title "Relationship between Diet Quality and Body Mass Index". The EOI requires researchers to provide a summary of the project, the aims, the surveys and data to be used and a statistical plan in order that the methods can be assessed for validity and to ensure no overlaps with other project proposals. The EOI for my PhD work was granted approval on 13/10/2011 and given the designation A342. Both a Memorandum of Understanding and a Confidentiality Statement were signed and lodged with ALSWH by all researchers involved in the project.

4.1.5 Participants of the thesis

This thesis includes participants from the ALSWH young and mid-age cohorts. Survey 3 (2001) for the mid-aged cohort (aged 50-55 years) and Survey 3 (2003) for the young cohort (aged 25-30 years), both used data from the DQESv2 (FFQ). Survey 5 (2009) for the young cohort (aged 31-36 years), included the DQEv2 (FFQ) data. For the mid-aged cohort (56-61 years) Survey 5 (2007) included only the sub-set of DQEv2 (FFQ) questions used to calculate the Australian Recommended Food Score (ARFS). Survey 6 (2010) for the mid-age cohort (aged 59-64) included the full FFQ data. Figure 4-1 details the surveys conducted, with numbers of women who responded to each survey for the young and mid-age cohorts. The surveys shaded in grey are those that I used in my studies.

Figure 4-1: Number of participants in each survey for both young and mid age cohorts.



4.1.6 Exclusion Criteria

The exclusion criteria included:

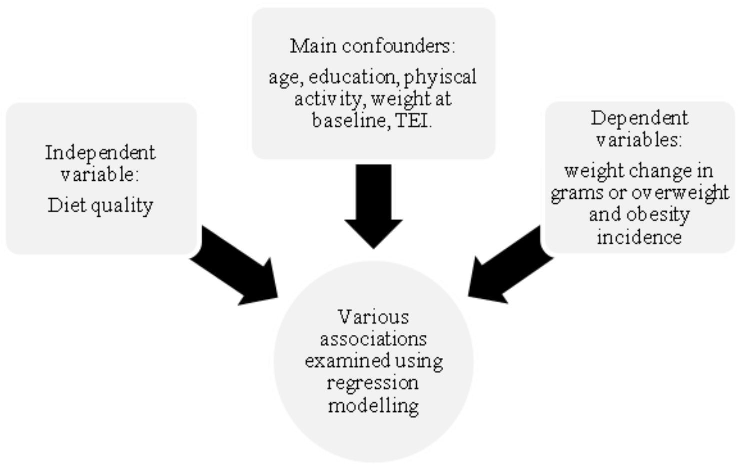
- Those who had cancer, type 2 diabetes, hypertension or cardiovascular disease (CVD), or were pregnant at baseline.
- Those with missing data for weight and/or BMI at baseline or follow-up; and
- Those who were underweight with a BMI ≤17kg/m², or those who were overweight or obese with a BMI >25kg/m² at baseline when performing logistic regressions.

4.1.7 The independent variable – Diet Quality

Figure 4-2 shows the overall study design. Diet quality was measured by one or more of the following indexes in each analysis: the ARFS, Au-DQI, and FAVI (scoring methods for each provided in detail in the following chapters).

The data on dietary intake were collected using the DQESv2 with 74 food items and 6 alcoholic beverage types over the previous year. In this thesis, the data used are data at 2001or 2003, as baseline dietary intake, and 2009 or 2010 as the second data point for examining the change in dietary intake in either the young or mid-age cohorts prospectively.

Figure 4-2: Overall design of the analyses conducted on the young and mid-aged cohorts of the Australian Longitudinal Study of Women's Health (ALSWH)



ARFS: Australian Recommended Food Score, TEI: Total Energy Intake

4.1.8 The dependent variable – weight change

The main outcome was weight change (kilograms) in women from 2001 to 2007 for the mid-age cohort and from 2003 to 2009 for the young cohort. The secondary outcomes were development of overweight or obesity in healthy weight women from 2001 to 2007 for the mid-age cohort and from 2003 to 2009 for the young cohort. Development of overweight and obesity was defined as developing a BMI ≥25kg/$m^{2.}$ or a BMI ≥30kg/m^2 respectively. Weight and height were self-reported in all surveys. BMI was calculated using the format: weight (kg)/ (height (in metres squared)). BMI was classified as follows: underweight BMI<18.5kg/m^2; healthy or normal weight 18.5≤BMI<25kg/m^2; overweight 25<BMI<30kg/m^2; obese BMI≥30kg/m^2. Weight change was calculated by subtracting weight at the last follow-up point from the baseline weight.

4.1.9 Confounders (Co-variates)

Multiple variables were considered as confounders in the analyses within this thesis.

4.1.9.1 Weight at baseline

Weight in kilograms was used as a continuous variable in the regression models.

4.1.9.2 Physical activity

Physical activity (PA) measured in metabolic equivalent per minute (MET.mins), according to the following equation: (3 * minutes walking) + (4 * minutes moderate activity) + (7.5 * minutes vigorous activities). PA was classified into four categories according to energy expenditure per week. The four categories were: Nil/sedentary (0 to <40MET.min/week); low (40 to <600MET.min/week); moderate (600 to <1200MET.min/week) and high (≥1200MET.min/week) (Brown & Trost, 2003, Brown & Bauman, 2000). There were two main questions regarding physical activity. The first question was *"How many times did you do each type of activity last week?"*, with the four response categories being: walking briskly, moderate leisure activity, vigorous activity and vigorous household or garden chores. All of these activities include examples to make it clear for the participants. The second question asked participants: how much time they spent in each of the activities over the last week, in hours and minutes (ALSWH, 2015).

4.1.9.3 Education

Education is a categorical variable organised into six groups, based on the participant's response to a question about the highest qualifications they have obtained. The groups are: no formal qualifications; school certificate; higher school certificate; trade/apprenticeship; university degree; higher university degree (ALSWH, 2015).

4.1.9.4 Smoking habits

Women were categorised into three groups according to smoking status: current smoker; quit smoking; or never smoked. These categories were formed using three questions about smoking: whether they currently smoked or not; and whether they had stopped smoking (ALSWH, 2015).

4.1.9.5 Menopausal status

Menopausal status and hormone replacement therapy were defined for the mid-age women only. There were six categories defined as follows: surgical menopause; hormone replacement therapy (HRT) use; oral contraceptive pill (OCP) use; pre-menopausal; peri-menopausal; and post-menopausal. The questions from the surveys used to define these categories were: *Have you (ever) had a hysterectomy?; Have you had a hysterectomy in the past 3 years?; Have you (ever) had both ovaries removed ?; Have you had both ovaries removed in the past 3 years?; Are you currently on hormone replacement therapy (HRT) ?; Are you currently taking the oral contraceptive pill for any reason?; Have you had a period or menstrual bleeding in the last 12 months?; Have you had a period or menstrual bleeding in the last 3 months?; Within the last twelve months; are your periods:- Less frequent;- About the same; More frequent; Changeable?* (ALSWH, 2015).

4.1.9.6 Total energy intake (TEI)

The total daily energy intake was used as a continuous variable and derived from the DQES_v2 FFQ data produced by Cancer Council Victoria. TEI was measured in kilojoules per day from both Food and alcohol intake.

4.1.9.7 Residential Location of participants

For the location of residence women were classified into three groups: Rural, Remote and Metropolitan Areas (RRMA). The Department of Primary Industries and Energy (1994), and the then titled Department of Human Services and Health (known now as Australian Government Department of Health) developed this area's classification. It was based on size, remoteness and distance to services and facilities and is consistent for all work with ALSWH data

4.1.9.8 Age

Date of birth was used to calculate age at each survey as a continuous variable in years.

4.1.10 Statistical analysis

All statistical analyses used the statistical program STATA, version 11. (StataCorp, 2011) Descriptive analyses for both the young and mid-age cohorts were conducted separately. The characteristics of the participants for each cohort were described and the distribution of the data checked for each variable. Histograms and box-plots were created for each continuous variable to check the normality of the data and means and medians were compared for each variable. Based on the results of this statistical testing the following analyses were employed: the mean and standard deviation were presented if the distribution of the data was normally distributed; the median and inter-quartile range was used to describe the variable if its distribution was not normal.

For the main analysis in all studies, three different models were used: 1) a crude model, which had diet quality as the independent variable and weight change as dependent variable; 2) a model which examined diet quality and weight change, adjusted for age, BMI at baseline, smoking, area of residence, education, physical activity, menopausal status; 3) a model similar to model 2, with the additional confounder of total energy intake (TEI). In the linear regression models weight change in kilograms (kg) was used as the dependent variable, and the coefficient was estimated. For incidence of overweight and/or obesity, logistic regression models were used to estimate the odds ratio for developing overweight and/or obesity in women over time.

Summary of the study samples for individual studies within this thesis

First analysis on the young women (Chapter 4)

Title: Diet Quality, measured by fruit and vegetable intake, predicts weight change in young women

Aim: To investigate the relationship between diet quality and weight gain in young women from the ALSWH, using three different diet quality indexes, the Australian Recommended Food Score (ARFS), Australian-DQI (Aus-DQI), and the Fruit and Vegetable Index (FAVI).

Sample: Participants for this analysis were drawn from the young women's cohort. Baseline (2003, aged 27.6±1.5years) and the six-year follow-up (2009, aged 33.7±1.5years) were the two data time points selected for this analysis. Participants were excluded if they had been diagnosed by a doctor as having diabetes, heart disease, or cancer (excluding skin cancer), or if they were currently pregnant. Of the 9081 young women at baseline, 8239 met the inclusion criteria. At follow-up, 8 200 of these young women were available, with 5856 eligible for inclusion. Complete baseline and follow-up data for weight, diet and confounders were available for 4287 women.

Second analysis on the young women (Chapter 5)

Title: Diet quality predicts six year weight change in healthy weight young women

Aim: To examine the relationship between diet quality, as measured by two diet quality indexes simultaneously, the ARFS and the FAVI, and prospective weight change over six years in a sample of disease-free, healthy weight young women from the ALSWH.

Sample: Participants for this analysis were drawn from the young cohort (mean age 27.6±1.5years, in 2003) and the six year follow-up (mean age 33.7±1.5 years, in 2009). Participants were excluded if they reported having a diagnosis of type 2 diabetes, impaired glucose tolerance, heart disease, any type of cancer (excluding skin cancer), were currently pregnant, or were not in the healthy weight range at baseline (2003). The number of those who were eligible and had complete data for weight and diet was 4083 women.

First analysis on the mid-aged women (Chapter 6)

Title: The Australian Recommended Food Score did not predict weight gain in mid-aged Australian women during six years of follow-up

Aim: To evaluate the relationship between diet quality, as measured by the Australian Recommended Food Score (ARFS), and six-year weight change in mid-aged Australian women.

Sample: This study was conducted in the mid-aged cohort. The follow-up time was from 2001 to 2007. These analyses were conducted in a sub-sample of women who were disease-free, by excluding those who self-reported any of the following conditions at either baseline or follow-up: type 2 diabetes; impaired glucose tolerance; heart disease (including heart attack and angina); stroke or any type of cancer, with the exception of skin cancer. Of the 11,226 mid-aged women recruited at baseline, 959 were excluded (diabetes n=320; impaired glucose tolerance n=69; heart disease and stroke n=218; cancer n=352) leaving 10,267 women who were eligible for the analysis. The total sample at follow-up was 10,638 women, with 1,538 women excluded (diabetes n=705; impaired glucose tolerance n=154; heart disease and stroke n=361; cancer n=318). The total number of women who were eligible for this study at follow up was 9,100. The total number of observations included in the analysis after excluding ineligible persons and those with missing ARFS or weight change data was n=7,715.

Second analysis on the mid-aged women (Chapter 7)

Title: Diet quality and six year risk of overweight and obesity amongst mid-age Australian women who were initially in the healthy weight range

Aim: To investigate whether diet quality, as measured by the ARFS, is associated with six-year risk of becoming overweight or obese.

Sample: A total of 1,107 women from the mid-aged cohort (47.6 to 55.8 years at baseline) and who were in the healthy weight range ($18.5 \leq BMI < 25 kg/m^2$), were free of chronic disease.

Third analysis on the mid-aged women (Chapter 8)

Title: Prospective changes in diet quality in mid-age Australian women and its association with weight change during nine years of follow-up

Aim: To examine the relationship between changes in diet quality, measured by the ARFS, and weight change over nine years of follow-up in mid-aged women.

Sample: The total number of those who reported plausible TEI and free of disease at baseline was 1,999 women.

Table 4-1: Summary of the studies conducted for this thesis

	Chapter/ Section	Aim	Paper title	Cohort	No/Criteria of participants	The diet indexes	Statistical methods
1	Four/1 The First analysis on young women	To examine the relationship between diet quality as the independent variable and weight change as the dependent variable in the young Cohort from the ALSWH over six years of follow-up. To identify any difference between various diet quality tools in determining the relationship between diet quality and weight change in young Cohort over a 6 year period.	Diet Quality, Measured by Fruit and Vegetable Intake, Predicts Weight Change in Young Women Authors: Authors: H. Aljadani, A. Patterson, D. Sibbritt, M. Hutchesson, M. Jensen, and C.E. Collins. **Published** in Volume 2013 (2013), 10 page in Journal of Obesity	Young	Young women (4287, with 1356 women identified as plausible subsample), aged 27.6 ± 1.5 years at baseline and followed from 2003 to 2009.	Tertiles of baseline of the Australian Recommended Food Score (ARFS), Australian Diet Quality Index (Aus-DQI), and Fruit and Vegetable Index (FAVI).	Multivariate linear regression
2	Five/2 The second analysis on the young women	To test the relationship between different diet quality indexes and weight change over a 6 year period in sub-groups of ALSWH women with a healthy weight from the young cohort (2003-2009).	The association between diet quality and the risk of overweight and obesity Authors: H. Aljadani; L. Al-Oboudi; A. Patterson; D. Sibbritt and C.E. Collins It will be submit to the Journal of Australian and New Zealand Public Health.	Young	Healthy weight young women from the ALSWH at the start followed from six years (2003-09)	Baseline of the ARFS and FAVI.	
3	Six/2 The first analysis on mid-aged women	To examine the relationship between diet quality as the independent variable and weight change as the dependent variable in mid-age Australian women from the Australian Longitudinal Study on Women's Health (ALSWH) over six years of follow-up.	The Australian Recommended Food Score did not predict weight gain in mid-age Australian women during six year of follow-up Authors: H. Aljadani; D. Sibbritt; A. Patterson; and C.E. Collins **Published** 2013 in Volume 37(4), pages 322-28. Journal: The Australian and New Zealand Journal of Public Health	Mid-age women	Mid age women who were disease-free, followed for six years.	Baseline of the ARFS	Multivariate linear regressions
4	Seven/3 The second analysis on the mid-aged women.	To test the relationship between diet quality and incidence of obesity and overweight over a 6 year period in sub-groups of ALSWH women with a healthy weight from the mid-aged cohort (2001-2007).	Diet quality and six year risk of overweight and obesity amongst mid-age Australian women who were initially in the healthy weight range Authors: H. Aljadani; A. Patterson; D. Sibbritt and C. E. Collins It is under review in the Health Promotion Journal of Australian	Mid-age women	Healthy weight mid-age women who were disease-free and plausible TEI, followed for six years	Baseline of the ARFS	Multivariate logistic regressions
5	Eight/3 The third analysis	To examine if there is any difference in weight change between those who eat healthier diet quality compared with those who decreased diet quality during nine years	Prospective change in diet quality and its relationship with weight change in mid-age women Authors: H. Aljadani; A. Patterson; D. Sibbritt and C.E. Collins.	Mid-age women	Mid-age women who were disease-free and plausible TEI at baseline, followed for	Tertiles of the changes of the ARFS (2001-2010)	Multivariate regression regressions

on the mid-aged women.	of follow-up (2001-2010) for mid-age women	It submitted to the Journal of Public health	nine years

Chapter 5 The First analysis on Young Women, (Section 2)

This article was published in 2013

Authors: Aljadani, Patterson, Sibbritt, Hutchesson, Jensen, and Collins.

Title: Diet quality, measured by fruit & vegetable intake, predicts weight change in young women

Journal: Journal Of Obesity (2013)

The Work presented in the manuscript was competed with collaboration with the co-authors (Appendix 6**)**

5.1 Overview

The literature review published on the relationship between diet quality and weight change in cohort based studies shows that there is no such study which has examined the association between diet quality indexes based on food items only. In addition, there have been very few studies that measured more than two dietary patterns using different indexes. Thus, this study reported in Chapter Five presents the analysis run in a sub-cohort of young women from the ALSWH.

5.2 Abstract

This study investigates the relationship between diet quality and weight gain in young women. Young women (n=4,287, with 1,356 women identified as plausible sub-sample aged 27.6±1.5 years at baseline) sampled from the Australian Longitudinal Study on Women's Health study completed a food frequency questionnaires in 2003, which was used to evaluate diet quality using three indices: Australian Recommended Food Score (ARFS); Australian Diet Quality Index (Aus-DQI); and Fruit and Vegetable Index (FAVI). Weight was self-reported in 2003 and 2009. Multivariate linear regression was used to examine the association between tertiles of each diet quality index and weight change from 2003-09. The ARFS and FAVI were significant predictor of 6-year weight change in this group of young women, while Aus-DQI did not predict weight change ($p>0.05$). In the fully adjusted model, those who were in the top tertile of the ARFS significantly gain lower weight gain compared with the lower tertile for the plausible TEI sub-sample, (β=-1.6 kg (95% CI:-2.67 to -0.56), $p=0.003$). In the fully adjustment model, young women who were classified in the highest FAVI tertile, and gained significantly less weight than those in the lowest tertile for the plausible TEI, (β=-1.6kg (95% CI:-2.4 to -0.3), $p=0.01$. In conclusion, overall diet quality measured by the ARFS and the frequency and variety of fruit and vegetable consumption may predict long term weight gain in young women. Therefore, health promotion programs encouraging frequent consumption of a wide variety of fruit and vegetables are warranted.

5.3 Introduction

Recently, there has been a focus on evaluating the association between the nutritional quality of dietary intake and health outcomes (Collins et al., 2008). Several studies have reported an inverse association between higher diet quality, all-cause and chronic disease specific mortality (Collins et al., 2008). Our recent systematic review demonstrated a significant association between poor diet quality and greater weight gain (Aljadani et al., 2013c).

A recent study demonstrated in a nationally representative sample in the United States, that younger adults have poorer diet quality, when compared with both children and older adults (Hiza et al.). The evidence indicates that early adulthood is a high-risk period for weight gain, especially for females (Norman et al., 2003, Adamson et al., 2007). For example, the Australian Longitudinal Study on Women's Health (ALSWH) data shows that when young women reach their forties they will be heavier than mid-aged women are now (Adamson et al., 2007). However, our systematic review found limited studies that have specifically examined the association between diet quality and weight gain amongst young women (Aljadani et al., 2013c). Greater understanding of the association between diet quality and weight gain among young women, may assist with the development of strategies for preventing weight gain during this life-stage.

In this study we are analysing the relationship between three different approaches of diet quality indices including: index based on the food groups, which is the Australian Recommended Food Score (ARFS), and nutrients based approach, the Diet Quality Index (DQI). In addition, we developed a new brief index that, based on consumption frequency and variety of fruit and vegetables items, is called the Fruit and Vegetables Index (FAVI). This tool can help to reduce the burden to both participants and researchers in terms of measuring diet quality. It can be used to predict weight change, and therefore weight gain prevention or treatment interventions. Evidence suggests that greater consumption of fruit and vegetables in adults is associated with lower weight gain in longitudinal studies (Ledoux et al., 2011) and greater weight reduction in the intervention studies (Ledoux et al., 2011).

Notably, two studies exploring the association between diet quality and weight gain among mid-aged women have shown mixed results. A longitudinal study, conducted in an American mid-aged population, demonstrated that those who achieved the highest score on the DQI had a smaller weight gain (3 pounds) than those who achieved the lowest DQI score (5-8 pounds) during eight years of follow-up (Quatromoni et al., 2006). In contrast, we have previously demonstrated that overall diet quality measured using the ARFS, did not predict weight gain in a sub-sample of mid-aged women from the ALSWH (Aljadani et al., 2013d).

Therefore, the aim of this study was to investigate the relationship between diet quality and weight gain in young women from the ALSWH, using three different diet quality indices ARFS, Australian-DQI (Aus-DQI), and the Fruit and Vegetable Index (FAVI).

5.4 Materials and Methods

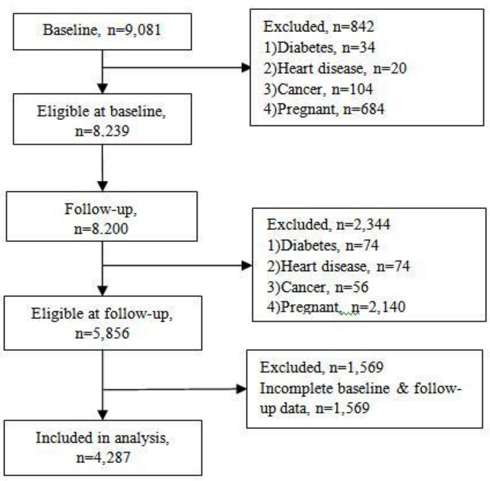
5.4.1 Subjects

The population is a subset from the ALSWH cohort study. ALSWH recruited women into three cohorts according to age at baseline (young, mid-aged and older). Further details of the cohort are published elsewhere (Brown et al., 1996). Participants in the current analysis were drawn from the young women's cohort. Baseline (2003, aged 27.6±1.5years) and the six year follow-up (f/u) (2009, aged 33.7±1.5years) were the two data time points selected for the current analyses. Participants were excluded if they had been diagnosed by a doctor as having diabetes, heart disease or cancer (excluding skin cancer), or if they were currently pregnant. Of the 9081 young women at baseline, n=8239 met the inclusion criteria. The response rate at follow-up totalled n=8,200 young women, with n=5856 eligible for inclusion. Complete baseline and follow-up data for weight, diet and confounders were available for 4,287 women (Figure 5-1).

5.4.2 Anthropometry, demographics & other health behaviours

Weight was self-reported at baseline (2003) and at follow-up (2009), in stones or kilograms (kg) to the nearest pound or gram, respectively. All data were converted to kilograms. Weight change (Δ) was calculated as the absolute difference (kg) in weight at follow-up from baseline. Participants self-reported their frequency of walking, moderate and strenuous physical activity (PA) (Brown et al., 2004). There are two questions, taken from the National Health Surveys which are validated and show reliability (Brown et al., 2004), The questions were used to derive a PA score in metabolic equivalents (METs) per minute (MET.mins) at baseline. The total MET minutes were calculated as follow: (3× minutes walking) + (4.0× minutes moderate activities) + (7.5 × minutes vigorous activities) (Brown & Bauman, 2000). The cut points of PA were as follow: Nil/sedentary 0 <40MET minutes/week, Low 40 <600MET minutes/week, moderate 600 <1200MET minutes /week and high physical activity ≥1200MET minutes/week. Highest qualification obtained was self-reported as: 'no formal qualifications', 'school certificate', 'higher school certificate', 'trade/apprenticeship', 'university degree or higher university degree'. Numbers of births were classified as: 'no births', 'one to two births', '≥three births'. The location of residence definitions used in the ALSWH dataset are taken from the ABS classifications. For this study, each region was classified as: urban (with 100,000 or more people), rural (with 200-999 people) and remote (<200 people). Relationship status was classified as 'married', 'de facto', 'separated', 'divorced', 'widowed' or 'single'. Participants self-reported smoking status as 'current smoker', 'never smoker', or 'ex-smoker'. The study was approved by the University of Newcastle and the University of Queensland Human Ethics committees and the current analysis on 13 /10/2011 (EOI A342).

Figure 5-1: Flow chart of participant selection for analyses



5.4.3 Dietary assessment

Baseline self-reported dietary intake was assessed using a food frequency questionnaire (Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2), Cancer Council of Victoria). The DQESv2 has been previously validated (Hodge et al., 2000b, Ireland et al., 1994) and assesses intake of 74 food items over the past 12 months. Usual consumption frequency of each food item is indicated on a ten-point likert scale, ranging from *'never'* up to *'three or more per day'*. Additional questions assessed the total number of daily serves of fruit, vegetables, bread, dairy products, eggs, fat spreads and sugar, as well as the type of bread, dairy products and fat spreads used. Nutrient intakes were computed using a food composition database of Australian foods (NUTTAB 1995, Australian Government Publishing Service, Canberra) and software developed by the Cancer Council of Victoria.

5.4.3.1 Australian Recommended Food Score (ARFS)

The ARFS is a food based index adapted to the Australian Adult population by Collins et al. (2008), from the original US version of the Recommended Food Score by Kant et al. (2000). The optimal ARFS reflects greater adherence to Dietary Guidelines for Australian Adults (2003). The ARFS ranges from zero to a maximum score of 74, with a higher score indicating greater diet quality. The seven sub-scales with different maximum points include vegetables (22 points), fruit (14 points), protein foods (14 points), grains (14 points), dairy (seven points), fats (one point), and alcohol beverages(two points) (Collins et al., 2008). Each food item is scored as one or zero, with an additional score for food quality. Scoring is independent of reported amounts of food, such that items consumed less than once a week scored zero and those consumed once a week or more scored one.

5.4.3.2 Australian Diet Quality Index (Aus-DQI)

The DQI was chosen as studies have shown that higher scores on this index are associated with lower weight gain (Quatromoni et al., 2006). A longitudinal study, conducted in a mid-aged US population, demonstrated that those who achieved the highest Diet Quality Index (DQI) scores had a smaller weight gain (3 pounds) than those who achieved the lowest DQI score (5-8 pounds) after eight years of follow-up

(Quatromoni et al., 2006). As part of the adaptation of the US DQI to the Aus-DQI, the scoring was adjusted to incorporate the Australian Nutrient Reference Values (Aus NRVs) (NHMRC, 2013b, Dietary Guidelines for Australian Adults, 2003). The original DQI was designed to evaluate adherence to the fourth edition of the Dietary Guidelines for Americans (1995) and each participant achieved one point for each of the following nutrients: "total fat (<30%kcal), saturated fat (<10%kcal), cholesterol (<300mg/d), sodium (<2400mg/d), and carbohydrate (>50%kcal)" (Quatromoni et al., 2006). The Aus-DQI was adapted to Australian recommendations. However, given there is currently no Australian recommendation for the intake of cholesterol, this sub-scale was omitted. In the Aus-DQI, each participant gets a maximum of one point for each of four sub-scales: total fat <35%kJ, saturated fat ≤7%kJ, carbohydrate ≥45%kJ and sodium <2300mg/d. These targets were set according to Australian and New Zealand Nutrient Reference Values (NHMRC, 2013b). The total Aus-DQI score ranges from zero to four points.

5.4.3.3 Fruit and Vegetable Index (FAVI)

Evidence suggests that greater consumption of fruit and vegetables in adults is associated with lower weight gain in longitudinal studies (Ledoux et al., 2011) and greater weight reduction among overweight and obese participants in the intervention studies (Ledoux et al., 2011). Fruit and vegetable consumption data, derived from the baseline DQESv2, were used to inform the development of the FAVI. The FAVI is divided into two sub-scales: the fruit sub-scale, which contains 13 items, including canned or frozen fruit and fruit juices, and 11 types of fresh fruit, such as oranges, apples, pears and the vegetable sub-scale which contains 24 items, including potatoes cooked without fat, tomato, zucchini, mushroom, celery, and beans. Consumption frequency of all fruit and vegetable items were scored using the full range of the FFQ Likert scale from zero to nine, with 'never' scored as zero and '≥3 times per day' scored as nine points. In the FAVI score zero points are awarded for those who consume no items of fruit and vegetables. One point is awarded for consuming each fruit or vegetable item less than once per month, two points for one to three times per month, three points for once per week, with an additional point awarded on an increasing scale for each additional frequency response category up to a maximum of nine points for consuming an item three or more times per day. The maximum possible score is 117 for the fruit sub-scale and 216 for the vegetable sub-scale, giving a maximum total FAVI score of 333 points. A higher FAVI score indicates a greater variety and frequency of usual fruit and vegetable consumption.

5.4.4 Statistical analysis

Data were assessed for normality, and presented as means and standard deviations. Results were considered statistically significant if $p<0.05$. Weight and macronutrient variables were treated as continuous variables. Each dietary quality index was categorised into tertiles based on the distribution of the total number of participants included in the study, to give approximately equal numbers in each tertile. For each diet quality index, data between the tertiles were compared using ANOVA. Multivariate Linear regression was used to predict six-year weight change (95% confident interval, P value). The diet quality index of interest was the independent variable(s), with the first tertile being the reference value. To address mis-reporting and try to identify the sub-group least likely to have under- or over-reported total energy intake, the ratio of energy intake (EI) to basal metabolic rate was calculated. Basal metabolic rate (BMR) for each woman was calculated using the Schofield equations. Using the Goldberg equations, for a moderate physical activity level of 1.55 for this group then a TEI of 1.27-2.1 times BMR can be considered plausible (Schofield, 1985, Black, 2000). Three different regression models were applied to both the total sample and the sub-sample with plausible total energy intakes: 1. Crude model: unadjusted, dependent variable=Δweight, independent variable=baseline diet quality index of interest. 2. The second model is adjusted specifically for the most important co-variates that were available in the ALSWH data set, the Specifically-adjusted model: adjusted for physical activity, education, number of births, location of residence, marital status, smoking, and weight at baseline. 3. Final model: sought to evaluate the impact of energy intake on the model and included all the co-variates as per model 2 above, but also included total energy intake (TEI). All statistical analyses were carried out using STATA (version 11.1 for windows, 2009, StataCorp LP, USA).

5.5 Results

5.5.1 Subject characteristics

The total number of women included in this analyses, with complete baseline and follow-up data on weight change and diet, was n=4,287.

Table 5-1 summarises subject characteristics at baseline and weight change. Overall, the mean weight change from 2003 to 2009 was +3.6±1.5 kg. A comparison of diet quality scores and co-variates for those with and without complete data on weight change from 2003 to 2009 indicated that there were no differences in diet quality score, measured by all three indexes, education, PA and smoking status, p>0.05(data not shown). For those who had missing data on FFQ, they also had missing data on the other co-variates.

5.5.2 Weight and macronutrients across diet quality index tertiles

There was no significant difference across tertiles of ARFS for mean weight change, but there were significantly differences in the means of energy intake (kJ/d), fibre (g/d), carbohydrate (%) and protein (%) intakes, total fat (%) and saturated fat (%) intakes observed across ARFS tertiles (Table 5-2). In the plausible TEI sub-sample, the top tertile of ARFS had the lower mean weight gain (2.9±7.9) kg however this was not significantly different compared to the second and lowest tertiles (3.4±7.7 kg and 4.0±7.9kg, respectively). The top tertile of ARFS had greater total energy intake (TEI) (kJ/d), fibre (g/d), carbohydrate (%) and protein (%) intakes, and lower total fat (%) and saturated fat (%) intakes compared with other tertiles. (Table 5-2)

There was no significant difference in the mean weight change across the Aus-DQI tertiles **(**Table 5-3**)**. Aus-DQI tertile 3 had lower TEI (kJ/d), fat (%), saturated fat (%), protein (%) and fibre (g/d) intakes, and higher carbohydrate intakes (%), compared with the other Aus-DQI tertiles (Table 5-3). In the plausible TEI sub-sample, there was no significant difference in weight changes between tertiles of Aus-DQI. There were significant differences in means of carbohydrate (%) and fiber (g/d), energy intake (kJ/d), total fat (%), saturated fat (%), protein (%) intakes.

There was a significant difference in mean weight change across the FAVI tertiles (p=0.003), with the third tertile of FAVI gaining the least amount of weight during the six years of follow-up compared with the other tertiles (Table 5-4). The intakes of fat (%) and saturated fat (%) were significantly lower while TEI, protein (%), carbohydrate (%) and fibre (g/d) intakes were significantly higher in the third FAVI tertile. In the plausible TEI sub-sample, those in the lower tertile of FAVI had significantly greater weight gain than those in the second and the top tertiles of ARFS **(**Table 5-4**).** In the plausible TEI the top tertile of FAVI had lower total fat (%), saturated fat (%) but greater intake of carbohydrate (%), Fiber (g/d). There were no significant differences between TEI and protein intake across FAVI tertiles.

5.5.3 Baseline diet quality indices as a predictor of six year weight gain

In the plausible TEI sub-sample, only those in the top tertile of the ARFS had significantly less weight gain (1.6 kg) compared with those in the lower tertile of the ARFS. In the fully adjusted model, those who were in the top tertile of the ARFS had significantly lower weight gain compared with the lower tertile for the plausible TEI sub-sample, (β=-1.6, CI: -2.67 to -0.56, p=0.003).

Baseline FAVI was a statistically significant negative predictor of weight gain in this group of young women, while ARFS and Aus-DQI were not statistically significant predictors of weight change (Table 5-5) Compared with the first tertile of FAVI, women in the third tertile had the lowest weight gain over six years (β= - 0.72, CI: -1.4 to -0.03, p=0.04), in the fully adjusted model.

In the plausible TEI sub-sample, we found that those in the second and third tertiles of FAVI had significantly less weight gain compared with the first tertile. More specifically, we found that, in the fully adjusted model, those who were in the top tertile of FAVI gained the lowest weight compared with other tertiles. (β=-1.6, CI: -2.4 to -0.3, p=0.01). The second tertile of FAVI: (β=-1.5, CI: -2.4 to -0.2, p=0.02), also had lower weight gain than the first tertile.

5.6 Discussion

The current study tested three different diet quality indices as predictors of weight change over the subsequent six year period in a cohort of young women participating in the ALSWH. It demonstrated that higher scores on either a food variety and frequency index (ARFS) or an index based on fruit and vegetable variety and frequency alone (FAVI), predicted lower six year weight gain in this group of women. In the whole sample the ARFS showed no relationship with prospective weight gain, while the Aus-DQI showed no relationship in either the whole or the plausible TEI sub-sample.

The main findings of this study support the role of increased fruit and vegetable consumption as a key strategy to prevent weight gain, particularly for young women. This is consistent with a recent prospective study by Vioque et al. (2008), among 206 healthy Spanish adults aged 15 to 80 years. Vioque et al found that those in the highest quartile of vegetable and fruit consumption (>698g/d) at baseline, as assessed by a FFQ, had a reduced risk of weight gain (≥3.41kg) compared with those who were in the lowest quartile of vegetable and fruit consumption during 10 years of follow-up (OR 0.22, 95%CI 0.06 to 0.81, P trend = 0.022). Another prospective study conducted by Kahn, et al. (1997), in 79,236 healthy white non-Hispanic American adults, found that greater consumption of vegetables (highest quintile) was associated with a smaller gain in BMI over 10 years of follow-up (β = -0.12; p=0.09, 0.012) for women and men respectively. A systematic review of experimental studies supports increasing fruit and vegetables to support weight management. (Rolls et al., 2004.) A randomised controlled trial in 97 obese adults aimed to assess the effect of two approaches to weight loss, a decreased dietary fat intake or an increased intake of fruit and vegetables plus decreased dietary fat intake over one year (both groups reduced fat by the same amount) (Ello-Martin et al., 2007). The main finding demonstrated that those who increased their consumption of fruit and vegetables and decreased dietary fat achieved significantly greater weight loss, 7.9±0.9kg compared with 6.4±0.9kg for the other group (Ello-Martin et al., 2007). A trial carried out in Brazil (Sartorelli et al., 2008) in 80 overweight people, found that those who increased their fruit and vegetable intake by

100g/d experienced lower weight gain (300g cf. 550g) over six months compared with those who did not change their intake for fruit and vegetables. In the whole sample, we found that higher TEI was associated with the highest FAVI score. However, we also found that higher FAVI scores were associated with the lowest weight gain. However, in the plausible TEI sub-sample there was no significant difference between TEI across the tertiles of FAVI, as shown in Table 5-4. One possible explanation for this is that there are only a limited number of energy-dense, nutrient-poor foods in the FFQ, meaning, TEI from these items may not be well captured. Those with a lower TEI may have higher energy intakes from these non-FFQ items. Although the ARFS and FAVI were strongly positively correlated with each other, the ARFS in the full sample did not predict weight gain, while FAVI did in both the whole and plausible energy intake samples. This suggests that neither the ARFS nor the FAVI capture the association between foods that are energy-dense, nutrient-poor and weight change. In the current study the focus was to examine the association between the healthful, nutrient-dense food items and weight change. Higher diet quality index scores have been shown in a review to predict the risk of future morbidity and mortality (Collins et al., 2008).

The Aus-DQI failed to predict weight gain during the follow-up period in this sample of young women, even though it incorporates sub-scales for the percentage energy from total fat, saturated fat and carbohydrate intake, and total sodium intake. The limited scoring scale and that it had not been previously validated limit the interpretation of this result. This also may be due to the limited list of energy-dense, nutrient-poor foods, particularly soda and other sweetened beverages within the DQES which is to be expected given that it was developed more than 20 years ago. Thus, an assumption and limitation is that TEI may be partly under-estimated due to the items in the FFQ. In the whole population, we found that the lowest intake of fiber across the Aus-DQI tertiles was for the top tertile, or highest diet quality scores. Among those women with plausible TEI however, we found that the highest Aus-DQI tertile was associated with higher intakes of fiber. This difference is likely due to mis-reporting of TEI and we expect that the results in the plausible TEI sub-sample are more likely to be more accurate.

The ALSWH cohort is a representative sample of the population of Australian women, and the weight change data from the current study indicate that weight gain is common among young women. In addition, very few young women achieved a high diet quality score. The mean diet quality score in the highest tertile of each index was not high, indicating that interventions seeking to optimise diet quality in this age group are warranted as has been suggested previously (Morrison et al., 2012, Blumfield et al., 2011, Hure et al., 2009). In addition, a recent systematic review (Hutchesson et al.) has highlighted that intervention studies specifically targeting body weight are needed to prevent the development of overweight and obesity in this age group.

There are a number of major limitations that need to be addressed. This includes that there are a large number of women with missing data on weight or dietary intake at baseline and follow-up. Furthermore, a limitation that needs to be acknowledged is loss to follow up. In the ALSWH study, attrition is most common in participants with a lower education, those not born in Australia and those with poorer health or who smoke (Lee et al., 2005). The potential impact of this attrition is that there may be selective loss of those whose weight change is greater and/or have poorer dietary intake than in those who have been retained. This potentially underestimates the ability of diet quality indexes to detect a relationship between dietary patterns and weight change. In addition, dietary intake was only measured once over this time period and we are therefore not able to evaluate how or whether the women changed their eating habits over time.

Furthermore, all data was self-reported including weight which introduces a potential reporting bias. A previous validation study of self-reported weight on mid-aged women from the ALSWH demonstrated that there was no clinical difference between self-reported weight and measured body weight (Burton et al., 2010). While a similar validation has not been done for the Young cohort of the ALSWH, it might be expected to give similar results. Another limitation that must be considered is that the Aus-DQI was not validated but was adapted from the original USA DQI which was based on American NRVs not Australian NRV’s. As a consequence, results should be interpreted with caution.

The strengths of this study include the use of a healthy representative sub-sample derived from ALSWH population, with an adequate follow-up period. In addition, we used appropriate and rigorous statistical analyses and three different approaches to the measurement of diet quality to reflect the National Dietary Guidelines for Australia, including two based on established methods and one new index based only on fruit and vegetable intake. This new tool provides a simple approach to diet quality assessment and successfully predicted weight change in this cohort of young women. Further research evaluating and validating the performance of FAVI in other age and gender groups is warranted.

5.7 Conclusion

Frequency and variety of fruit and vegetable intake, and overall diet quality, predicted weight gain over six years in this healthy population group of young women. Strategies to encourage young women to more frequently consume a greater variety of fruit and vegetables are required, and may assist to prevent weight gain in this age group.

Table 5-1: Demographic characteristics of young women in the Australian Longitudinal Study on Women's Health (ALSWH) (n=4,287) at baseline (2003) and follow-up (2009)

	Baseline		Follow-up	
Characteristic	**Total sample (n=4,287)**	**Valid TEI (n=1,356)**	**Total sample (n=4,287)**	**Valid TEI (n=1,356)**
Anthropometry				
Obesity (%)	15.7	11.6	20.6	16.7
Overweight (%);	22.5	19.6	25.0	23.6
BMI; mean±SD	24.8±5.5	23.9±4.9	26.2±6.0	25.2±5.5
Weight (kg); mean±SD	68.3±15.8	66.0±14.1	71.7±17.4	69.4±15.5
Diet Quality Index Scores				
ARFS	29.5±9.2	31.4±8.8	*n/a*	*n/a*
Aus-DQI	1.4±0.8	0.7±0.9	*n/a*	*n/a*
FAVI	78.0±39.7	94.1±26.9	*n/a*	*n/a*
Demographics				
Age (years); mean±SD	27.6±1.5	27.7±1.5	33.7±1.5	33.8± 1.5
Total energy intake (kJ); mean±SD	6980.7±2921.1	8975.3±1386.3	*n/a*	*n/a*
Physical activity in METs (nil/ low/ moderate/ high); (%)	8.9/35.3/22.8/33.0	8.9/9.7/20.4/31.1	*n/a*	*n/a*
Smoking status (never/ ex-smoker/ current); proportion (%)	58.7/18.3/23.0	60.1/16.5/33.4	*n/a*	*n/a*
Residence (urban/ rural/ remote); proportion (%)	57.3/39.0/3.7	55.3/41.0/3.7	*n/a*	*n/a*
Highest education (nil/ school certificate/ trade/ university degree); proportion (%)	1.5/31.0/3.3/64.3	1.0/29.9/3.1/66.0	*n/a*	*n/a*

TEI =total energy intake, ARFS =Australian Recommended Food score, FAVI =fruit and vegetables index, Aus-DQI =Australian Diet Quality Index

Table 5-2: Weight change data (2003 to 2009) and baseline macronutrient intakes (2003) for young women in the Australian Longitudinal Study on Women's Health (ALSWH) by tertile of Australian Recommended Food Score (ARFS)

	ARFS tertiles (Total sample n=4,287)				ARFS tertiles (Valid TEI sub-sample n=1,356)			
	1	2	3		1	2	3	
Number (n)	**(n=1,433)**	**(n=1,426)**	**(n=1,428)**	***p-value***	**(n=402)**	**(n=437)**	**(n=517)**	***p-value***
Mean ± SD	**(19.7±4.5)**	**(29.5±2.0)**	**(39.8±5.0)**	***(ANOVA)***	**(21.3±3.6)**	**(30.1±2.4)**	**(40.4 ±5.1)**	***(ANOVA)***
∆Weight (kg); mean±SD	3.9 ±8.6	3.6±8.1	3.3±8.4	0.2	4.0±7.9	3.4 ±7.7	2.9 ±7.9	0.09
Baseline weight (kg); mean±SD	68.8±16.8	67.9±15.5	68.2107±14.9	0.16	65.7±13.9	65.5 ±14.8	65.6 ±13.7	0.4
Follow-up weight (kg); mean±SD	72.2±18.1	71.8±17.7	71.35±16.3	0.44	69.7±15.4	68.9 ±16.1	69.5 ±15.1	0.7
Energy intake (kJ/d); mean±SD	6372.3±2903.5	7091.2±2905.5	7558.6±2825.8	<0.0001	8819.6±1339.1	8993.7±392.4	9080.8 ±1408.9	0.02
Macronutrient and Fiber intakes at baseline								
Total fat (% energy); mean±SD	35.2±6.1	33.7±5.9	32.5±5.8	<0.0001	38.2±5.1	37.4 ±4.8	35.1 ±4.9	<0.0001
Saturated fat (% energy); mean±SD	16.4±3.7	15.4±3.5	14.4±3.4	<0.0001	16.5±3.3	15.8 ±2.9	14.2 ±3.0	<0.0001
Protein(% energy); mean±SD	19.7±3.4	20.5±3.3	20.9±3.4	<0.0001	19.2±3.2	19.6 ±2.8	20.0 ±3.1	0.0005
Carbohydrate (% energy); mean±SD	44.9±6.9	45.5±6.7	46.29±6.4	<0.0001	40.9±6.0	41.2 ±5.3	42.9 ±5.4	<0.0001
Fiber (g/d); mean±SD	15.4±6.9	18.9±7.5	22.25±8.0	<0.0001	20.4±5.9	22.8 ±5.7	26.1 ±6.7	<0.0001

Table 5-3: Weight change data (2003 to 2009) and baseline macronutrient intakes (2003) for young women in the Australian Longitudinal Study on Women's Health (ALSWH) by tertile of Australian Diet Quality Index (Aus-DQI)

	Aus-DQI tertiles (Total sample n=4,287)				Aus-DQI tertiles (Valid TEI sub-sample n=1,356)			
	1	**2**	**3**		**1**	**2**	**3**	
Number (n)	**(n=1,433)**	**(n= 1,426)**	**(n=1,428)**	***p-value***	**(n=402)**	**(n=437)**	**(n=517)**	***p-value***
Mean±SD	**(0.6±0.5)**	**(2.0 ±0.0)**	**(3.0±0.2)**	***(ANOVA)***	**(0.61±0)**	**(1.0±0.0)**	**(2.3±0.4)**	***(ANOVA)***
∆weight (kg); mean±SD	3.7±8.5	3.7±8.3	3.3±7.9	0.3	3.6±8.1	2.9±6.9	3.5±7.8	0.48
Baseline weight (kg); mean±SD	69.1±16.8	67.9±14.3	66.5±13.7	<0.0001	67.7±15.4	63.5±11.6	63.8±11.8	<0.0001
Follow-up weight (kg); mean±SD	72.3±18.0	71.51±16.3	69. 6±15.7	<0.0001	71.2±16.5	66.4±13.3	67.3±13.9	<0.0001

Energy intake (kJ/d); mean±SD	7658.6 ±2839.2	7539.3±2641.9	5235.7±1389.9	<0.0001	9252.6±1394.3	8642.1±1306.7	8546.6±1256.3	<0.0001
				Macronutrient and Fiber intakes at baseline				
Total fat (% energy); mean±SD	39.1±3.6	31.9±3.3	28.3±4.4	<0.0001	39.8±3.0	35.6±3.6	30.4±3.7	<0.0001
Saturated fat (% energy); mean±SD	16.5±2.8	12.9±2.3	11.3±2.6	<0.0001	17.0±2.5	14.8±2.9	12.2±2.3	<0.0001
Protein (% energy); mean±SD	20.4±3.4	20.65±3.8	19.7±3.0	<0.0001	19.8±2.8	20.3±3.7	18.6±2.9	<0.0001
Carbohydrate (% energy); mean±SD	38.7±4.5	45.4±4.0	49.8±4.7	<0.0001	38.7±3.9	42.2±3.3	48.8±4.0	<0.0001
Fiber (g/d); mean±SD	18.7±7.7	20.1±9.8	17.7±6.4	<0.0001	21.8±5.4	23.3±6.8	27.3±7.4	<0.0001

Table 5-4: Weight change data (2003 to 2009) and baseline macronutrient intakes (2003) for young women in the Australian Longitudinal Study on Women's Health (ALSWH) by tertile of Fruit & Vegetable Index (FAVI)

	FAVI tertiles (Total sample n=4,287)				**FAVI tertiles (Valid TEI sub-sample n=1,356)**			
	1	**2**	**3**		**1**	**2**	**3**	
Number (n)	**(n=1,433)**	**(n=1,426)**	**(n=1,428)**	***p-value***	**(n=402)**	**(n=437)**	**(n=517)**	***p-value***
Mean ± SD	**(34.6±28.0)**	**(83.1 ±7.9)**	**(117.2 ± 18.9)**	***(ANOVA)***	**(63.5±11.4)**	**(89.4 ±6.5)**	**(120.4 ± 18.0)**	***(ANOVA)***
Δweight (kg); mean±SD	4.4±8.9	3.4±7.7	3.3±8.6	0.002	4.5±8.6	2.9±6.9	2.9±7.9	0.003
Baseline weight (kg); mean±SD	69.0±17.0	68.3±15.7	67.9±15.1	0.1	66.1±15.1	66.0±14.2	65.9±13.3	0.98
Follow-up weight (kg); mean±SD	72.1±17.7	71.8±17.4	71.2±16.9	0.3	70.6±16.4	68.9±15.4	68.8±14.9	0.17
Energy intake (kJ/d); mean±SD	6282.7±2638.8	6819.3±2551.7	7602.7±3296.4	<0.0001	8892.1±1388.3	8924.5±1333.5	9077.9±1423.1	0.1
				Macronutrient and Fiber intakes at baseline				
Total fat (%); mean±SD	35.2±6.2	33.9±5.8	32.9±5.9	<0.0001	38.13±4.9	37.12±5.0	35.4±5.00	<0.0001
Saturated fat (%); mean±SD	16.4±3.8	15.56±3.5	14.7±3.5	<0.0001	16.4±3.1	15.6 ±3.13	14.5±3.1	<0.0001
Protein (%); mean±SD	19.7±3.4	20.4±3.2	20.6±3.5	<0.0001	19.3±3.0	19.6±2.9	19.8±3.2	0.0491
Carbohydrate (%); mean±SD	44.8±6.7	45.4±6.4	46.1±6.9	<0.0001	40.7±5.5	41.4±5.5	42.8±5.7	<0.0001
Fiber (g/d); mean±SD	15.0±6.9	17.9±6.8	21.9±8.4	<0.0001	20.7±5.8	22.8±5.9	25.8±6.8	<0.0001

Table 5-5: Multiple linear regression models to predict of six-year weight change in young women from the Australian Longitudinal Study on Women's Health.

Predictor: Diet Quality Index	**Model***	**Tertile (vs Tertile 1)**	**Total sample: ΔWeight (kg) *β* co-efficient (95% CI)**	***p-value***	***Valid TEI sub-sample* ΔWeight (kg) *β* co-efficient (95% CI)**	***p-value***
ARFS	*Crude*	2	-0.32 (-0.99, 0.28)	0.29	-0.60(-1.7, 0.46)	0.27
		3	-0.69 (-1.3, 0.08)	**0.03**	-1.14(-2.16, -0.12)	**0.03**
	Adjusted	2	-0.16 (-0.79, 0.47)	0.63	-0.93(-1.96, 0.09)	0.07
		3	-0.34 (-0.97, 0.30)	0.29	-1.59(-2.63, -0.53)	**0.003**
	Final	2	-0.18 (-0.81, 0.46)	0.58	-0.95(-2.0, 0.7)	0.07
		3	-0.38 (-1.03, 0.27)	0.25	-1.6(-2.67, -0.56)	**0.003**
Aus-DQI	*Crude*	2	-0.05 (-0.71, 0.60)	0.876	-0.68(-1.79, 0.42)	0.2
		3	-0.51 (-1.14, 0.12)	0.112	-0.10(-1.12, 0.92)	0.8
	Adjusted	2	-0.04 (-0.71, 0.63)	0.905	-0.80(-1.93, 0.31)	0.2
		3	-0.60 (-1.25, 0.06)	0.073	-0.46(-1.52, 0.61)	0.4
	Final	2	-0.05 (-0.73, 0.63)	0.885	-0.81(-1.95, 0.33)	0.2
		3	-0.62 (-1.32, 0.07)	0.078	-0.45(1.53, 0.62)	0.4
FAVI	*Crude*	2	-0.96 (-1.62, -0.31)	**0.004**	-1.60(-2.67, -0.54)	**0.003**
		3	-1.09 (-1.75, -0.44)	**0.001**	-1.61(-2.62, -0.58)	**0.002**
	Adjusted	2	-0.61 (-1.28, 0.07)	0.079	-1.4(-2.53, -0.43)	**0.006**
		3	-0.68 (-1.36, 0.00)	0.051	-1.5(-2.59, -0.42)	**0.006**
	Final	2	-0.63 (-1.30, 0.05)	0.070	-1.5(-2.4,-0.2)	**0.02**
		3	-0.72 (-1.42, -0.03)	**0.041**	**-1.6(-2.4,-0.3)**	**0.01**

*Crude model: unadjusted, Δweight=dependent variable, diet quality index=independent variable; Adjusted model: adjusted for physical activity, education, number of births, area of residence, marital status, smoking and weight at baseline; Final model: the adjusted model plus total energy intake. **Bold if P value < 0.05**

Chapter 6 The Second analysis on Young Women (Section 2)

This article is prepared to be submitted

Authors: Aljadani, Al-Oboudi, Patterson, Sibbritt, and Collins.

Title: Frequency and variety of healthy foods, fruit and vegetables predicts lower six year weight gain in young women

Journal: Australian and New Zealand Public health

The Work presented in the manuscript was competed with collaboration with the co-authors (Appendix 7**)**

6.1 Overview

This chapter presents an analysis of the young women from the ALSWH. It reports the results on a free-disease sub-cohort of young women who identified as those who reported the healthy weight at baseline. This analysis differs from the analysis in Chapter 5 that included all women across the different BMI groups. The current analysis included women with a healthy weight only at the start of the study.

6.2 Abstract

Background: Cohort studies have shown that overall diet quality is a predictor of weight change and health outcomes. Few studies have compared results within the same cohort using multiple diet quality indices. We previously demonstrated that diet quality, measured by fruit and vegetable variety and frequency (FAVI) but not overall diet quality (ARFS), was associated with lower six year weight gain in young women from the Australian Longitudinal Study of Women's Health (ALSWH).

Aim: To evaluate the relationship between diet quality, measured by both the ARFS and FAVI indices, and weight change over a six year period in healthy young women initially of normal weight at baseline.

Methods: Linear regressions multivariate models were performed on 4,083 disease-free women of normal weight ($18.5 \leq BMI < 25 kg/m^2$), aged 27.6 years at baseline (2003).

Results: The women had a low mean (SD) baseline diet quality as measured by both indices [ARFS (maximum 72) =29.9 (9.2) and FAVI (maximum 333) =94.2(29.1)] and gained 3.7kg during the six years of follow-up. For every one unit increase in either ARFS or FAVI there was a small but statistically significantly lower 6-year weight gain of 33g and 12 grams respectively.

Conclusion: Consuming a greater variety of healthful core foods more frequently, or fruit and vegetables alone, predicted lower prospective weight gain. This has important

implications for health promotion. Further research is needed to examine diet quality as a predictor of weight gain over a longer follow-up period and in diverse population groups.

6.3 Introduction

Measuring overall diet quality and how dietary intake aligns with National Dietary Guidelines using specific diet quality and variety indices has become more common in epidemiological studies. Of particular interest is how these various diet quality indices relate to overall morbidity and mortality outcomes (Wirt & Collins, 2009).

Weight gain is a risk factor associated with adverse health indicators (Kopelman, 2000) as well as increased morbidity and mortality (WHO, 2013b), even when weight gain occurs within the healthy weight range (Kawachi, 1999). After the age of 18 years, those who gain ≥5kg are at higher risk of developing type 2 diabetes (OR: 1.9) and cardiovascular disease (OR: 1.25) compared with those who maintain their weight (Kawachi, 1999). Also, those who are obese are more likely to suffer from hypertension (RR up to 2.35) and specific cancers including colorectal, breast, uterine and kidney (RR up to 1.75) (Access Economics, 2008). Worldwide, the prevalence of overweight and obesity has increased dramatically (Kolotikin et al., 2001, WHO, 2013b), with 26% of adults being obese and an additional 39% considered overweight in 2014 (WHO, 2013b). Increased incidence of overweight and obesity has been reported in Europe, including the UK, and in the USA, China, Middle East and others (WHO, 2014).

Evidence indicates that young adults have the poorest dietary intake compared with other age groups (Hiza et al., 2013). Also, young women are at risk of gaining greater weight than all other age groups (Hiza et al., 2013, Norman et al., 2003, Adamson et al., 2007). Research from the Australian Longitudinal Study of Women's Health (ALSWH) found that young women are gaining weight faster than mid-aged women did at the same life-stage, and that young women will be heavier than mid-aged women by the time they enter their forties (Adamson et al., 2007).

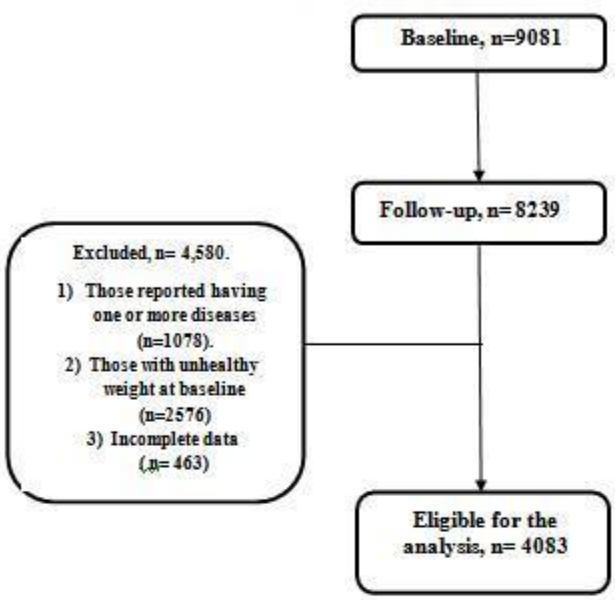
While the causes of overweight and obesity are multi-factorial and complex, diet is one major modifiable risk factor. Studies demonstrate that food habits, dietary patterns, diet quality and total food intake predict future weight gain (McCrory et al., 2002). Our recent systematic review highlighted that only a limited number of studies have examined the relationship between diet quality and prospective weight change (Aljadani et al., 2013a, Aljadani et al., 2015). We previously examined the association between two diet quality indexes, the valid tool of measuring diet quality Australian Recommended Food Score (ARFS) (Collins et al., 2015) and a newly developed Fruit and Vegetable Index (FAVI), and weight gain during six years of follow-up in a sample of young women. Of the 4,287 women from the ALSWH, 1356 had reported a valid Total Energy Intake (Aljadani et al., 2013b). Overall, those who were in the top tertile of FAVI (mean (SD): 117.2 (18.9) out of a maximum total of 333 points) had relatively lower weight gain by 72g, p=0.04 compared to those with the lowest mean scores (SD) 34.6 (28.0) points). We found that higher ARFS (top tertile) was associated with lower weight gain only within the valid TEI sub-sample, p>0.05 (Aljadani et al., 2013b). However, this analysis included women across different weight and health status groups. In the current analysis we focused on those within the healthy weight range at the start of the analysis because maintaining a healthy weight is important for individual well-being and overall public health. Diet quality can play an important role in preventing weight gain and achieving optimal health for women during the child-bearing years (Guelinckx et al., 2008, Adamson et al., 2007, Ebrahimi-Mameghani et al., 2007). Therefore, the aim of the current analysis was to examine whether, in disease free young women who were in the normal BMI range at baseline, higher diet quality, assessed using the ARFS and FAVI indices, was associated with lower prospective weight gain.

6.4 Materials and Methods

6.4.1 Participants

The sample is a subset from the ALSWH cohort study which recruited women into three age cohorts at baseline in 1996 (young, mid-age and older). Further details are reported elsewhere (Brown et al., 1998, Brown et al., 1996). Participants in the current analysis were drawn from the young cohort (aged 27-31 years in 2003) and followed up for six years to 2009. Participants were excluded if they reported having a diagnosis of type 2 diabetes, heart disease, any type of cancer (excluding skin cancer), were currently pregnant, or were not in the healthy weight range in 2003 (healthy weight defined as ($18.5 \leq BMI < 25 kg/m2$). Figure 6-1 summarizes the selection criteria for the population in the current analysis. The study was approved by the University of Newcastle and the University of Queensland Human Research Ethics committees.

Figure 6-1: The numbers of participants selected in the current analysis



6.4.2 Anthropometry

Weight and height were self-reported at both baseline (2003) and follow-up (2009), in kilograms (kg) and meters. Weight change (Δ) was defined as the absolute difference (kg) in weight from 2003 to 2009. BMI was calculated at each time point by dividing body weight in kilograms by height in meters squared. Women were classified according to World Health Organization (WHO) criteria as: 1) underweight, BMI<18.5; 2) healthy weight, 18.5≤BMI<25; 3) overweight, 25≤BMI<30; or 4) obese if 30≤BMI.

6.4.3 Confounders

Participants self-reported their frequency of walking and moderate and strenuous physical activity (PA) in 2003, which was used to derive a PA score in metabolic equivalents (METs) per minute (MET. Mins) (ALSWH, 2015). Education level was self-reported as: 'no formal or nil, 'school certificate', 'trade/apprenticeship', 'university degree or higher degree'. Location of residence was categorized as urban, rural or remote. Participants self-reported smoking status as 'current smoker', 'never smoker', or 'ex-smoker'. Marital status reported was defined as; 'married', 'defacto', 'separated', 'divorced', 'widowed', or 'single'. The TEI (kJ/day) and nutrient intakes were quantified from the Australian nutrient composition database using the Nutrient Data Table (NUTTAB).(Lewis et al., 1995). Number of children was classified as: 1) those who had no child, 2) those who had one to two children and 3) those who had three or more children.

6.4.3.1 Dietary intake assessment and diet quality indices:

Dietary intake was self-reported using the Dietary Questionnaire for Epidemiological Studies Version 2 (DQESv2) food frequency questionnaire (FFQ) which assesses intake of 74 food items over the previous 12 months (Ireland et al., 1994). The DQESv2 has been previously validated in young women in ALSWH (Hodge et al., 2000b). Usual consumption frequency of each food item is indicated on a 10-point Likert scale, ranging from 'never' up to 'three or more per day'. Additional questions assessed the total number of daily serves of fruit, vegetables, bread, dairy products, eggs, fat spreads and sugar, as well as the type of bread, dairy products and fat spreads used. Nutrient intakes were computed using a food composition database of Australian foods (Australian Government, 2013b) and software developed by the Cancer Council of Victoria.

6.4.3.2 The Australian Recommended Food Score (ARFS):

The ARFS was adapted from the USA Recommended Food Score (RFS) (Kant & Thompson, 1997) and previously validated (Collins et al., 2008, Collins et al., 2015). Points in the ARFS are awarded based on regular consumption of FFQ items that align with recommendations in the National Dietary Guidelines and the Australian Guide to Healthy Eating (Collins et al., 2008, Dietary Guidelines for Australian Adults, 2013). The ARFS scoring method is reported in detail elsewhere (Collins et al., 2008). Briefly, it is made up of seven sub-scales, with a score range from 0-72 points. The sub-scale scores are calculated from the following food groups, with one point awarded for each item reported as being consumed at least once a week. The total score within each sub-scale is: vegetables 22 points (including potato cooked without fat); fruit 14 points; protein foods 14 points; grains 14 points; dairy seven points; fats one point. The maximum ARFS score is 72, reflecting the highest diet quality score , and most optimal nutrient intakes (Collins et al., 2008) with the highest quintile of ARFS have higher intakes of key nutrients, lower intakes of total fat and saturated fat compared to those in the lowest ARFS quintile. Also higher ARFS score associated with better self-reported health, compared to those in the lowest ARFS quintile, (Collins et al., 2008).

6.4.3.3 The Fruit & Vegetable Index (FAVI)

Fruit and vegetable consumption data, derived from the baseline DQESv2 , were used to inform the development of the FAVI score (Aljadani et al., 2013b). FAVI is divided into two sub-scales. The fruit sub-scale contains 13 items, including canned or frozen fruit and fruit juices, and 11 types of fresh fruit, such as oranges, apples, pears and the vegetable sub-scale contains 24 items, for example potatoes cooked without fat, tomato, zucchini, mushroom, celery. Consumption frequency of all fruit and vegetable items were scored using the full range of the FFQ 10 point Likert scale from 'never', scored as zero, up to '≥3 times per day' scored as nine points. The maximum possible score was 117 for the fruit sub-scale and 216 for the vegetable sub-scale, giving a maximum total FAVI score of 333 points, with a higher FAVI score indicating a greater variety and frequency of usual fruit and vegetable consumption (Aljadani et al., 2013b).

6.4.4 Statistical analysis

Descriptive data were presented as mean and standard deviations. Social-demographic variables were reported across tertiles of diet quality indices separately. P-values from ANOVA and chi-square tests were reported to compare between co-variables across tertiles of scores. Multiple linear regressions were used to evaluate six-year weight change, to test the relationship between each diet quality measure and longitudinal weight change. Three different regression models were applied: 1) a crude model (unadjusted), where the dependent variable was weight change, and the independent variables were baseline diet quality index of interest; 2) a specifically-adjusted model, where model 1 was adjusted for physical activity, education, number of births, area of residence, marital status, smoking, and weight at baseline; and 3) a fully-adjusted model, where the same variables were used as in model 2, but with the addition of total energy intake (TEI). All statistical analyses were carried out using STATA (StataCorp, 2011). Statistical analyses were considered statistically significant if $p<0.05$.

6.5 Results

From a total population sample of 9,081 women at baseline, 4,083 women met the inclusion criteria and had complete data at both baseline and follow-up. A total of 298 women were excluded due to being underweight, while 1,343 were excluded due to being overweight and 935 due to being obese at baseline. Figure 6-1 shows the selection of participants in the current study. There was no significant difference in diet quality scores (ARFS, FAVI) or confounders (physical activity, smoking, education), between those who did and did not have missing data for weight change, $p>0.05$ (data not shown).

6.5.1 Characteristics of subjects at baseline

Table 6-1 summarises the demographic and anthropometric characteristics of participants at baseline and follow-up. On average, the women were aged 27.6±1.5 years and gained 3.54±6.7kg over six years follow-up. The mean (±SD) baseline diet quality scores were: ARFS 28.3±9.2; and FAVI 73.1±44.2, with a mean total daily energy intake of 6,848.5±2,620.9kJ.

Table 6-2 summarises body weight and socio-demographic data by tertiles of ARFS. It indicates that there were significant differences in weight change, energy intake, physical activity and smoking status by tertiles of ARFS.

Table 6-3 summarises the body weight and socio-demographic data by tertiles of FAVI, indicating again, significant differences in weight change, energy intake and physical activity by tertiles.

6.5.2 The relationship between diet quality index scores and weight change over 6 years in linear regressions

Table 6-4 reports the results of the multivariate linear regression analyses between ARFS and FAVI and weight change over six years. ARFS was significantly associated with lower weight gain in both the crude and fully adjusted models, while FAVI was significantly associated with lower weight gain in all the three models. In the fully adjusted model, for every increase in score of 1 point on the ARFS and FAVI, there was a significantly lower 6-year weight gain by 33 and 12 grams respectively (95% CI=-0.065 to -0.003; p=0.033) (95% CI=-0.021 to -0.022; p=0.016).

6.6 Discussion

In a disease free sample of young women classified as being in the normal weight range at baseline, higher diet quality scores using two indices were significantly associated with lower prospective weight gain over six years. For every one point higher baseline score for each of the diet quality indexes young women gained significantly less weight, although the absolute amount was small (33 and 12 grams respectively) over six years. This means that those who usually consumed an additional five types of healthy food items or fruit and vegetables on a weekly basis gained 165 grams and 62 grams less weight during follow-up than those who did not. This association between higher ARFS and FAVI scores and lower weight gain is important at the population level. It is possible that the true magnitude of the relationship between diet quality and weight change may be underestimated due to reliance on self-reported data for weight and dietary intake. Weight and height were previously validated (Burton et al., 2010) and the results showed that the difference between self reported and objectively measured weight and height was small and not clinically important, and the authors concluded that self-reported and objectively measured weight and height were in good agreement (Burton et al., 2010). In addition, the dietary data was derived from a limited FFQ food list, which may have limited the ability to capture all food items usually consumed in this population group. One strength of the current study however was the use of two indices to evaluate diet quality. The ARFS was based on variety and frequency of healthful food items that align with recommendations in the Australian Dietary Guidelines, while the FAVI index assesses only fruit and vegetable variety and frequency intake. Moreover, this study used data on a sub-sample of healthy weight women only, from a large representative national Australian dataset (ALSWH), and followed women for a significant period of time.

The current findings suggest that consuming a greater variety of nutrient dense healthful foods is associated with significantly lower prospective weight gain, but the absolute amount is very small. Higher diet quality measured by both indices in this analysis was also associated with higher energy intakes from the foods captured by the FFQ, although total energy intake was not associated with weight gain. This suggests that promoting better diet quality will not exacerbate weight gain over time. However, energy intake may have changed during the six years of follow-up. In addition, we previously demonstrated that higher ARFS aligns with more optimal nutrient intakes and eating patterns (Collins et al., 2008), such as those recommended in the Australian Dietary Guidelines. In the current study we found that more frequent consumption and a greater variety of healthful foods, as measured by the ARFS, were significantly associated with lower body weight gain (165 grams) over six years of follow-up, and that those in the top tertile of ARFS (higher score) had significantly lower weight gain than those in the lower tertile of ARFS (3.7±6.7kg compared with 4.1±6.8kg). This finding is consistent with our previous study conducted on 4,287 young ALSWH women across all BMI categories. In that analysis of those with valid TEI, those with the highest ARFS scores had significantly lower weight gain during the period from 2003-2009 (Aljadani et al., 2013b). Nevertheless, this was in contrast to another study of 7155 mid-aged women from the ALSWH, where we found that at this older life-stage ARFS scores were not related to prospective weight change (Aljadani et al., 2013d). One possible reason for the variation in results is that the relationship between diet quality and weight change differs with age. In the current and previous study, the population was young women who are transitioning through the child-bearing years while in the mid-aged group they are transitioning through menopause. Some of the variation may be due to the fact that women who are overweight or obese are more likely to under-estimate their body weight (Dahl et al., 2010), which may mask the true relationship between dietary intake and weight change over time (Aljadani et al., 2013d). Those women with a higher BMI are also more likely to mis-report dietary intakes (Lara et al., 2004). We hypothesize that young women in the current study who were of a healthy weight at baseline were likely to be more accurate reporters of both diet and weight change at follow-up.

In the current study, those who had higher FAVI scores also had significantly less weight gain, compared with those who had lower scores, during follow up. This is consistent with our previous study (Aljadani et al., 2013b) which found an association between higher FAVI scores and less weight gain over time) for women of all body weights. These results are also in agreement with Vioque et al. 2008 (Vioque et al., 2008) whose study of 206 disease free adults aged 15 to 80 years in Spain found that those who were consuming greater intakes of vegetables and fruit (>698g/d) at baseline had a reduced risk of weight gain (≥3.41kg) compared with those who consumed lower intakes of vegetables and fruit over 10 years of follow-up. Furthermore Kahn et al. (1997), found that more variety and frequent intake of vegetables (highest quintile) was associated with a smaller gain in BMI over 10 years of follow-up for women and men in a large longitudinal analysis of 79,236 healthy white non-Hispanic American adults. A systematic review of intervention studies demonstrated that increasing fruit and vegetables is important for weight management (Rolls et al., 2004). An experimental study in 2008 by (Sartorelli et al.) that enrolled 80 overweight adults, found that those who increased their fruit and vegetable intake by 100 g/d experienced lower weight gain over six months compared with those who did not change their intake of fruit and vegetables. Therefore, further research promoting optimal diet quality, and especially increased variety and frequency of fruit and vegetable intake, as a strategy to limit weight gain is warranted.

While physical activity plays an important role in change in weight, undertaking only low levels of physical activity, could also explain weight gain over time. Around one third of those with the lowest levels of physical activity also had low levels of education and the majority lived in urban areas. This suggests these specific sub-groups should be targeted with interventions specifically to prevent weight gain and to achieve a healthy weight.

Limitations in the current study must be acknowledged. The data, including body weight and dietary intake, are self-reported and thus potentially subject to recall bias. However, there was no clinically significant difference between self-reported and measurement weight, also women were of healthy weight to start with, and weight was self-reported on both occasions which moderate the bias of self-reported. The other limitation was in the use of self-reported FFQ data, which is associated with mis-reporting, particularly as body weight increased. Although the DQESv2 used in this analysis has been previously validated (Hodge et al., 2000b), it does not include a wide range of energy-dense, nutrient-poor foods and therefore may not be representative of the true dietary patterns of those with the poorest eating patterns and would therefore have poor diet quality. However, this study has several strengths. Importantly, it compared two approaches to assessing diet quality in healthy weight women at baseline. In addition, the study analyzed longitudinal data from a large, nationally representative sample of young women.

6.7 Conclusion

Women from the young ALSWH cohort gained weight over six years of follow-up. However, those with a diet based on greater variety and more frequent consumption of healthful foods gained slightly less weight. This suggests that consuming a diet that aligns with national dietary guidelines, particularly that includes a greater frequency and variety of fruit and vegetables, may help slow the rate of weight gain, but is not likely to prevent the risk of weight gain at this life stage. In addition, further research is needed over a longer time frame, and in other population groups to further examine the relationship between change in diet quality and weight change, and the impact change in potential confounder variables over time.

Table 6-1: Description of subject characteristics and anthropometric measurement for 4,083 young women over the period 2003-2009

Variable		Mean ± SD baseline	Mean ±SD follow-up
Diet quality scores at baseline			
ARFS		29.9±9.2	N/a
FAVI		94.2±29.1	N/a
Weight change		3.7±6.7	Na
Healthy weight (%)		100%	74
Overweight (%)		Excluded	20
Obese (%)		Excluded	5
TEI* (kJ)		6809.2±2610.9	N/a
Subject characteristics			
Age (years)		27.6±1.5	33.7± 1.5
Physical Activity (Met. minutes)		1178.5±1407.2	1178.8 ± 1410.2
		Percentage	
Smoking Status	Non smoker/ ex-smoker/ smoker	58/18/24	60/23/17
Area of Residence	Urban/ Rural/ remote	60/36/3	62/34/4
Education	No formal/ School certificate/Trade and apprentice/ University degree and higher	1/28/24/47	Na
Marital status	Married/defacto/separated/ divorced/widowed/single.	38/21/3/1/0/37	61/16/2/2/0/18

ARFS: Australian Recommended Food score, FAVI: fruit and vegetables index, TEI – Total Energy Intake

Table 6-2: Social-demographic variables of young women in the Australian Longitudinal Study on Women's Health (ALSWH) (n = 4,083) at baseline (2003) and follow-up (2009) by tertile of Australian Recommended Food Score (ARFS) baseline

	Baseline				Follow-up			
Number (n) Mean ± SD (ARFS)	**1 (n=1,434) (21±4.5)**	**2 (n=1,371) (30±2.0)**	**3 (n=1,278) (41.8±5.0)**	***p-value* *(ANOVA)* *Chi-2***	**1 (n= 1,434) (21 ±4.5)**	**2 (n= 1,371) (30 ±2.0)**	**3 (n= 1,278) (41.8 ±5.0)**	***p-value* *(ANOVA)* *Chi-2***
ΔWeight (kg); mean±SD	4.1±6.8*	3.6±6.5	3.7±6.7*	0.04	Na	Na	Na	
Weight (kg); mean±SD	60.6±8.69*	60.9±7.4	61.4±8.05*	0.02	65.32±11.54	65.33±10.78	65.47±10.09	0.93
Healthy weight (%)	35.80	33.40	30.80	0.36	35.15	34.25	30.60	0.06
Overweight (%)	Na	Na	Na	N	36.46	32.68	30.86	0.06
Obesity (%)	Na	Na	Na	Na	45.45	28.57	25.97	0.06
Energy intake (kJ/d); mean±SD	6273.98±2535.54*	6836.42±2479.29*	7412.62±2730.99*	0.00	Na	Na	Na	
Age (years); mean±SD	27.49±1.46	27.52±1.44	27.63±1.46	0.15	33.62±1.44	33.63±1.4360	33.73±1.460	0.14
Physical activity in METs (nil/ low/ moderate/ high); (%)	12/39/21/28	6/35/24/40	4/26/23/47	0.00	15/40/22/23	12/38/22/28	8/34/25/33	0.0 < 0.001
Smoking status (never/ ex-smoker/ current); proportion (%)	36/32/41	33/32/33	31/36/26	0.00	36/31/48	34/36/28	31/33/24	0.0 < 0.001
Residence (urban/ rural/ remote); proportion (%)	35/38/34	34/33/37	31/29/29	0.00	35/39/32	34/32/34	31/29/34	0.0 < 0.001
Highest education (nil/ school certificate/ trade/ university degree); proportion (%)	57/ 44/ 44/ 33	22/ 30/ 33 / 34	22/ 26/ 23/ 33	0.00	Na	Na	Na	

Table 6-3: Social-demographic variables of young women in the Australian Longitudinal Study on Women's Health (ALSWH) (n = 4,083) at baseline (2003) and follow-up (2009) by tertile of baseline FAVI

	Baseline				Follow-up			
Number (n) Mean ± SD FAVI	**1 (n=766) (52±13)**	**2 (n= 1,681) (84±9.0)**	**3 (n= 1,636) (121±19)**	***p-value (ANOVA) Chi-2***	**1 (n= 766) (52. ±13)**	**2 (n= 1,681) (84 ±9.0)**	**3 (n= 1,636) (121 ±19)**	***p-value (ANOVA) Chi-2***
∆Weight (kg); mean±SD	4.86±7.27	3.79±6.35	3.50±6.71	0.00	NA	Na	NA	
Weight (kg); mean±SD	60.73±9.69	60.92±7.42	61.37±8.11	0.012	65.68±12.31	65. 39±10.79	65.23±10.35	0.72
Healthy weight (%)	16	43	41	0.00	15	44	42	0< 0.001
Overweight (%)	Na	Na	Na	Na	17	41	42	0 < 0.001
Obesity (%)	Na	Na	Na	Na	21	47	32	0 < 0.001
Energy intake (kJ/d); mean±SD	6154.22±2741.90	6534.43±2357.55	7353.63±2720.18	0.00	Na	Na	Na	
Age (years); mean±SD	27.49±1.46	27.53±1.44	27.63±1.46	0.23	33.62±1.45	33.64±1.44	33.74±1.46	0.74
Physical activity in METs (nil/ low/ moderate/ high); (%)	15/39/22/24	12/38/22/28	8/34/25/33	0.00	18/38/23/21	13/39/23/25	8/35/23/33.	0 < 0.001
Smoking status (never/ ex-smoker/ current); proportion (%)	16/14/20	43/40/42	41/47/38	0.00	16/13/21	43/42/46	41/45/33	0 < 0.001
Residence (urban/ rural/ remote); proportion (%)	16/19/15	43/41/38	41/40/47	0.00	15/18/13	43/42/41	42/40/46	0 < 0.001
Highest education (nil/ school certificate/ trade/ university degree); proportion (%)	37/ 24/ 16/ 13	31/ 41/ 50/ 42	31/ 35/ 34/ 44	0.00	Na	Na	Na	Na

Table 6-4: The relationship between diet quality index scores and weight change over 6 years (2003-2009) for 4,083 young women, obtained from linear regression models.

Predictor	Model	B	95% C.I.	p-value
ARFS	1	-0.043	-0.072, -0.015	0.003*
	2	-0.029	-0.058, 0.001	0.059
	3	-0.033	-0.065, -0.003	0.033 *
FAVI	1	-0.015	-0.025, -0.006	0.001 *
	2	-0.011	-0.020, -0.001	0.027*
	3	-0.012	-0.021, -0.002	0.016*

* Statistically significant (p <0.05)

Model 1. Crude model: weight change as dependent variable and the diet quality index as the independent variable.

Model 2. Specifically adjusted model: adjusted for PA, education, number of births, area of residence, marital status, smoking, weight at baseline.

Model 3. Fully adjusted model: the same as specifically adjusted model plus TEI.

Chapter 7 The First analysis on Mid-age Women (Section 3)

This article was published in 2013

Authors: Aljadani, Sibbritt, Patterson, and Collins.

Title: The Australian Recommended Food Score did not predict weight gain in middle-aged Australian women during six year of follow-up

Journal: Australian and New Zealand Public Health Journal (2013)

The Work presented in the manuscript was competed with co-authors (Appendix 8**)**

7.1 Overview

Evidence on the role of diet quality and its contribution to weight status change shows inconsistent results among women in cohort studies. This chapter presents the results of the analysis which aimed to evaluate the relationship between diet quality, as defined by the ARFS, and body weight change in middle-aged women from the ALSWH during six years of follow-up. In order to emphasise the results in this chapter, a further analysis was conducted amongst middle-aged women who reported a healthy weight and a valid TEI at the start of the study. Chapter 8 presents an analysis in those who were at a healthy weight at the start of the study in order to inform strategies to achieve body weight stability over time and to avoid further weight gain for those in menopausal transition. Chapter 9 is the third analysis which was conducted on a sub-cohort of middle-aged women who were identified as having a valid TEI and who were followed up for longer period of nine years.

7.2 Abstract

Objective: To evaluate the relationship between diet quality score, as measured by the Australian Recommended Food Score (ARFS) and six-year weight gain in middle-aged Australian women.

Methods: Participants were a sub-sample of women from the Australian Longitudinal Study on Women's Health (ALSWH) (n=7155, aged 48 to 56 years) who were followed up from 2001 to 2007. The ARFS was derived from responses to a sub-set of questions from a food frequency questionnaire, with possible scores ranging from 0 to 74 (maximum). Absolute weight gain was calculated from the difference in self-reported weight between 2001 and 2007. Linear regression was used to test the relationship between diet score and weight change.

Results: On average, women gained weight during follow-up (1.6±6.2kg) and had a mean baseline ARFS of 32.6 (SD 8.7) which was not optimal. There was no association between ARFS and weight change during follow-up (β=0.016; p=0.08) in the fully

adjusted model that included total energy intake, education, area of residence, baseline weight, physical activity, smoking and menopause status.

Conclusion: Weight gain and low ARFS were common. However, diet quality as measured by the ARFS did not predict 6-year weight gain.

Implication: This lack of association may be due to limitations related to AFRS or be a false negative finding. Further research is warranted to evaluate the impact of promoting optimal diet quality on weight gain prospectively.

7.3 Introduction

Internationally, the prevalence of overweight and obesity has increased rapidly (WHO, 2013a), with the World Health Organisation estimating that in 2008 obesity affected at least 500 million adults worldwide, with an additional 1.5 billion considered overweight (WHO, 2013b). In Australia in 2004-05, (ABS, 2005) 54% of adults were considered overweight or obese and this combined percentage increased to 61.4% in 2007-08 (ABS, 2008).

Middle-aged women are at particular risk of weight gain due to the menopausal transition and at this life stage are likely to gain greater amounts of weight than men of the same ages (Au et al., 2012). A previous study examining weight gain in the middle-aged cohort of the Australian Longitudinal Study on Women's Health (ALSWH) found that more than 33% of the women gained 2.25kg or more over two years (Williams et al., 2006). Those who gained 2.25kg or more had a significantly higher proportion of body fat, higher total cholesterol and blood pressure compared with those who gained less than 2.25kg or lost weight over 4 years during the menopausal transition (Williams et al., 2006).

The causes of weight gain are multi-factorial and complex. However diet is one major modifiable risk factor. Human and animal studies demonstrate that food habits, food quality and total food quantity predict future weight gain (McCrory et al., 2002). A systematic review of the relationship between diet quality and prospective weight gain in adults found only a limited number of studies (Aljadani et al., 2013a). These studies had varying methodologies in regard to the method or tool used to assess diet quality, how body weight change was evaluated, and also in the approach to statistical analyses. In addition the conclusions varied, with some studies (n=4) reporting a positive correlation between weight change and diet quality and other studies finding no relationship (n=3) (Aljadani et al., 2013c).

Measuring diet quality, in terms of how closely eating patterns and nutrient intakes align with National Dietary Guidelines, has recently become a focus within public health nutrition research. The importance of optimising diet quality has been acknowledged in the 2013 revised Dietary Guidelines for Australians (NHMRC, 2013b). In addition, a review of the relationship between diet quality, as assessed using various dietary indices or tools and health outcomes demonstrated that these tools are able to quantify the risk of some health outcomes, including biomarkers of disease and risk of CVD, some cancers and total mortality (Wirt & Collins, 2009). Given that weight gain could be an early indicator of risk for adverse health outcomes, its relationship with diet quality requires examination. However, as higher diet quality has been reported as being associated with higher energy intake, evidence is needed as to whether optimising dietary quality, in line with national dietary recommendations, does not lead to weight gain over time.

The Australian Recommended Food Score (ARFS) has been developed and validated previously as a measure of overall diet quality in the middle-aged cohort from the ALSWH and shown to align with National Dietary Guidelines for Australian adults (Collins et al., 2008). Higher ARFS scores were associated with a greater variety of nutrient dense core foods and better intakes of key nutrients (Collins et al., 2008). However, the ARFS has not previously been used to examine the relationship with prospective weight change in middle-aged women.

Therefore, the aim of this study was to examine the relationship between diet quality score, as measured by the Australian Recommended Food Score (ARFS), and six year weight gain in women in the middle-aged cohort of ALSWH.

7.4 Methods

7.4.1 Study population

The ALSWH is a prospective cohort study of a nationally representative sample of Australian women. It was established in 1996 with more than 40 000 women divided into three cohorts based on the age of women at baseline: young (18-22years) (n=14 779), middle-aged (45-49years) (n=14 099) and older women (70-74years) (n=12 939). The purpose of the ALSWH is to examine the health status and a range of social, psychological and environmental factors affecting health and well-being over time. Participants were randomly selected from National Health Insurance database and have been shown to be broadly representative of the Australian population for women in the same age groups (Brown et al., 1996). This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the Human Ethics committees of both the University of Newcastle and the University of Queensland. Written informed consent was obtained from all participants.

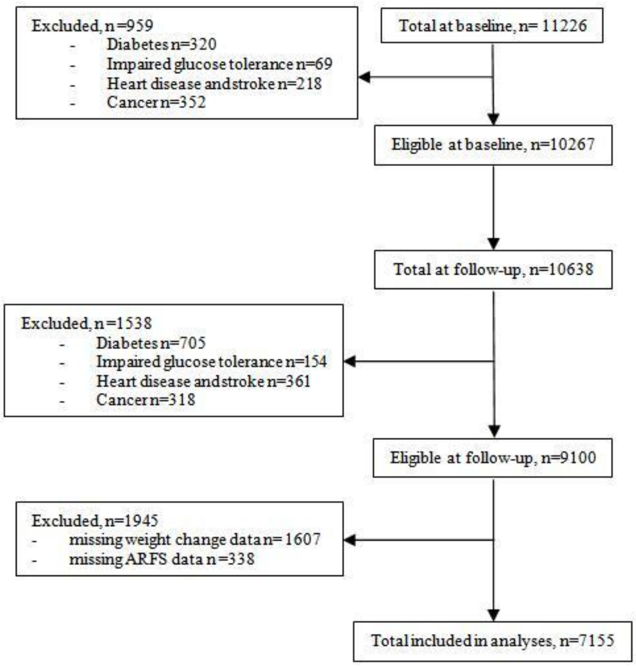
7.4.2 Participants

The current study was conducted in the middle-aged cohort. The follow-up time was from 2001 to 2007. The current analyses were conducted in a sub-sample of women who were disease free by excluding those who self-reported any of the following conditions at either baseline or follow-up; type 2 diabetes, impaired glucose tolerance, heart disease (including heart attack and angina), stroke, or any type of cancer, with the exception of skin cancer. Of 11,226 Middle-aged women at baseline, with 959 women excluded including (Diabetes n=320; Impaired glucose tolerance n=69; Heart disease and stroke n=218 and Cancer n=352) remind a total number of 10,267 were eligible for the analyses. The response rate at follow-up was a total of 10,638 women, with 1538 women excluded including (Diabetes n=705; Impaired glucose tolerance n=154; Heart disease and stroke n=361 and Cancer n=318). The total number of women who were eligible for this study was 9,100. The total number of observations included in the analysis after excluding ineligible persons and those with missing ARFS or weight change data is n=7715 (Figure 7-1).

7.4.3 Dietary intake

Dietary intake was assessed using the Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2) FFQ developed by the Cancer Council of Victoria (Ireland et al., 1994). This quantitative FFQ, with a total of 74 food items and 6 alcoholic beverages, is completed via self-report and asks about intake over the previous 12 months using frequency options that range from 'never' up to 'three or more per day'. The FFQ has been validated in Australian women previously (Hodge et al., 2000b) and the nutrient output is derived using the NUTTAB95 Australian Nutrient Database (Lewis et al., 1995), the Australian government food composition database using software developed by the Cancer Council of Victoria.

Figure 7-1: Flow chart of participant's selection for the analysis



7.4.4 Australia Recommended Food Score (ARFS)

The diet quality score was assessed using the ARFS, which was adapted from the Recommended Food Score (RFS) (Kant & Thompson, 1997) and previously validated for use in the middle-aged cohort of ALSWH (described in detail elsewhere) (Collins et al., 2008). The ARFS calculation is based on regular consumption of FFQ items that align with the recommendations in the National Dietary Guidelines and the Australian Guide to Healthy Eating (Dietary Guidelines for Australian Adults, 2003, Collins et al., 2008). The ARFS scoring method is reported in detail elsewhere (Collins et al., 2008). Briefly, it is made up of seven sub-scales and has a score range from 0-74. The sub-scale scores are calculated from the following food groups with one point awarded for each item reported as being consumed at least once a week. The total score within each sub-scale is: vegetables 22 points (including potato cooked without fat); fruit 14 points; protein foods 14 points; grains 14 points; dairy seven points; fats one point and alcoholic beverages two points (Collins et al., 2008). The maximum ARFS score is 74, reflecting the healthiest or most optimal diet quality score. We previously reported that among the middle-aged ALSWH cohort, those in the highest quintile of ARFS had better self-reported health status, higher intakes of key nutrients, and lower intakes of total fat and saturated fat compared to those in the lowest ARFS quintile (Collins et al., 2008).

7.4.5 Body weight

The six year weight change (kg) was calculated by subtracting weight in 2007 from baseline weight in 2001. Weight was self-reported and this method has been previously validated in a study of 159 women with a mean BMI 26.70±5.18 (Burton et al., 2010).

7.4.6 Co-variates

7.4.6.1 Physical activity

Given that physical activity (PA) is an important confounder of body weight (Kimokoti et al., 2010), PA was measured using minutes of metabolic equivalents of task (MET. mins) based on self-reported walking and moderate and strenuous physical activity as follows; (3 × minutes walking) + (4 × minutes of moderate activity) + (7.5 × minutes of vigorous activity), with PA used as continuous variable in the models. For descriptive analyses PA was classified into four groups based on weekly energy expenditure as follows; nil/sedentary (0 to <40MET.min/week), low (40 to <600MET.min/week), moderate (600 to <1200MET.min/week) or high (≥1200MET.min/week).

7.4.6.2 Education

Level of education was categorized into six groups based on highest qualification obtained as follows; no formal qualifications, school certificate, higher school certificate, trade/apprenticeship; university degree or higher university degree.

7.4.6.3 Smoking habits

Given that smoking status can affect weight change (Kimokoti et al., 2010), women were categorised into three groups according to smoking status as follows; current smoker, ex-smoker or never smoked. Current smoker was defined as usually smoking more than 10 cigarettes per a day.

7.4.6.4 Menopausal Status

Menopausal status has previously been shown within the ALSWH to be a strong predictor of weight gain (Brown et al., 2005). Hence it was included as a confounder and categorised based on self-report as follows; 1) surgical menopause if uterus, ovaries or both removed, 2) hormone replacement therapy (HRT) user, 3) oral contraceptive (OCP) user, 4) pre-menopause if they had menstruated in the last 3 months and reported no change in menstrual frequency in the last 12 months, 5) peri-menopause if they reported changes in menstrual frequency or 3-11 months of amenorrhea, or 6) post-menopause if they reported amenorrhea for 12 consecutive months or more.

7.4.6.5 Total energy intake

Total energy intake (TEI) was derived from the FFQ data as megajoules per-day using NUTTAB95 as described above. A sub-analysis performed to assess the relationship between those who had valid data on TEI and weight gain over time. TEI mis-reporters were identified using the ratio of reported energy intake to BMR, and applying the Goldberg cut-offs (Tooze et al., 2012) as previously reported in this cohort (Collins et al., 2008).

7.4.6.6 Area of residence

Based on post code, an area of residence variable was created with three categories of urban, rural and remote.

7.5 Statistical analysis

The weight gain and ARFS data was assessed for normality and found to be normally distributed. Thus means and standard deviations were used to describe the data. Three main linear regression models were used to test the relationship between diet quality score as measured by ARFS, and absolute weight gain during the period from 2001 to 2007, as follows; 1) a crude model which examined diet score and weight gain, where ARFS was the independent variable and weight gain the dependent variable, 2) a partially adjusted model including ARFS as the independent variable and weight gain as dependent variable with adjustment for the main confounders (education, area of residence, weight in kg at baseline, physical activity, smoking status and menopause) and 3) a fully adjusted model similar to model 2, but with the addition of TEI. This model was employed to separately examine to what degree the FFQ derived TEI explained the relationship between ARFS and weight change. This is because our interest is in the potential application of ARFS alone in practice, where TEI would not be known. In addition, the previous ARFS validation study (Collins et al., 2008) demonstrated that in both the full samples and the sub-sample least likely to have mis-reported energy intake, that the relationship between higher ARFS and more optimal macro- and micronutrient intakes was similar. While there was a weak correlation between energy intake and ARFS in the full sample, this disappeared when examined in the valid reporter sub-sample. In addition, when nutrient intakes were expressed per 1000 Calories, the positive associations between ARFS and nutrient intakes largely remained (Collins et al., 2008).

The same three linear regression models were also applied to identify any relationship between ARFS subscales and weight gain, with both as continuous variables. No adjustments were made for multiple hypothesis testing. All statistical analyses were performed using the statistical program STATA (version 11.1 for windows, 2009, StataCorp LP, USA) (StataCorp, 2011).

7.6 Results

A comparison between those participants classed as misreported (based on TEI) (n=5561) and those participants classed as non-misreporters (n=2154) found no difference between the groups. Therefore, all participants (n=7715) were included in the presented analyses.

7.7 Descriptive analyses

Table 7-1 summarises the characteristics of the women in the cohort (n=7155). The mean ARFS was 32.6(±8.7) and the majority of participants reported no (17%) or low physical activity (37%), while the remainder reported moderate (21%) and high (25%) levels of physical activity. The majority of participants (55%) had never smoked, while 14% identified as current smokers. More than 50% of participants lived in a rural area, but the original recruitment method for ALSWH oversampled rural and remote women to achieve adequate samples. Almost half the participants had completed a secondary education (31%), while 14% had attained a University undergraduate or postgraduate degree.

Further analyses were done to compare those with and without missing FFQ data, with no differences found in weight change over time (data not shown). In addition, we compared ARFS in those who had data on weight change (n=7155) and those who did not (n=1607), and found that there was no significant different in the score.

7.8 Longitudinal analysis

Table 7-2 reports six year weight gain by quintiles of the ARFS. The first quintile reflects the lowest ARFS and the last quintile, the highest ARFS. Weight increased non-significantly within all quintiles, with no significant difference in weight gain between ARFS quintiles (p=0.53).

Table 7-3 reports the results of the linear regression analyses examining the relationship between ARFS and six-year weight gain. There was no statistically significant relationship between ARFS and weight gain in any of the three models ($p>0.05$). There were no significant associations between any ARFS subscales and weight gain.

7.9 Discussion

This study investigated the relationship between diet quality, as measured using the Australian Recommended Food Score, and weight gain in a healthy sample of middle-aged Australian women and found no significant association between ARFS and six year weight gain. This suggests that a dietary pattern that focuses on usual consumption of a greater variety of foods and that aligns with national guidelines is not associated with greater weight gain in this group of women.

However, the finding in the current study are consistent with results of a study conducted by Kimokoti, et al. (2010), in 15 151 adults from the Framingham Off Spring and Spouse Study (FOS) which used the Framingham Nutritional Risk Score to measure diet quality, and found no relationship with weight gain over 16 years of follow up (Kimokoti et al., 2010). In another study by Sanchez-Villegas, et al. (2006), of 6 319 adults from the Seguimiento University of Navarra (SUN) Cohort, there was no significant relationship between the Mediterranean Diet Scores (MDS) and weight gain over two years (Sanchez-Villegas et al., 2006). While in a recent study by Lassale, et al. (Lassale et al.) in 3 151 adults evaluated the relationship between six different diet quality indices, all reflecting adherence to national healthy dietary recommendations, and 13-year weight change. There was no relationship between any of the diet quality scores and weight change in women. In contrast, two other studies have found that higher diet quality was associated with lower weight gain over time in both men and women, compared to weight gain in those with the lowest diet quality (Quatromoni et al., 2006, Beunza et al., 2010). In these two studies the indices used to evaluate dietary intake were the Diet Quality Index (Quatromoni et al., 2006) and the MDS, respectively (Beunza et al., 2010).

It was reported previously that a higher ARFS was an indicator of more favourable nutrient intake profiles in this population, including higher fibre, beta-carotene, folate, thiamine, niacin, riboflavin, vitamin C, vitamin E, calcium and iron (Collins et al., 2008). Higher ARFS scores were also consistent with more optimal macronutrient profiles in terms of higher percentage energy intakes from carbohydrate, protein and monounsaturated fat and a lower percentage energy from total fat and saturated fat (Collins et al., 2008).

The mean ARFS in this population was not high, indicating that diet quality could be improved. Women on average consumed a relatively low variety of nutrient dense foods within each ARFS subscale, potentially placing them at increased risk of diet-related chronic disease, including CVD and some cancers (Wirt & Collins, 2009).

The diet quality indices used in previous studies have been constructed differently with varying sub-scales used, including regular consumption of differing but specific food items; and/or inclusion of sub-scales reflecting specific nutrient intakes such as saturated or total fat; and assignment of differing weightings to sub-scales making direct comparisons difficult. In addition, previous studies (Beunza et al., 2010, Sanchez-Villegas et al., 2006) assessed the relationship with weight change in adults in general and then adjusted for gender, while other studies examined the relationship between diet quality and weight change separately for men and women (Quatromoni et al., 2006, Lassale et al., 2012, Kimokoti et al., 2010). However, the current study supports the majority of previous literature which indicates that dietary patterns that are in line with national dietary guidelines are not associated with prospective weight gain in middle aged women.

7.10 Strengths and limitations of the study

Previous studies have investigated the relationship between a range of diet quality indices and weight gain in adults. The strength of the current study is that it is the first to examine this relationship using the ARFS. While it has been shown to predict nutrient intakes and health outcomes previously (Collins et al., 2008) this longitudinal analysis was conducted on a large number of middle-aged healthy women from the nationally representative ALSWH) with follow-up for six years.

However, the limitations must be acknowledged, and include that ALSWH data is self-reported, including body weight. Women were excluded from the analysis if they had self-reported specific disease states, which may have introduced bias as some may have had disease which they were not aware of at assessment and subsequently improved their diet and reduced weight over the follow-up period. In addition the ARFS does not capture food portion size, which is an important factor impacting on TEI and the association between dietary intake and weight change over time. However, the current study was not examining the relationship between portion size and weight gain. There was a large number of a participants with missing weight and/ or FFQ data, although there was no difference between those who mis-reported TEI and those who did not, or between those with missing weight or ARFS data.

The present study is limited by the fact that weight is self-reported. However, the impact may have been moderated by the fact that weight was self-reported on both occasions. Although a previous study (Burton et al., 2010) showed that women in the middle-age cohort tended to under report their weight and height, the difference between self reported and objectively measured weight and height was not clinically important and authors concluded that self-reported and objectively measured weight and height were in good agreement. The degree of mis-reporting cannot be verified in the current study and results should be interpreted with caution. Further, future studies examining accuracy of self-reporting of weight over time are needed. In addition, no adjustments were made for multiple statistical testing.

7.11 Conclusion and implication

While women in the middle-aged cohort gained weight over a six year period, their total ARFS as an indicator of overall diet quality did not predict weight gain. This means that consuming a dietary pattern that aligns with national dietary guidelines does not lead to weight gain in this population. This may indicate that women can safely be advised to follow the national dietary guidelines without risk of weight gain. However, further research is needed to confirm this.

The current analysis found that ARFS was not related to weight gain in this group of middle aged women. It is possible that there is no association, or the lack of relationship may be a false negative and a true association does exists; or it may have arisen due to limitations specific to the ARFS as a measure of diet quality such that the elements of diet responsible for weight gain were not captured; or the limited number of foods in the original FFQ it was derived from includes. Finally, it is possible that population wide changes in eating habits that were also not detected in the current analysis are contributing to weight gain, particularly as the FFQ in the current study was first developed in the 1980s. Thus, it would be useful to explore the relationship between weight change the ARFS across other time frames and in other age and population groups, including males. Furthermore, research is required to explore the relationship between the ARFS and risk of developing lifestyle related chronic conditions, including cardiovascular disease and type 2 diabetes.

Acknowledgement

We wish to thank the Australian Longitudinal Study on Women's Health Steering Committee for permission to undertake the study. The first author would like to thank Clare Collins, David Sibbritt and Amanda Patterson for their supervision and advice. We would also like to thank Dr Megan Jensen and Ms Amy Ashman for editorial assistance.

Disclosure

The authors have no conflicts of interest to declare.

Table 7-1 Demographic characteristics of participants from the middle-aged cohort of the Australian Longitudinal Study on Women's Health (n=7155)

Variable		Descriptive Statistics					
		Baseline			Follow-up		
		Mean	SD	Range	Mean	SD	Range
ARFS[b]		32.6	8.7	6–61	-	-	-
Age (years)		52.4	1.4	48.0–56.0	58.4	1.4	54-62
Weight (kg)		70.1	14.2	36–150	71.5	14.4	37-155
BMI		26.3	5.1	13-62	26.9	5.2	15-58
Weight difference		1.6	6.2	-40 to 38	-	-	-
Energy Intake (kJ)		6648.7	2515.2	1251.4–54779.8	-	-	-
		%			%		
Physical Activity	Nil	17			15		
	Low	37			26		
	Moderate	21			23		
	High	25			36		
Smoking Status	Non-smoker	55			62		
	Ex-smoker	31			28		
	Smoker	14			10		
Area of Residence	Urban	38			39		
	Rural	57			56		
	Remote	5			5		
Menopause Status	Surgical menopause	27			31		
	HRT use	19			7		
	OCP use	9			0.1		
	Premenopause	19			0.2		
	Perimenopause	25			2.2		
	Postmenopause	10			60		
Education	No formal	18			-		
	School certificate	32			-		
	Higher school certificate	17			-		
	Trade/ apprentice	30			-		
	Certificate/ diploma	16			-		
	University degree	9			-		
	Higher degree	5			-		

ARFS, Australian Recommended Food Score; BMI, body mass index; SD, standard deviation; - No available data

Table 7-2 Mean six-year absolute weight and BMI change across quintiles of diet quality score as measured by the ARFS in women from the middle-aged cohort of the Australian Longitudinal Study on Women's Health (n=7155)

	Australian Recommended Food Score (ARFS)				
	1st quintile (21±4) (n=1446)	2nd quintile (29±2) (n=1638)	3rd quintile (34±1) (n=1334)	4th quintile (38±1) (n=1321)	5th quintile (45±4) (n=1416)
Weight (kg)	1.7	1.7	1.3	1.6	1.7
SD[b]	6.5	6.5	6.2	5.7	5.9
BMI	0.6	0.6	0.5	0.6	0.6
SD[b]	2.4	2.5	2.3	2.2	2.2

BMI, body mass index; SD, standard deviation

Table 7-3 Longitudinal predictors of six-year weight change in women from the middle-aged cohort of the Australian Longitudinal Study on Women's Health (n=7155)

Predictor	Model	Coefficient	(95% C.I.)	p-value
ARFS	1[a]	-0.000	(-0.017, 0.016)	0.981
	2[b]	0.009	(-0.008, 0.026)	0.315
	3[c]	0.011	(-0.007, 0.028)	0.236
Vegetable	1[a]	0.013	(-0.020, 0.047)	0.424
sub-scale	2[b]	0.022	(-0.012, 0.056)	0.195
	3[c]	0.025	(-0.010, 0.059)	0.159
Fruit	1[a]	-0.023	(-0.068, 0.022)	0.312
sub-scale	2[b]	0.007	(-0.040, 0.059)	0.780
	3[c]	0.009	(-0.038, 0.056)	0.709
Protein	1[a]	0.064	(-0.010, 0.137)	0.090
sub-scale	2[b]	0.068	(0.006, 0.143)	0.073
	3[c]	0.076	(0.0004, 0.152)	0.051
Grain	1[a]	-0.086	(-0.165, -0.007)	0.034*
sub-scale	2[b]	-0.056	(-0.137, 0.025)	0.173
	3[c]	-0.052	(-0.137, 0.025)	0.230
Dairy	1[a]	0.058	(-0.084, 0.200)	0.425
sub-scale	2[b]	0.066	(-0.078, 0.210)	0.370
	3[c]	0.063	(-0.081, 0.208)	0.389
Fat	1[a]	0.032	(-0.269, 0.334)	0.834
sub-scale	2[b]	0.126	(-0.179, 0.432)	0. 419
	3[c]	0.121	(-0.186, 0.428)	0.440
Alcohol	1[a]	-0.156	(-0.386, 0.074)	0.183
sub-scale	2[b]	-0.055	(-0.289, 0.179)	0.648
	3[c]	-0.053	(-0.287, 0.181)	0.659

*Statistically significant results ($p<0.05$)
[a]Unadjusted model
[b]Adjusted for education, area of residence, baseline weight (kg), physical activity, smoking status, menopause.
[c]Adjusted for the same confounders in model two, plus total energy intake

Chapter 8 The Second analysis on Mid-age Women, (Section 3)

This article accepted in the Health Promotion Journal of Australia (2015)

Authors: Aljadani, Patterson, Sibbritt, and Collins.

Title: Diet quality and six year risk of overweight and obesity amongst mid-age Australian women who were initially in the healthy weight range

Also part of this work presented as poster presentations in the manuscripts in different conferences as follow:

- The Annual Meeting of the Australia and New Zealand Obesity Society (ANZOS) in 2013. Melbourne.
- The Australasian Epidemiological Association Annual Scientific Meeting 2014. Auckland, New Zealand.

The Work presented in the manuscript was competed with collaboration with the co-authors (Appendix 9**)**

8.1 Overview

The previous chapter (Chapter 7) reported the result of the association between the ARFS and six-year prospective weight change in a group of women with all being within BMI range. The conclusion of the chapter revealed that higher diet quality score is not associated with weight change in this group of women. The current chapter presents the analysis in a group of the same age as participants in Chapter 7, but only those who identified as healthy weight and valid TEI at baseline.

8.2 Abstract

Issue addressed: This study investigated the association between diet quality, measured using the Australian Recommended Food Score (ARFS), and six-year risk of becoming overweight or obese in mid-age women from the Australian Longitudinal Study of Women's Health (ALSWH).

Methods: Women (n=1107), aged 47.6-55.8 years, who were healthy weight (Body Mass Index (BMI) ≤18.5 to <25.0kg/m^2) at baseline and who reported valid Total Energy Intakes were included in the analysis. BMI was calculated from self-reported height and weight in 2001 and 2007. ARFS scores were calculated from data collected using a validated Food Frequency Questionnaire (Dietary Questionnaire for Epidemiological Studies Version 2). Logistic regression was used to examine the relationship between ARFS score as a continuous variable and risk of becoming overweight or obese.

Results: Six-year incidence of overweight was 18.5% and obesity 1.1%. Mean ARFS (SD) was 35.3 (8.1) and 34.3 (8.8) [maximum possible 74] among those who remained within the healthy weight and those who became overweight or obese at follow-up, respectively. There was no relationship between baseline ARFS and risk of becoming overweight or obese over six years. Women who were smokers (OR=1.5; 95% CI 1.11, 2.09; p=0.008) or reported a higher baseline weight (OR=1.1; 95% CI 1.10, 1.18; p<0.001) were more likely to become overweight or obese.

Conclusions: Among mid-age ALSWH women who were of a healthy weight, poor diet quality was common. Higher diet quality was not associated with risk of overweight or obesity after six years, yet smoking status and weight at baseline were. Promoting greater variety of healthy foods does not increase risk of weight gain in mid-age women.

So what? Mid-age women, especially smokers, need to be supported to optimise lifestyle behaviours to reduce risk of becoming overweight or obese. Better diet quality alone will not achieve maintenance of a healthy weight, but should be encouraged to improve other health outcomes.

Key words: diet; diet quality; overweight; obesity; mid-age; women.

8.3 Introduction

Obesity is increasing rapidly internationally and is associated with increased morbidity and mortality (World Health Organization, 2013b, World Health Organization, 2014). In 2014 the World Health Organization (WHO) reported, of women aged ≥18 years worldwide, 40% were overweight and 15% were obese (World Health Organization, 2014). In Australia the prevalence of overweight and obesity in women increased from 54.7% in 2007-08 to 56.2.4% in 2011-12 (Australian Health Survey, 2012).

Diet quality is a term used to indicate overall nutritional quality and variety of the entire diet. Diet quality indexes aim to numerically capture both aspects in a single continuous variable in order to avoid focussing on nutrient intakes alone (Wirt & Collins, 2009). While dietary intake plays a key role in weight change, evidence is contradictory on the role of diet quality measured by specific indexes or diet quality scores as a predictor of becoming overweight or obese (Quatromoni et al., 2006). Exploring the relationship between diet quality and the incidence of overweight or obesity is important in order to inform strategies to prevent weight gain and improve population health (McNaughton et al., 2012, Kant et al., 2000, Wirt & Collins, 2009, Wirfält et al., 2013, McNaughton et al., 2009). Our recent systematic review found that higher diet quality was significantly associated with decreased risk of overweight and obesity in adults across 16 international longitudinal studies (Haya Aljadani & Amanda Patterson, 2015).

Diet quality indexes are usually country and population specific due to variations in eating habits and cultures. The Australian Recommended Food Score (ARFS), is a validated diet quality index (Collins et al., 2008, Collins et al., 2015) and has been previously shown to be associated with dietary patterns aligned with the Australian Dietary Guidelines and better self-reported health in mid-age women from the Australian Longitudinal Study of Women's Health (ALSWH) (Collins et al., 2008, National Health and Medical Research Council, 2013a).

Previously a study (Aljadani et al., 2013d) that examined ARFS and prospective weight gain in mid-aged women from the ALSWH across all BMI categories at baseline, found no relationship between better diet quality and prevention of weight gain. Here we evaluate the relationship between diet quality as measured by the ARFS, and risk of becoming overweight or obese only amongst women who were initially of a healthy weight, in order to provide guidance on the role of diet quality in maintaining healthy weight as women progress through mid-age.

Moreover, evidence confirms mid-age women are at a particularly high risk of weight gain due to the menopausal transition, and are more likely to gain greater amounts of weight than men of the same age (Williams et al., 2014). Thus, the aim of the current study was to examine whether higher ARFS, is associated with a lower six-year incidence of overweight or obesity in mid-age ALSWH women (aged 47.6 to 55.8 years) of healthy body weight at baseline.

8.4 Materials and methods

8.4.1 Sample

The current analysis used ALSWH data from 2001 to 2007 obtained from 1,107 mid-age women who were initially of a healthy weight (18.5≤BMI<25.0kg/m2) and who reported valid Total Energy Intakes (TEI) at baseline.

From the total cohort (n=10,638) those who were overweight (BMI ≤25.0to<30.0kg/m2, n=2,851), obese (BMI≥30.0kg/m2, n=1,745), or underweight (BMI<18.5kg/m2, n=124) at baseline, or had BMI data missing (n=490) were excluded. In addition, women (n=2,025) were excluded if they reported any of the following at baseline or follow-up: type 2 diabetes, impaired glucose tolerance, heart disease, stroke, or breast, cervical or bowel cancer, or had greater than or equal to four missing Food Frequency Questionnaire (FFQ) responses that contributed to the calculation of ARFS (Collins et al., 2008). To identify women with valid TEI, Schofield equations were used to calculate Basal Metabolic Rate (BMR) for each participant, based on age and self-reported weight (Schofield, 1985), with a Physical Activity Level (PAL) of 1.55 applied to calculate individual Estimated Energy Requirements (EER). EERs were compared with individual TEI derived from the FFQ, and the Goldberg cut-offs (Tooze et al., 2012) were applied to identify those with valid TEI. A number of 2,296 women were identified as those who reported invalid TEI and thus excluded from the current analysis.

The ALSWH was approved by the human research ethics committees of the Universities of Newcastle and Queensland. Further details are reported elsewhere (Brown et al., 1996).

8.4.2 Dietary intake

Dietary intake was assessed and collected as part of the ALSWH survey procedure in 2001 using the Dietary Questionnaire for Epidemiological Studies Version 2 (DQESv2), an FFQ developed by the Cancer Council of Victoria (Ireland et al., 1994) and previously validated (Hodge et al., 2000a). The DQESv2 asks participants to report consumption of 74 food items and six-alcoholic beverages over the previous 12 months using a 10-point frequency scale which ranges from never and less than once per month up to 5-6 times per day. Additional questions ask about portion size, number of serves and specific types of dairy products and fat spreads.

8.4.2.1 Australian Recommended Food Score

ARFS is a diet quality index that uses a subset of DQESv2 questions. The ARFS has a score range from zero to 74. Higher scores reflect dietary patterns more closely aligned with recommendations in the Australian Dietary Guidelines and the Australian Guide to Healthy Eating (Dietary Guidelines for Australian Adults, 2003, National Health and Medical Research Council, 2013b). In scoring the ARFS, one point is awarded for meeting specific recommendations, otherwise zero is allocated. Scoring is independent of reported amounts of food items. For instance, one point is awarded if a particular vegetable or fruit is consumed once per week or more frequently, and zero if the item is consumed less often. There are seven sub-scales with additional points awarded for optimal types or amounts of foods within sub-scales. These include: Vegetables (22 points); Fruit (14 points); Protein Foods (14 points); Grains (14 points); Dairy (7 points); Fats (1 point); Alcoholic Beverages (2 points). Detailed methods and validation are reported elsewhere (Collins et al., 2008, Aljadani et al., 2013d). Consuming no alcohol scores zero due to the U shaped association between alcohol intake and health status (Collins et al., 2008).

8.4.2.2 Weight status

Weight and height were self-reported. BMI was calculated as weight (kg)/height (m)^2 (World Health Organization, 2013b). A validation study found that while the mid-age women tended to under-report weight and height, there was good agreement, and differences between self-report and objective measures were not clinically important (Burton et al., 2010). Weight change from baseline to follow-up was categorised into groups from highest weight gain to weight loss as; high weight gain (>10kg), moderate weight gain (>5 to 10kg), low weight gain (>2.25 to 5 kg), weight stable (-2.25 to +2.25 kg) and weight loss (>-2.25 kg) (Williams et al., 2006).

8.4.2.3 Confounders

Education was categorised into 'no formal', 'school certificate (up to 13 years schooling)', 'trade or diploma', and 'university degree or post-graduate degree'. Area of residence was categorised as urban, rural and remote based on was based on size, remoteness and distance to services and facilities (Australian Longitudinal Study on

Women's Health, 2015). Participants self-reported physical activity (PA) as walking, moderate and vigorous PA frequency using standard questions from the Australian National Health Surveys, which have been shown to be both valid and reliable (Brown et al., 2004). These questions were used to derive a PA score in metabolic equivalents (METs) per minute (MET.mins). Total MET minutes were calculated and categorised into four groups: nil/sedentary (0 to <40 MET.min/week), low (40 to <600 MET.min/week), moderate (600 to <1200 MET.min/week) and high (≥1200 MET.min/week) (Brown & Bauman, 2000). Smoking status was categorised as never smoked, current smoker and quit smoking. Menopause was categorised into surgical menopause, hormone replacement therapy (HRT) use, oral contraceptive (OCP) use, pre-menopausal, peri-menopausal, and post-menopausal. The TEI (kJ/day) and nutrient intakes were quantified from the Australian nutrient composition database using the Nutrient Data Table (NUTTAB) (Lewis et al., 1995).

8.4.2.4 Statistical analyses

Descriptive statistics, including means and standard deviations, were calculated as the data were normally distributed. All analyses were conducted using STATA (version 11) (StataCorp, 2011). Analysis of variance (ANOVA) was used to compare mean ARFS across BMI and weight groups. Logistic regression was used to examine the relationship between ARFS as a continuous variable and risk of becoming overweight or obese. Due to the small number of women who became obese, numbers were combined with those for overweight in the regression models. The analysis used 'a fully adjusted model' with the ARFS score as a continuous independent variable, and overweight or obesity incidence as the dependent variable, with those remaining 'healthy weight' as the reference group. The model was adjusted for education, area of residence, baseline weight, physical activity, smoking status, menopause status and energy intake.

8.5 Results

8.5.1 Demographic characteristics

Table 8-1 summarises demographic characteristics of the 1,107 mid-age women who were of a healthy weight and had reported a valid TEI at baseline. The mean ARFS was 35.1 (8.2) out of a possible score of 74. During six years of follow-up women gained an average of 2.0 ± 4.7kg. The majority of women reported low PA levels (40 to < 600 MET.mins/week) and had never smoked (**Table 8-1**). Almost half of the women (48%) were considered weight stable, while only four percent gained more than 10kg. The combined incidence of overweight or obesity over the six year period was 19.6% (n=217), (data not shown).

8.5.2 Weight Change during follow-up by BMI category

Table 8-2 describes the percentage of women in each weight gain category by BMI category at follow-up. More than a quarter gained between 2.25-10kg yet remained within the 'healthy' BMI range. A small number of women (0.6%) gained more than 10kg yet remained within the healthy BMI range (Table 8-2), while all of the women who were obese at follow-up had gained more than 10kg.

8.5.3 Nutrient and Australian Recommended Food Score

Table 8-3 summarizes the dietary intake data by six year follow-up BMI category. Those who remained in the healthy weight range reported a significantly lower energy intake (8519 kJ/day) compared with those who became overweight or obese (8728 kJ/day). The proportion of energy from protein and fat were within the Acceptable Macronutrient Distribution Ranges (AMDR) of 15-25% and 20-35% of energy respectively, while the percent energy from carbohydrate was less than the AMDR (45-65%). There were no significant differences in the ARFS sub-scale between those who remained in the healthy weight range and those who become overweight or obese at follow-up (Table 8-3).

There were no statically significantly differences between TEI, macronutrient intakes and ARFS in mid-age women based on five weight change categories over six years of follow-up. (Supplementary table S1)

8.5.4 ARFS and confounders and the incidence of overweight or obesity using logistic regression

Table 8-4 reports the odds of becoming overweight or obese compared with those who remained in the healthy weight BMI category using the ARFS as the independent variable. Total ARFS score was not significantly associated with risk of becoming overweight or obese over six years. Moderately active women were less likely to become overweight or obese compared with women reporting not being physically active (OR=0.5; 95% CI: 0.26 0.79; p=0.005). Women who reported being smokers at baseline were more likely to become overweight or obese compared to non-smoking women (OR=1.5; 95% CI: 1.11, 2.03; p=0.008). Higher weight at baseline was associated with increased risk of becoming overweight or obese (OR=1.1; 95% CI: 1.10, 1.18; p<0.001). Those women who reported that they were postmenopausal at baseline were more likely to become overweight or obese compared with those who were still premenopausal or who had been through menopause by follow-up (OR=1.4; 95% CI: 1.05, 1.80; p=0.02).

Analyses were conducted to compare the valid TEI (n=1,107) group with the total group combined (n=3,403) (data not shown). The demographic characteristics in total and valid TEI groups were not significantly different.

8.6 Discussion

This six year prospective study on weight change in mid-age Australian women who were initially of a healthy body weight, demonstrates that having higher diet quality is not associated with risk, either increased or decreased, of becoming overweight or obese. However those women who were postmenopausal, current smokers, physically inactive, with lower education, and higher baseline weight within the healthy range (BMI ≤18.5 to< 25.0kg/m2) were at greater risk of developing overweight or obesity. Almost half of all the women remained weight stable over six years, meaning that they were within 2.25kg of their baseline weight, while only four percent gained more than 10kg over this time. However, the cumulative incidence of overweight and obesity was approximately 20%, a figure of significant concern. This is a substantial proportion of the healthy weight population and suggests that mid-age women should be a specific target for population based weight gain prevention strategies.

The prospective patterns of individual weight change varied considerably among women, even when they remained within the same BMI category. For example, of those who remained in the healthy BMI range, more than half were weight stable, 7.8% gained 5-10kg and less than one percent gained >10 kg over six years. Among those who became overweight, approximately 40% had gained 5-10kg. Only 15% reported losing weight, however we were unable to determine whether this was intentional or unintentional.

Previously we reported no association between ARFS and weight change in mid-age ALSWH women across all BMI categories at baseline (Aljadani et al., 2013d). However, the current study differed from the previous study (Aljadani et al., 2013d), which was conducted on 7,155 mid-age women across all BMI categories, in that this current study includes only women who were within the healthy weight range at baseline who reported valid TEI (n=1,107).

Overall, diet quality was low among mid-age women in the current study. The mean total ARFS was in the low thirties, from a maximum score of 74. Even within the highest quintile of ARFS the mean score was 46, indicating that there is considerable room to improve diet quality amongst women at this life stage (Collins et al., 2008). The few studies to date examining diet quality in Australian adults have consistently shown that poor diet quality is common (Zarrin et al., 2013, McNaughton et al., 2008), particularly amongst mid-age women, and that many do not meet national dietary recommendations (Ball et al., 2004, Arabshahi et al., 2012, Mishra et al., 2004). However, the results should be interpreted with caution as direct comparison between these studies cannot be made due differences in statistical approaches and adjustment for confounders, follow-up periods and differences in the indexes used. There are significant variations in the components of each diet quality index, and the scoring methods across the ARFS, the Dietary Guideline Index (DGI) (Arabshahi et al., 2012, McNaughton et al., 2008) and the Australian Dietary Quality Index (Aussie-DQI) (Zarrin et al., 2013).

Despite this, all of these studies found that women had low diet quality scores and more specifically the current study found that women consumed a low variety of vegetables, whole-grains, reduced fat dairy foods and lean sources of protein. McNaughton et al (2008) found that no adult women in their study achieved the optimal score in two sub-scales of the DGI (food variety and lean protein), while only seven percent, 22%, 30% and 55% achieved the full score for the DGI sub-scales of cereals, vegetables, dairy and fruit (McNaughton et al., 2008). Ball et al (2004) found that the majority of mid-age women did not comply with the recommendation for breads, cereals, dairy and iron. Recently, Mishra et al (2014) found that the majority of mid-age women (50-55 years) from ALSWH did not meet the recommendations in the Australian Dietary Guidelines 2013, especially for dairy and vegetable intakes. Similarly, results from the 2011-12 Australian Health Survey revealed that the majority of mid-age women did not meet the recommendations for vegetable intakes (ABo, 2012). This finding itself is a major public health concern as poor diet quality is linked to higher risk of non-communicable diseases and premature death (Wirfält et al., 2013, McNaughton et al., 2012, McNaughton et al., 2009), while optimal diet quality has been shown to be associated with better health outcomes and self-reported quality of life among women aged 55 to 56 years (Milte et al., 2015). Collectively, these results suggest that mid-age women should be targeted for interventions to promote higher diet quality through consumption of a greater variety of healthy core foods such as vegetables, lean protein and reduced fat dairy foods.

In fact, we have previously shown that ASLWH women in the highest ARFS quintile have higher nutrient intakes with lower intakes of total and saturated fat, and reported better health compared to the lowest ARFS quintile (Collins et al., 2008). Higher diet quality as measured by the ARFS reflects greater adherence to the National Dietary Guidelines for adults. While the current analysis found that higher ARFS was associated with higher TEI, it was not associated with an increased risk of becoming overweight or obese. This could be due to limitations of the FFQ, including that it has a limited number of food items, particularly those that are energy-dense, nutrient-poor. So it could be that those who usually consumed a greater variety of healthy foods, and therefore had a higher diet quality, may have been better able to report an accurate picture of their usual intake, and that those with poorer diet quality scores also had high intakes of energy-dense, nutrient-poor items, not captured by the DQESv2. Although energy intake was included as a confounder in the fully adjusted model, there was also a large proportion (67.5%) of women who reported an invalid TEI. This is not surprising given that the food list from the DQESv2 was developed in the 1980s and is unlikely to reflect the current food supply, particularly in terms of packaged, processed foods and sweetened beverages. Therefore it is possible that women may not have under-reported food intake purposefully, but rather did not have the opportunity to report on foods which contribute significantly to overall energy intake. It is also possible that changes in dietary habits during follow-up are an additional source of confounding. The fact that diet, height and weight data are self-reported is a limitation in itself, although Burton et al (2010) have demonstrated that the self-reported anthropometric data is valid among women in ALSWH (Burton et al., 2010). Another limitation that should be acknowledged is that the ARFS may not be sensitive enough to detect small changes in diet quality as statistically significant, or that the diet quality amongst women at this life stage is relatively homogenous, making small differences difficult to detect. The study does have a number of strengths, including use of the ALSWH data which includes a large representative sample of Australian women with six years of follow-up data and adjustment for a broad range of confounding variables.

Given that more women gained weight than lost weight, strategies are needed to raise awareness of the short and long-term consequences of weight gain during this life stage (Williams et al., 2006). Non-dietary predictors of overweight or obesity were more apparent and included being physically inactive, smoking, menopausal, and less educated and higher baseline weight conferring the greatest risk. The literature consistently suggests that smoking status and physical inactivity are major factors leading to greater prospective weight gain (Brown et al., 2005, Kimokoti et al., 2010).

Unsurprisingly, those classified as being moderately physically active were less likely to become overweight or obese, but unexpectedly those classified as highly physically active did not have a lower risk of becoming overweight or obese. This could be due to misreporting, misclassification of PA, changes in PA patterns during follow-up, or women using PA as a means to try and address their increasing weight.

8.7 Conclusion

This current study in mid-age women who were initially of a healthy weight at baseline and who reported valid TEI, found no relationship between weight change and diet quality, as measured by the ARFS, and the risk of becoming overweight or obese over six years of follow-up. The majority of mid-age women consumed diets that rated low in terms of the ARFS diet quality score. This is a major concern and women at this life stage should be engaged into health promotion interventions that aim to optimise eating habits generally. Although this strategy alone cannot address the rising incidence of overweight and obesity, it indicates that mid-age women need support to moderate energy intake, optimise diet quality and lifestyle behaviours together with being physically active and not smoking, to reduce the risk of weight gain at this life stage. Future research should examine the relationship between women routinely consuming a high quality diet and prospective weight gain.

Table 8-1: Demographic characteristics related to weight change in for mid-age women from the ALSWH who were of a healthy weight and who reported a valid Total Energy Intake (TEI) at baseline (n=1,107).

Variable		**Mean (SD)**	**Range**
ARFS		35.1 (8.2)	8 – 60
Age baseline (yrs)		52.4 (1.5)	49.2 – 55.8
Age at follow-up (yrs)		58.4 (1.5)	55.2 – 61.7
Weight baseline (kg)		60.5 (6.3)	43 – 80.7
Weight at follow-up (kg)		62.5 (7.6)	44.5 – 100
Six year weight change (kg)		2.0 (4.7)	-11.3 – 30.8
TEI at baseline (kJ/d)		8560.3 (1150.3)	
		Percentage (%)	
Physical	Nil sedentary	11	
Activity	Low	34	
	Moderate	26	
	High	29	
Smoking	Non smoker	58	
Status	Ex-smoker	28	
	Smoker	14	
Area of	Urban	30	
Residence	Rural	58	
	Remote	8	
Menopause	Surgical menopause	22	
Status	hormone replacement therapy	23	
	oral contraceptives	10	
	Pre-menopause	20	
	Peri-menopause	25	
	Post-menopause	1	
Education	No formal	13	
Variable	School certificate	45	
ARFS	Trade or diploma	23	
Age baseline	University degree or post-graduate degree	19	
(yrs)	Mean (SD)	Range	
	35.1 (8.2)	8 – 60	
	52.4 (1.5)	49.2 – 55.8	

ARFS = Australian Recommended Food Score, TEI = Total Energy Intake. nil/sedentary (0 to < 40 MET.min/week), low (40 to < 600 MET.min/week), moderate (600 to <1200 MET.min/week) or high (≥ 1200 MET.min/week).

Table 8-2: The percentage of mid-age women from the ALSWH with a healthy weight and valid TEI at baseline (n=1,107), who gained or lost weight during six years follow-up across the healthy weight, overweight and obese BMI categories.

BMI categories at 6-year follow-up	Weight loss >-2.25 kg (%)	Weight stable ±2.5 kg (%)	Low weight gain >2.25 to <5kg (%)	Middle weight gain >5 to ≤10kg (%)	High weight gain >10kg (%)	Total (%)
Healthy weight (n=2665)	15.6	57.5	18.6	7.8	0.6	100
Overweight (n=701)	0.0	7.8	32.7	44.4	15.1	100
Obese (n=37)	0.0	0.0	0.0	0.0	100	100

TEI – Total Energy Intake

Table 8-3: Total energy intake (TEI), macronutrient intakes and diet quality, measured using the Australian recommended Food Score (ARFS), in mid-age women from the Australian Longitudinal Study on Women's Health (ALSWH) (n=1,107) who were of a healthy weight and reported a valid TEI at baseline by six year follow-up weight status category (healthy weight and overweight/obese).

	Healthy weight Mean (SD)	Overweight or obesity Mean (SD)	P
ARFS	35.3(8.1)/74 points	34.3(8.8)/74 points	0.10
The ARFS sub-scales			
Vegetables-sub-scale	14.0 (4.0)/22 points	14.0(4.0)/22 points	0.50
Fruit sub-scales	6.0 (3.0)/14 points	5.0(3.0)/14 points	0.10
Protein sub-scales	6.0 (2.0)/14 points	5.0(2.0)/14 points	0.40
Grain sub-scale	5.0 (2.0)/14 points	4.0(2.0)/14 points	0.20
Dairy sub-scales	2.0 (1.0)/7points	2.0(1.0)/7points	0.20
Fat sub-scales	0.6 (0.5)/1point	0.5(0.5)/1point	0.30
Alcohol sub-scale	0.7 (0.5)/2points	0.8(0.4)/ 2 points	0.05
Energy intake, and macronutrient intake			
TEI (kJ/d)	8519.2(1135.9)	8728.5(1195.4)	0.02*
Energy Intake food (kJ/d)	8113.0(1198.3)	8271.7(1 287.4)	0.09
Energy Intake alcohol (kJ/d)	406.2(508.8)	456.8(495.9)	0.19
Carbohydrate (%)	40.5(6.1)	39.8(6.7)	0.15
Total Fat (%)	33.8(5.1)	33.6(5.4)	0.78
Protein (%)	19.2(2.9)	19.5(3.2)	0.24

* Statistically significant difference ANOVA (p <0.05), ARFS = Australian Recommended Food Score, TEI= Total Energy Intake.

Table 8-4: The Australian Recommended Food Score or confounders and the risk of becoming overweight or obese during 2001-07 in 1,107 mid-age women from the ALSWH with healthy weight and valid TEI at baseline, compared with those who remained in healthy BMI category.

Predictor	Odds Ratio	95% CI	P
ARFS•	0.99	(0.968, 1.010)	0.303
Moderate active	0.5	(0.26, 0.79)	0.005*
Smokers	1.5	(1.11, 2.03)	0.008*
Baseline weight	1.1	(1.10, 1.18)	< 0.001*
Postmenopausal	1.4	(1.05, 1.80)	0.02*

•Model 1 is a fully adjusted model, with diet quality as the independent variable and weight change as dependent variable and adjusting for education, area of residence, baseline weight (kg), physical activity, smoking status and menopause and Total Energy Intake.

ARFS = Australian Recommended Food Score.

*Statistically significant (p<0.05)

Chapter 9 The Third analysis in Mid-age Women, (Section 3)

This article submitted to the Journal of Public Health

Authors: Aljadani, Patterson, Sibbritt, and Collins.

Title: Prospective change in diet quality in mid-age Australian women and its association with weight change during nine years of follow-up

Also part of this work accepted as poster presentation in the international conference on Diet and Activity Methods (2015). Brisbane Australia. (Poster presentation)

The Work presented in the manuscript was competed with collaboration with the co-authors (Appendix 10**)**

9.1 Overview

While the previous analyses in mid-age women show no relationship between baseline diet quality measured by the ARFS and weight change prospectively over six years, the analysis reported in this chapter aimed to evaluate the association between the changes in diet quality during nine years and prospective weight in a sample of mid-age women followed for nine years.

9.2 Abstracts

Objective: To examine whether change in diet quality, as measured by the Australian Recommended Food Score (ARFS), is associated with change in weight in mid-age Australian women over nine years of follow-up.

Design: Diet quality was measured by the ARFS using data derived from a validated Food Frequency Questionnaire (DQESv2)) completed in 2001 (baseline) and 2010 (follow-up). The ARFS contains seven subscales including vegetables, low fat dairy and fruit; with total scores ranging from zero to 74. Change in the ARFS was calculated by subtracting the ARFS at follow-up from the ARFS at baseline. Weight change was calculated by taking weight at follow-up from weight at baseline.

Setting: Women were eligible if they did not have any of the specified conditions at baseline and if they reported a valid total Energy Intake (TEI) determined using the Goldberg cut-point method. Multivariate linear regressions were used to evaluate the relationship between changes in diet quality and change in weight.

Subjects: A total of 2,381 women were included.

Results: When participants were grouped into tertiles based on ARFS score change, it was found that those in the top tertile of the ARFS score change improved their eating (7±4 points on average), while those in the lowest and middle tertiles achieved the following scores respectively (-9 ±5 points on average) and (-1±2 points on average). Overall, women gained an average of 2.3±7.2kg. Only those in the top tertile of change in the ARFS had significantly lower weight gain compared with those women in the lower tertile; β=-1.2kg (95% CI: -2.31, -0.11; p=0.03).

Conclusion: Targeting improvements in diet quality of mid-age women may be an important strategy to reduce weight gain that is common at this life stage. Further research examining the best way to optimise diet quality in mid-age women is warranted.

Keywords: diet quality, weight gain, mid-age women, longitudinal, cohort

9.3 Background

Obesity is linked to an increase in the risk of morbidity and mortality. The latest global prevalence of overweight and obesity figures reported by the World Health Organization (WHO) revealed that the rate in women is considerably higher than in men (WHO, 2014). Some sub-groups are at even greater risk of gaining weight, such as mid-age women experiencing menopausal transition (Au et al., 2012, Williams et al., 2014).

Previously, considerable research has examined the relationship between single nutrient intakes or food items and chronic disease or health outcomes (McCarron & Reusser, 2000). The findings of these studies are important in understanding the function and role of single nutrients or foods and the relationship with health outcomes and disease risk, including CVD (McCarron & Reusser, 2000). However, we consume whole diets and not individual components of food or isolated nutrients, and it is therefore important to understand more about the diet as a whole. Moreover, the impact of a single nutrient in research can be too small to capture, while the impact of whole diets, which contain many nutrients, may be easier to identify and capture (Hu, 2002). Diet quality scores are one method that can be used to measure diet intake as whole, with reviews indicating that diet quality can predict the risk of morbidity and mortality (Waijers et al., 2007, Wirt & Collins, 2009). However, knowledge about changes in diet quality scores, particularly in terms of food variety (Vadiveloo et al., 2013) and its impact on health outcomes, such as changing weight over time is limited (Aljadani et al., 2015, Vadiveloo et al., 2013).

This current study considers the impact that diet quality score change may have on weight change over a nine year period in mid-age women. This investigation is important because it provides evidence on the impact of changing diet quality, in terms of variety of healthy foods, on weight over time. Specifically, the aim of this current study was to examine the impact of change in diet quality as measured by the validated Australian Recommended Food Score (ARFS) (Collins et al., 2015, Collins et al., 2008) on weight change in mid-age women, free of disease and with valid total Energy Intakes (TEI) at baseline, over a nine year period.

9.4 Materials and methods

9.4.1 Population

Data were obtained from the mid-age cohort of women participating in the Australian Longitudinal Study on Women's Health (ALSWH) at two points in time, 2001 and 2010. The ALSWH was established in 1996 and aimed to follow women for 20 years. The study recruited over 40,000 female participants in three cohorts, based on age: young women (18-22 years), mid-aged women (45-49 years) and older women (70-74 years) (Brown et al., 1996). The over-arching aim of the ALSWH cohort study is to examine the social, psychological and physical predictors of a range of mental health, well-being and health outcomes over time. The National Health Insurance database (Medicare) was used as a sampling frame to recruit women as it is the most up to date and complete dataset for women and permanent residents in Australia. Participants were randomly selected from the Medicare database.

9.4.2 Participants

Analyses were restricted to data obtained from the mid-age cohort (n=2,381) who completed questionnaires in 2001 and 2010. Women were excluded if they reported any of the following chronic diseases at baseline: type 2 diabetes, impaired glucose tolerance, heart disease, stroke or breast, cervical or bowel cancer. A valid TEI was identified using Schofield equations to calculate Basal Metabolic Rate (BMR) for each participant, based on age, self-reported weight with a Physical Activity Level (PAL) of 1.55 applied to calculate individual Estimated Energy Requirements (EER). EERs were compared with individual TEI derived from the FFQ and Goldberg cut-offs applied to identify those with valid TEI. The TEI(kJ/day) and nutrient intakes were quantified from the Australian nutrient composition database using the Nutrient Data Table (NUTTAB) (Lewis et al., 1995).

The ALSWH was approved by the Human Research Ethics Committees of the Universities of Newcastle and Queensland. Further details are reported elsewhere (Brown et al., 1996).

9.4.3 Dietary assessment

Dietary intake was assessed in both Survey 3 (2001) and Survey 6 (2010) of the ALSWH using the Dietary Questionnaire for Epidemiological Studies Version 2 (DQESv2), an FFQ developed by the Cancer Council of Victoria (Ireland et al., 1994) which has previously been validated in Australian women (Hodge et al., 2000b). The DQESv2 asks participants to report consumption of 74 food items and six-alcoholic beverages over the previous 12 months using a 10-point frequency scale which ranges from never and <once per month up to 5-6 times per day.

9.4.3.1 Diet quality

The Australian Recommended Food Score (ARFS) was used to assess Diet Quality. To calculate change in ARFS scores, the ARFS at follow-up was subtracted from the ARFS at baseline. The ARFS is a validated diet quality index (Collins et al., 2008, Collins et al., 2015), based on the American Recommended Food Score (Kant & Thompson, 1997). The ARFS has a binary scoring method, with scores ranging from zero up to 74 points. The ARFS contains a total of 74 items arranged into seven sub-scales. Each item scores one point if a person meets 100% of the specific recommendation, and zero if otherwise. Higher scores reflect dietary patterns more closely aligned with recommendations in the Australian Dietary Guidelines and the Australian Guide to Healthy Eating (2003, NHMRC, 2013b). The seven sub-scales have various point allocations, and additional points are awarded for optimal types or amounts within sub-scales. These include: Vegetables (21 items +1 point for ≥4serves daily =22 points); Fruit (13 items + 1 point for ≥2serves daily =14 points); Protein Foods (14 points), including animal protein (8 animal protein items, 1 point ≤2 eggs weekly; 7 items scored 1 point for 1–4 serves/week of beef, lamb, pork, poultry, fish/seafood (3 items); + 6 plant protein items each item scored 1 point for ≥1 serve weekly =14 points); Grains (13 items +1 point for ≥4 serves per day =14 points); Dairy (5 items +1 point for using skim or reduced fat milk +1 point for >500ml milk per day =7 points); Fats (1 point for using poly or monounsaturated margarine =1 point); Alcoholic Beverages (1 point for beer/wine/spirits up to 4 days per week +1 point for 2 or less drinks each occasion =2 points) (Collins et al., 2008). Consuming no alcohol scores zero due to the U shaped association between alcohol intake and health status (Collins et al., 2008).

9.4.3.2 Weight

Weight was self-reported. Weight change was calculated by subtracting weight in 2001 from weight in 2010.

9.4.3.3 Confounders

Women were asked about their highest level of education attained, which was categorised into school certificate (≤11 years schooling), higher school certificate (12-13 years schooling), trade/apprenticeship, undergraduate university degree and post-graduate degree. The changes in area of residence were categorised into those who lived in urban areas in 2001 and 2010, those who lived in rural areas in 2001 and 2010, those who lived in an urban area in 2001 and moved to a rural area by 2010, those who lived in a rural area in 2001 and moved to an urban area by 2010. The changes in smoking status were categorised as those who reported that they never smoked in 2001 and 2010, those who reported smoking only in 2010, those who reported they were current smokers in 2001 and 2010, and those who were smokers in 2001 and quit smoking by 2010. The changes in menopause status were categorised as: women who were pre-menopausal or were using oral contraceptive (OCP) in 2001 to being peri-menopausal in 2010, those who were pre-menopausal in 2001 to being post-menopausal (or surgical menopause) in 2010, women who were peri-menopausal in 2001 and remained peri-menopausal or had begun hormone replacement therapy (HRT) in 2010, women who were peri-menopausal in 2001 and became post-menopausal in 2010, and those women who were post-menopausal at baseline. TEI (kJ/day) and nutrient intakes were quantified using the Australian nutrient composition database and the Nutrient Data Table (NUTTAB) (Lewis et al., 1995).

9.4.3.4 Physical activity

Participants self-reported walking, moderate and strenuous physical activity (PA) frequency (Brown et al., 2004). This information was used to derive a PA score in metabolic equivalents (METs) per minute (MET.mins). Total MET minutes were calculated and categorised into four groups: nil/sedentary (0 to <40MET.min/week), low (40 to <600MET.min/week), moderate (600 to <1200MET.min/week) and high (≥1200MET.min/week) (Brown & Bauman, 2000). The change in physical activity from 2001 to 2010 was calculated as Met.min at baseline subtracted from the Met.min at follow-up.

9.4.3.5 Statistical Analyses

All analyses were conducted using STATA (version 11) (StataCorp, 2011). All change data were checked for normality and found to be normally distributed. Analysis of variance (ANOVA) was used to compare means of the continuous variables across tertiles of ARFS change. Multivariate linear regressions were used to examine whether change in the ARFS, classified as tertiles, impacted on weight change from 2001 to 2010. The models included change in ARFS (grouped as tertiles), as the independent variable and weight change (in kg) as the dependent variable. The lower tertile of change in ARFS was the reference group in the regression models. Two separate linear regressions were applied: a crude and a fully adjusted model, the latter of which was adjusted for changes in confounder variables or for baseline results (ie. change in education, smoking status, area of residence, menopause status, baseline weight, baseline ARFS, and baseline TEI).

9.5 Results

Of the 10,267 women in the mid-age cohort in 2001, 5,989 met the inclusion criteria and had ARFS and body weight data at both 2001 and 2010. Of these, only 2,381 women were deemed to have a valid TEI reported.

Note that in a sub-analysis aimed at comparing those women with a valid TEI (n=2,381) and those with an invalid TEI (n=3,608) it was found that there were no significant differences between the two groups in terms of age, education, menopause status, area of residence and smoking status variables. However, there were significant differences in the prevalence of healthy weight and obesity at baseline. The prevalence of healthy weight at baseline for those with an invalid TEI was 34% compared with 50% for those women with a valid TEI. The prevalence of obesity at baseline for those with an invalid TEI was 23% compared with 16% for the valid TEI sample. The means (SD) TEI was 6,680 (2,527) kJ/d and 8,957 (1,414) kJ/d for those with an invalid TEI and those with valid TEI respectively.

During the nine years of follow-up, on average all participants were heavier (2.3 (7.2) kg) and reported a small decline in diet quality by 2 (8) points on average (**Table 9-1**). Overall results show an increase in the prevalence of obesity by 11%, while no significant changes in physical activity during the nine years were observed.

When women were categorised into tertiles, based on the distribution of change in the ARFS scores, there were significant differences in weight changes, PA status at baseline and education between women in these tertiles. On average, weight change was (+2.6(6.8)), (+2.2(7.5)) and (+1.5(7.4)) for those in the lower, middle and top tertiles of change in ARFS score, with p=0.04 (Table 9-2).

Table 9-3 shows the change in ARFS sub-scale scores across tertiles of change in ARFS scores over nine years. Across the tertiles of all sub-scale change scores, there were significant differences detected between 2001 and 2010, with p-values <0.001. The greatest increases in sub-scale scores were seen for the vegetables (3(3) points), fruit (2(3) points) and protein (2(2) points) sub-scales, scores among those who were classified into the highest tertile of change in ARFS. For those in the lowest tertile of change in ARFS, the greatest decreases were for the vegetables (-5(4 points)), fruit (-2(3points)) and grains (-2(2 points)) sub-scales.

During the period 2001 to 2010, the mean (SD) weight change among all women was 2.3 (7.2) kg. Over the follow-up period, there were significant differences in weight change across ARFS change score tertiles (p=0.04) (Table 9-2). On average, those women in the top tertile of ARFS change (healthier diet) gained the least weight 1.5 (7.4), while those in the middle and lower tertiles gained similar amounts of weight, with values of 2.2(7.5), 2.6(6.8) kg respectively.

In the Fully Adjusted multivariate linear regression model, over nine years of follow-up, only mid-age women who significantly increased their diet quality score (Tertile 3) had lower weight gain compared with those women in the lowest tertile of change (Tertile 1) whose diet quality decreased; β: -1.2 (95% CI: -2.31, -0.11),(p=0.03) (Table 9-4).

In a sub-analysis, it was found that changes in smoking and physical activity status, as well as weight at baseline, were significantly associated with weight change during the follow-up period. Those who were smokers in 2001 and quit smoking by 2010, gained the most weight compared with those who were non-smokers at both baseline and follow-up, (β=3.04, p=0.001). Those who had increased their physical activity at follow-up, gained relatively less weight (β=-0.05, p <0.0001) (data not shown).

9.6 Discussion

The study findings indicate a strong inverse association between improvements in diet quality and lower weight gain among mid-age Australian women. Those who improved their diet quality gained significantly less weight compared with those whose diet quality worsened over the nine years of follow-up, even though, overall women reported a mean weight gain of 2.3(7.2)kg and a decrease in diet quality score of -2(8) points during this time. Our findings are in contrast to the only other Australian study (Arabshahi et al., 2012) that has examined the impact of diet quality change, measured by the Dietary Guidelines Index (DGI), on body weight change over time. That study found no relationship between change in diet quality and weight change in women over 15 years of follow-up, and while it is unclear why, it could be due to differences in the measurement of diet quality, study design or difference in adjustment for confounders.

There have only been a few other studies that have aimed to evaluate the relationship between changes in diet quality and weight status longitudinally (Quatromoni et al., 2006, Boggs et al., 2013, Asghari et al., 2012, Sanchez-Villegas et al., 2006). Similar to our results, these studies also observed an inverse association between change in diet quality and BMI change (Asghari et al., 2012) or weight change (Quatromoni et al., 2006, Sanchez-Villegas et al., 2006), or the risk of obesity (Boggs et al., 2013).

Women, aged 49-56 years at baseline, who had higher diet quality score (higher Quintile) measured by Diet Quality Index (DQI) gained significantly lower weight 3.3 (1.7.4) Ib, compared with 8.0(13.0) Ib for those who had lower diet score (lower quintile) over eight years of follow-up (Quatromoni et al., 2006). Similar results found by Asghari et al. (2012), that a positive change in Healthy Eating Index (HEI) was associated with relatively lower weight gain (-0.03)kg compared with those who had a negative diet score in adults followed for 6.7 years (Asghari et al., 2012). Consistency with the previous studies, a study found that those in the highest quartile of diet quality aligned with the Mediterranean Diet Patterns (MDP), was associated with lower weight gain by 0.7kg than those who were at the lower quartile of scores (Sanchez-Villegas et al., 2006). Higher diet quality at baseline and follow-up was also associated with lower risk of obesity as found by Boggs et al. (2013), those with a healthy weight at baseline (BMI: 18.5 to 24.9kg/m^2) found that improved diet quality score, measured by the Alternative Healthy Eating Index (AHEI), and during six years had lower risk of developing obesity with BMI≥30kg/m^2 (Boggs et al., 2013).

Women undergoing menopausal transition are at high risk of gaining weight (Williams et al., 2014) and not meeting the dietary recommendations (Ball et al., 2004). This current study shows that mid-age Australian women are gaining weight and have poor diet quality, as indicated by nine years of follow-up of the ALSWH cohort. Even those women in the highest tertile of change in ARFS score, who showed modest improvements in their ARFS score over time, still gained weight. This finding is in agreement with other Australian studies (McNaughton et al., 2008, Mishra et al., 2010, Mishra et al., 2014, Arabshahi et al., 2012, Zarrin et al., 2013, Ball et al., 2004, Australian Health Survey, 2012), that also found poor diet quality among mid-age women. The details of our ARFS sub-scale analysis suggests that those women who gained the least weight, consumed more vegetables, fruit and lean protein over time. It is important to emphasize that the women who improved their diet quality over nine years had the lowest weight gain during this time.

There is substantial evidence about the benefits of high fruit and vegetable intakes in terms of preventing chronic disease, including some type of cancers, such as gastrointestinal cancer (WHO, 2010, Boeing et al., 2012), and this evidence supports consumption of more than five servings of fruit and vegetables per day to lower risk of heart disease (He et al., 2007) The World Health Organisation has reported that low intakes of fruit and vegetables are linked to 1.7 million premature deaths around the world (WHO, 2010). Fruits and vegetables contain large amounts of water and fibre (soluble and insoluble), are low in fat and are nutrient dense, but relatively low in energy (WHO, 2013a). It is therefore not surprising to find that increased consumption of fruit and vegetables contributed to lower weight gain (WHO, 2010).

The ARFS aims to capture the intake of a variety of healthy foods considered core, yet it does not determine portion size or estimate energy intake. Its relationship with weight is therefore based on the fact that greater consumption of quality core foods can influence energy intake by displacing less healthy energy dense but nutrient poor foods. This study found that improvements in the consumption of variety of most healthy food groups (ie ARFS sub-scales) was linked to lower weight gain in the long term (ie. nine years). These findings are similar to those of a study by Azadbakht and Esmaillzadeh (2011), that showed that intake a variety of healthy foods was associated with lower risk of weight gain in young Iranian women aged ≥18years (Azadbakht & Esmaillzadeh, 2011). In contrast, another study found that increased dietary variety contributed to an imbalance in energy intake, leading to weight gain (Kennedy, 2004).

Our previous study in mid-age ALSWH women (Aljadani et al., 2013d) conducted on 7,155 mid-age (48 to 56 years) ALSWH women, free from disease, found that baseline diet quality was not associated with weight gain or loss over six years of follow-up. This current study examined the impact of changes in the ARFS on weight gain during a longer follow-up period (nine years), and highlights the importance of changes in diet quality on weight gain over time. Assessment of dietary intake over time is therefore essential to understanding the role of diet quality on weight gain.

This was a robust epidemiological analysis of a long term cohort study in a representative sample of mid-age Australian women. There are however some limitations that should be noted. Dietary intake and weight were self-reported; however, the DQESv2 (FFQ) has been previously validated in Australian women (Hodge et al., 2000b), and self-reported weight in the ALSWH cohort shows good agreement with objective measurements (Burton et al., 2010). The determination of TEI was not ideal due to the limited number of energy dense nutrient poor foods and beverages listed in the FFQ, however, this is the case for most epidemiological studies that utilise a FFQ. Energy mis-reporting is common for FFQ data, but inclusion of women who were identified as having a valid TEI may minimize the bias associated with this for our study. A strength of this study is that the ARFS has been validated and adapted for use in Australian populations (Collins et al., 2008, Collins et al., 2015), and the major strength of our analyses is the longitudinal nature of the study, allowing us to account for changes in diet quality while adjusting for changes in confounders such as smoking, physical activity and menopausal status.

9.7 Conclusion

Those women, who changed their dietary intake to include a healthier variety of foods, gained the least weight, while those with the poorest diet quality gained the most weight over time. Hence, optimizing and improving diet quality is an important strategy in terms of reducing the incidence of overweight and obesity in women during mid-life. As this study showed an overall decline in diet quality scores among all women, a strategy needs to be implemented where by mid-age women should be encouraged to consume a greater variety of healthy foods more frequently to slow the inevitable weight gain associated with menopausal transition. In addition, Further studies are require to inform researchers of the boarder social, economic and environmental barriers that may not be amendable to change simply by providing advice or health professional support to improve their behaviours, including the consumption of a varied diet at this life stage.

Table 9-1: Description of subject characteristics and anthropometric measurement for those with valid TEI mid- age women over the period 2001-2010

Variable		Mean (SD) baseline	Mean(SD)follow-up
ARFS at baseline		35(9)	32(8)
Change in ARFS over nine years		Na	-2(8)
Weight		68.5(13.7)	72.7(15.7)
Change in weight over nine years		Na	2.3(7.2)
The prevalence of the following			
Underweight (%)		2.15	2
Healthy weight (%)		50	37
Overweight (%)		31	34
Obese (%)		16	27
Subject characteristics			
TEI* (kJ/d)		8,956.5(1,414.0)	Na
Age (years)		52(2)	62(2)
Physical Activity (Met. minutes)		1012.9(1414.2)	1,220.3(1,539.2)
Change Physical Activity		Na	239.9(1,678.6)
		Percentage	
Smoking Status	Non smoker/ ex-smoker/ smoker	57/30/13	62/29/9
Area of Residence	Urban/ Rural/ remote	35/60/5	38/57/4
Education	No formal/ School certificate/Trade and apprentice/ University degree and higher	18/32/17/23	15/24/19/41
Marital status	Married/defacto/separated/ divorced/widowed/single.	77/6/3/8/3/3	70/6/4/11/6/3
Menopause status	Surgical menopause/ HRT use/OCP use/Pre-menopausa/Peri-menopausal/Post-menopausal	27/20/9/19/24/1	37/4/0/0/59

ARFS: Australian Recommended Food score, TEI – Total Energy Intake

Table 9-2: Sociodemographic variables of mid-age women in the Australian Longitudinal Study on Women's Health (ALSWH) (n = 1,999) at baseline (2001) and follow-up (2010) by tertile of changes of the Australian Recommended Food Score (ARFS)

	Baseline				**Follow-up**			
Number (n) **Mean ± SD** **(ARFS)**	**1** **(n=778; 39%)** **(-9 (5))**	**2** **(n=557; 28%)** **(-1(2))**	**3** **(n=664; 33%)** **(7(4))**	***p-value*** ***(ANOVA)*** ***Chi-2***	**1** **(n=778; 39%)** **(-9(5))**	**2** **(n=557; 28%)** **(-1(2))**	**3** **(n=664; 33%)** **(7(4))**	***p-value*** ***(ANOVA)*** ***Chi-2***
ARFS	39(7)	35(8)	30(8)	0.00*	30(7)	34± 8	37(8)	0.00*
Change in weight (kg); mean ± SD	Na	Na	Na	Na	2.6(6.8)	2.2±7.5	1.5(7.4)	0.04*
Weight (kg); mean±SD	69.0 (13.1)	69.1(14.1)	67.7(13.4)	0.27	71.6(14.2)	71.2 ± 15.6	69.0(13.1)	0.02*
Underweight/Healthy/overweight/ obese) (%)	30/42/45/37	30/32/28/39	40/26/27/23	0.07	33/40/44/42	25/33/29/36	42/28/27/22	1.13
Energy intake (kJ/d); mean±SD	8,980.3(1406.7)	8,896.2(1,427.2)	8,806.0(1,381.0)	0.18	Na	Na	NA	Na
Age (years); mean±SD	52.4 (1.5)	52.5(1.5)	52.5(1.5)	0.61	61.4(1.5)	61.5(1.5)	61.5(1.5)	0.53
Physical activity in METs (nil/ low/ moderate/ high); (%)	39/40/41/45	28/31/37/32	33/29/22/23	0.00*	44/44/42/40	28/29/31/36	28/27/27/24	0.41
Changes in PA (METs)	Na	Na	Na	Na	150.7(1,476.1)	343.8 (1,757.4)	368.5(1,440.9)	0.07
Smoking status (never/ ex-smoker/ current); proportion (%)	42/42/40	31/34/28	27/24/33	0.22	42/42/41	31/34/29	27/24/31	0.64
Residence (urban/ rural/ remote); proportion (%)	43/41/45	31/32/33	26/27/22	0.90	43/41/42	30/32/41	27/27/17	0.90
Highest education (nil/ school certificate/ trade/ university degree); proportion (%)	48/34/34/25	29/35/32/34	22/31/33/41	0.00*	34/38/40/47	28/30/33/32	38/31/27/21	0.00*

*Statistically significant

Table 9-3: the changes of the ARFS subscales (2001 to 2010) for mid-age women in the Australian Longitudinal Study on Women's Health (ALSWH) by tertile of ARFS

	Changes of the ARFS tertiles (n=1,999)			
Changes in the ARFS subscales(Mean ± SD)	**1 (n=778; 39%) (-9(5))**	**2 (n=557; 28%) (-1(2))**	**3 (n=664; 33%) (7(4))**	***p-value (ANOVA)***
ARFS (baseline)	39(7)	35(8)	30(8)	<0.001*
Vegetables	-5(4)	-1(3)	3(3)	<0.001*
Fruit	-2(3)	-0.04(2)	2(3)	<0.001*
Diary	0.02(1)	0.2(1)	0.5(1)	<0.001*
Grain	-2(2)	-0.5(2)	0.5(2)	<0.001*
Protein	-0.10(2)	1(2)	2(2)	<0.001*
Fat	-0.10(1)	-0.07(0.5)	0.03(1)	<0.001*
Alcohol	-0.10(1)	-0.07(0.5)	0.03(1)	<0.001*

Table 9-4: Multiple linear regression models to predict of nine-year weight change in mid-age women from the Australian Longitudinal Study on Women's Health

Predictor: Diet Quality Index	**Model**	**Tertile (Comparator Tertile 1)**	**∆Weight (kg) *β* co-efficient (95% CI)**	***p-value***
Change in ARFS (2001-2010)	*Crude*	2	-0.41(-1.32, 0.49)	0.37
		3	-1.06(-2.01,-0.10)	0.03*
	Fully adjusted	2	-0.33(-1.28, - 0.62)	0.49
		3	-1.2(-2.31, -0.11)	0.03*

* statistically significant, Crude model: the dependent variable is nine- year weight change in kg and independent variable the nine-year change in ARFS score in tertiles, fully adjusted model: same as the crude model plus adjustment for changes in confounder variables (including education and smoking status, area of residence, menopause status) and baseline weight, baseline ARFS, and total Energy Intake. The lower tertile of the ARFS was the reference group in models.

Chapter 10 Final Discussion (Section 4)

10.1 Overview

This chapter highlights the overall findings in my thesis and compares them to the available literature. This concluding Chapter also summarises the strengths and limitations of the studies conducted within my thesis, provides future recommendations and an overall conclusion.

10.2 Summary of findings and discussion of the systematic review on the association between diet quality and weight change status

The main focus on methods of measuring diet quality in my thesis was the use of "*a priori*" defined diet quality indexes. Diet quality can be defined as a method of evaluating the overall nutritional quality of an individual's usual dietary intake relative to recommendations in national dietary guidelines. It includes the concept of variety of healthy food items. The main aim of the systematic review was to synthesise the best available evidence of the association between diet quality measured by "*a priori*" defined dietary indexes or scores, and longitudinal changes in anthropometric measurements, including changes in weight or waist circumference, or the incidence of overweight or obesity in adults. The number of studies included in my initial systematic review of the association between different diet quality indexes and weight change was limited. Only eight studies were included based on the search that covered the period 1970 to March 2011. That systematic review was published in the Joanna Briggs Institute Database of Systematic Reviews and Implementation Reports. Since 2011 a number of additional studies have been published in this area. Therefore, I have updated the review and identified a further six new studies (excluding my own two papers) that have been undertaken that meet the inclusion criteria, and these were added to the review (Chapter 3). The review of the literature highlights the recent interest in these types of studies that focus on diet quality indexes and body weight outcomes. Also, the six recent studies used a number of different diet quality indexes compared to the studies included in the previous systematic review up till early 2011. This suggests growing support from epidemiologists for the utility of using diet quality indexes as a method of assessing overall dietary patterns and healthiness, or otherwise of eating patterns using these pre-defined methods. The increased interest in developing and creating new indexes to measure diet quality likely reflects this growing interest in methods to assess adherence or alignment with National Dietary Guidelines, as opposed to reporting intakes based on the traditional methods of assessing food intake alone.

I have included my two papers in Chapter 3 because this chapter is a review paper of all the existing literature, while in this section (10.2) of the thesis I did not discuss the findings of these two papers, the results of my papers will be discussed in the next two sections. In this section I will discuss the findings of the other six studies identified in the updated systematic review, plus the initial eight studies from the first stage of the systematic review.

The overall outcome of this review up to 2014, is that being in the healthiest or highest quintile of diet quality was associated with lower weight gain, measured as increases in BMI in the range of 0.06 to 0.22 kg/m2 over time periods ranging from at least a one year up to 14 years of follow-up, compared to those in the poorest or lowest quintile of diet quality. In other words, this review highlights that weight gain in adults over time is common, even amongst study participants who achieved high diet quality index scores, meaning that their dietary intakes were more likely to align with national dietary guidelines. Summarising the total body of evidence, participants experienced greater weight gain during follow-up with the majority of participants across the included studies also commonly on average having poor diet quality.

My observation from this review is that the diet quality indexes that assess adherence to Mediterranean Diet Patterns, and those that are based on sub-scales for both foods and nutrients, such as DGI and HDS, were better able to predict prospective weight change, compared to the indexes based on nutrient sub-scales only, such as the FNRS. Unfortunately, there is a gap in the literature for diet quality indexes based on food components only. Thus additional studies are needed to evaluate the ability of diet quality indexes based on food sub-scales only, to predict prospective changes in weight in men and women.

Furthermore, the findings of this review indicate that researchers need to give greater attention to factors that affect the conclusions drawn. For example, misreporting of TEI and evaluating the changes in dietary habits over time. Although misreporting of TEI is a very important factor, only a few studies have attempted to measure it or adjust for this in statistical analyses. Also, out of the 14 studies from the review only five studies (Arabshahi et al., 2012, Asghari et al., 2012, Boggs et al., 2013, Sanchez-Villegas et al., 2006, Quatromoni et al., 2006) have measured change in diet quality over time. From this review, it was found that those who had better diet quality gained significantly less weight compared with those who had poorer diet quality over time. Therefore, researchers should consider whether diet has been measured on more than one occasion during follow-up, and should examine the impact of changes in diet quality over time in association with weight change.

In addition, there are some other factors that need attention from investigators. Gender, initial BMI, ethnicity, and smoking status play important roles in the association between diet quality and body weight change. For example, two studies that examined the relationship in both men and women, found that baseline diet quality is a predictor of weight change in men but that was not the case in women (Lassale et al., 2012, Arabshahi et al., 2012).

The study by Boggs et al. (2013), provides the strong evidence as to the importance of baseline BMI and the maintenance of high diet quality over time (Boggs et al., 2013). Ethnicity also seems to be an important factor that impacts the relationship between diet quality and weight change in adults (Zamora et al., 2010). Smoking status is another important factor but has rarely been evaluated in regards to diet quality and weight gain. In a study by Kimokoti et al. (2010), an association was found amongst those who had quit smoking, with those who had the poorest diet quality gaining an additional 5.2 kg of weight compared to those who had a higher diet quality score.

Another aspect that needs consideration is alcohol intake. Almost all of the instruments used to quantify dietary quality include moderate alcohol intake as a positive component. While some have demonstrated positive associations with health outcomes (Grønbæk, 2009), alcohol contains a significant amount of energy in a readily consumable form, and it may be that even moderate drinking of alcoholic beverages contributes significantly to higher overall energy intake, confounding the relationship between diet quality and weight gain. The role of energy intake from beverages is obviously an issue but unfortunately, it was not clear from this review because only four diet quality tools specifically included sweetened beverages as a separate component score. These were the HDS by Forget et al. (2013), the AHEI-2010 and DASH used by Boggs et al. (2013), and the PNNS-GS by Lassale et al. (2012), which also included one point for water and soda water. These indexes found significant inverse associations with lower weight change in adults with lower intakes of sweetened beverages over time. Thus, I suggest that further analyses should consider energy intake from alcohol and beverages, and should either include them as separate component sub-scales in future proposed diet quality indexes or consider intakes of them as potential confounders and adjust for this within analyses.

In conclusion, based on findings from this review, using the concept of diet quality appears to be a good indicator of overall dietary patterns and can be useful for predicting body weight change over time. Optimal diet quality, characterised by eating patterns that are rich in vegetables, fruit, whole grains and cereals, low fat dairy products and with low total fat and saturated fat intakes, is associated with a lower risk of gaining greater weight in adults over time compared to those with poor diet quality. The current literature also suggests that baseline diet quality can be a strong predictor of weight change in men compared to women in prospective studies. A definitive statement cannot be made at this time due to the impact of initial weight and other confounders, such as changes in food habits over time, misreporting of TEI, EI from beverages, and initial BMI, that have not been adequately considered in previous research. Thus, future investigations required and should take into account the impact of these factors.

Therefore, in my thesis I have conducted analyses that examined the impact of food-based guidelines by using the ARFS in young and mid age cohorts from the ALSWH. In addition, I have created a diet quality instrument based on variety and frequency of fruit and vegetable intakes and made the recommendation to increase intake of these healthful foods, i.e. fruit and vegetables. Also, in one of my studies in young women, I have compared and examined prospective weight change using three diet quality indexes; the DQI based on nutrient components, the validated ARFS and the FAVI that are both based on food items only.

10.3 Summary of findings and discussion for the analyses in young age ALSWH women

One aim of my thesis was to investigate the relationship between diet quality and weight change in women during specific follow-up periods. Another aim was to compare between the productivity of different indexes of weight change over time in women. In addition, my systematic review (Aljadani et al., 2013a, Aljadani et al., 2015) identified a gap in the literature in that none of the studies identified used any indexes based on food components only, and very few studies compared between the productivity of two diet quality indexes, or more, on weight change over time. For this purpose women from the young cohort in the ALSWH were studied. Three indexes were selected to quantify diet quality, one of them was the validated ARFS (Collins et al., 2008, Collins et al., 2015) which was developed specially for the Australian population to examine dietary patterns relative to the Australian Dietary Guidelines (NHMRC, 2013b). The two other indexes are the five point DQI and a new index composed for this thesis called FAVI.

Two separate studies were conducted on sub-cohorts of young women from the ALSWH. The first of these studies is presented in Chapter 5 (Aljadani et al., 2013b), and had the purpose of evaluating the impact of three diet quality indexes on weight change over six years of follow-up, in a sub-cohort of disease-free young women, of participants with valid TEI, who were followed up over six years. The same trend of prospective weight change found in the systematic review was found in these Australian young women where the majority of these young women were gaining weight (3.6 ± 1.5kg) over the six years of follow-up and consuming poor dietary quality, as measured by the ARFS (m=29.5/74 score), Aus-DQI (m=1.4/4 score) and FAVI (78/333 score). As the women had poor diet quality, they may not be meeting the recommended food intake targets of healthy food, such as fruit and vegetables, whole-grains, low fat dairy, lean protein. The ARFS and FAVI results suggest that they had especially low intakes of fruit and vegetables, a finding consistent with ALSWH cross-sectional results by Mishra et al. (2014), that showed that the majority of young women did not meet the recommended servings of cereals/wholegrain, vegetables and dairy and that these women consumed less variety of and had lower fruit and vegetable intakes than recommendations. This is also consistent with what has been shown in other studies internationally (Hall et al.).

In regards to the main outcomes of the study, those in the third tertile (ie. highest diet quality category) for total FAVI score were gaining a very small but significantly lower amount of weight prospectively (-1.6kg) compared with those in the first tertile (ie. poorest diet quality) for a total score of FAVI. Higher ARFS scores (third tertile) were found to be associated with lower weight gain by (-1.6kg) as compared with those in the first tertile. In order to emphasise the findings of the significant association between the ARFS and FAVI and lower weight gain during six years of follow-up, a similar study was conducted (Chapter 6), but only those of healthy baseline weight ($18.5 \leq BMI < 25$ kg/m^2), were included in the analysis and followed for the same period (2003-2009). The results among the healthy weight sub-sample of young women are important not just to confirm the previous results of the trend of prospective weight gain and the quality of dietary patterns, but more importantly to derive recommendations to promote healthy behaviours which relate to dietary intake, and food habits to manage and maintain healthy weight and avoid gaining weight in this age group of women. The conclusion obtained in this analysis among women with a healthy weight women at baseline was similar to that of the previous study, in that women on average gained 3.7 kg over six years, and the majority of women had poor diet quality as measured by the ARFS and FAVI. This analysis emphasises the role of eating a greater variety of healthful foods and more frequently, as measured by the ARFS or FAVI, in preventing slightly lower prospective weight gain. For a 10 point increase in score using ARFS or FAVI there was a lower weight gain of 330 grams and 120 grams respectively over six years of follow-up in young women.

Thus, promoting greater variety and frequency of intakes of healthy foods, including fruit and vegetables can assist in terms of prevention of greater weight gain. Both studies, Chapter 5 (Aljadani et al., 2013b) and Chapter 6, on the cohort of young ALSWH women found similar results, that higher diet quality measured by the ARFS or FAVI did not protect young women from gaining weight, but that higher diet quality was associated with a lower weight gain. These findings should alert researchers to the fact that the majority of young women had poor diet quality as measured by the given indexes, and that there is room for substantial improvements in their eating habits.

The current findings are important for transferring the results into public health and clinical practice, where women at this age should be encouraged to make changes to their diet, such as using low fat dairy instead of full fat, whole grain bread instead of white bread, consuming fruit as a snack, and adding one or two types of vegetables to each main meal, to make a significant long term difference, contributing to lower weight gain in their life. The message arising from these analyses are simple and safe messages to promote health and well-being individually and at the population level. Targeting small, incremental and achievable improvements in diet intake (Koh et al., 2014, Jancey et al., 2014) throughout their life span will be important to obtain a sufficient difference in order to slow or prevent weight gain.

It is also important to educate women about the positive health implications of consuming a greater variety of fruit and vegetables and other healthy foods more frequently, in order to prevent or delay chronic disease, including CVD, in addition to slowing weight gain prospectively. Such knowledge may assist women in adjusting their health behaviours including having a healthy diet. This could have positive effects on their children and families. The findings also indicate that promoting adherence to the current National Dietary Guidelines is warranted as both the systematic review and the current analyses in young women show similar outcomes. Dietary quality patterns aligned with national guidelines are associated with lower weight gain, but the majority of the population sample had low overall diet quality.

10.4 Summary of findings and discussion for the mid-age women

In Chapters 7, 8 and 9, three sub-cohorts of women from the ALSWH were examined to evaluate the association between diet quality and change in weight status in mid-age Australian women. The research reported in Chapters 7 and 8 aimed to evaluate the relationship between baseline diet quality score, as measured by the ARFS, and six-year weight change (reported as a continuous variable in kilograms), and separately as the risk of becoming overweight or obese (as a categorical variable) respectively. These two studies are similar in that the analyses were conducted on the sub-cohorts of mid-age ALSWH women who were free from chronic disease and followed up for the same six year period (2001 - 2007). Women were eligible if they reported having no medical condition (e.g. type 2 diabetes or heart disease) at baseline or at follow-up. However, there are some important differences between these two separate analyses reported in Chapters 7 and 8. The second analysis (Chapter 8) included only those women who self-reported a healthy weight ($18.5 \leq BMI < 25.0 kg/m^2$) and who were identified as reporting a valid TEI at baseline. This sample contrasts to the first analysis in (Chapter 7) that included all women, from all BMI categories, with no exclusions based on validity of TEI or otherwise.

A total of 7155 mid-age women were eligible for the analysis in Chapter 7, while only 1107 women were eligible for the second analysis (Chapter 8). That is, they formed the sub-cohort of mid-age women with a healthy weight and valid TEI at baseline. Multivariate linear regression was used to test the relationship between diet quality score as continuous variable and weight change in the first analysis (Chapter 7), while in the second one (Chapter 8), multivariate logistic regression was used to examine whether baseline diet quality, defined by the ARFS was associated with six-year incidence of overweight or obesity. In order to understand the relationship between a change in women's diet quality over time and prospective weight change, a unique third analysis (Chapter 9), was conducted in the same population (mid-age cohort of ALSWH), but with some differences in the inclusion criteria, follow-up period and aim of the analysis. This analysis used the results from the second evaluating of dietary intake as well examined whether improving diet quality over a nine year period, as measured by the ARFS, was associated with weight change (2001 to 2010).

This study, presented in Chapter 9, included those who reported having no medical conditions at baseline only, (eg. Type 2 diabetes, heart disease), and who also reported valid TEI. The longitudinal changes in diet quality were calculated by subtracting the ARFS score at follow-up from the baseline ARFS score for each participant. Data for 2381 mid-age ALSWH women who were followed for nine years (2001-2010) were available. Multivariate linear regression was used to evaluate the relationship between change in diet quality, by tertiles, and nine year change in weight.

The main finding from the body of research presented in Chapters 7, 8 and 9 confirm that baseline diet quality, as measured by the ARFS, was not associated with weight change or the risk of becoming overweight or obese. However, improvement in diet quality over time as measured by the ARFS was associated with lower weight gain by -1.2 kg, compared with those who decreased ARFS score over nine years of follow-up. The differences in weight gain between tertiles of ARFS change are not clinically important, but these are indeed important at a population level in preventing prospective weight gain in this age of women who are at a greater risk of obesity. These findings were consistent with studies carried out in Australia (Arabshahi et al., 2012) and Europe (Yannakoulia et al., 2009, Lassale et al., 2012), that did not detect a relationship between baseline diet quality and prospective weight change or the risk of overweight or obesity in women. Two other studies that enrolled adults also show no relationship between diet quality and weight gain during 16 years (Kimokoti et al., 2010) or two years of follow-up.(Sanchez-Villegas et al., 2006) In contrast, a number of American and European studies (Wolongevicz et al., 2010, Mendez et al., 2006, Romaguera et al., 2010, Quatromoni et al., 2006, Beunza et al., 2010) did find significant negative associations between baseline diet quality and the risk of gaining weight. Collectively, the healthiest baseline diet quality was associated with lower weight gain, measured as increases in BMI in the range of 0.06 to 0.22 kg/m^2 over time periods ranging from at least one year up to 14 years of follow-up compared to those in the poorest diet quality category (Aljadani et al., 2015).

The absence of the relationship between baseline diet quality, as measured by the ARFS, and the risk of gaining weight in mid-age women, may be due to a change in dietary habits at this life stage or other factors associated with menopause. Given that Chapter 9 detected an important and strong inverse association between change in diet quality and weight gain prospectively over nine years follow-up in the mid-age women, in general the majority of women were gaining weight and had relatively poorer diet quality over nine years of follow-up. The group of women who were included in the top tertile ARFS of change improved their diet quality over nine years (7±4 points), while those in the lowest and middle tertiles had worse ARFS scores of -9±5 points and -1±2 points respectively. Weight gain was 1.5(7.4)kg, 2.2(7.5)kg, 2.6(6.8)kg for those in the top, middle and lower tertiles of change score, respectively. Only those who were in the top tertile of ARFS change score had significantly lower weight gain compared with the lowest tertile of the ARFS change score; β =-1.2 kg (95% CI: -2.31, -0.112; p=0.031). The results indicating this relationship with improved diet quality are consistent with a number of other studies (Boggs et al., 2013, Asghari et al., 2012, Quatromoni et al., 2006) that have examined change in diet quality over time and found that improved diet quality scores during follow-up predicted lower weight gain and incidence of obesity. Two other recent studies (Arabshahi et al., 2012, Sanchez-Villegas et al., 2006) however found that improved diet quality over time was not related to change in body weight.

Consideration of the differences between the previous studies is important and interpretation of the results should be treated with caution. Across all studies there are differences in culture related to food and eating, varying follow-up periods, different study designs and more importantly the definition of the "a priori" diet quality scoring methods. That is the diet quality score chosen varied in terms of the components and scoring related to cut-off values, the diet recommendations against which the sub-scales are compared, and the way scoring methods are applied. For example, the Australian study by Arabshahi et al. (2012), used the Dietary Guidelines Index (DGI), which is based on 15 food items including fruit, vegetables, cereal, dairy and others. A number of USA studies (Wolongevicz et al., 2010, Quatromoni et al., 2006) used the

FNRS, which is based on 19 nutrient components, including Vitamins E, B-12, B-6, Calcium and other nutrients. Many European studies used the Mediterranean diet adherence pattern score (Mendez et al., 2006) or the r-MED (Romaguera et al., 2010), the DQI (Quatromoni et al., 2006) or the MDS (Beunza et al., 2010). These indexes use scoring methods that measured how a person's dietary intake aligns with MDP, which is a specific food pattern characterised by regular consumption of vegetables, fruit, legumes, cereals, nuts, fish and foods rich in olive oil, as well as a low in intake of foods high in saturated fat, dairy products, meat and poultry. Moreover, the inconsistent results of the previous studies examining baseline diet quality and weight gain could be due to a number of factors, not least of which could be an inability of the diet quality tools to differentiate study participants adequately. In addition, some studies (Beunza et al., 2010, Sanchez-Villegas et al., 2006) assessed the relationship with weight change in adults in general, with adjustment for sex, while other studies examined the relationship between diet quality and weight change separately by sex, e.g. for women only (Quatromoni et al., 2006, Lassale et al., 2012, Kimokoti et al., 2010).

My research has shown that the majority of mid-age women had poor diet quality, as defined by the ARFS diet quality index and were gaining weight over time, and that women were getting heavier at each follow-up, with an average weight gain between 2 to 3kg over six to nine years. Collectively, the average total diet quality score (ARFS) was between 32 to 35 points out of a possible top score of 74 points. While Chapter 9, found that over nine years of follow-up women on average consumed dietary patterns that were slightly worse in terms of diet quality. From the analyses conducted, I found that after nine years of follow-up women in general consumed less vegetables, fruit and whole-grains than at baseline. During nine years of follow-up, those who gained the least weight (third tertile of the change in ARFS) consumed more vegetables, fruit and protein, while those who gained the most weight (first tertile of the change in ARFS) decreased their consumption of vegetables, fruit and grains.

Poor diet quality has been found to be associated with greater risk of chronic diseases (McNaughton et al., 2012, Kant et al., 2000, Wirt & Collins, 2009, Wirfält et al., 2013, McNaughton et al., 2009). My research highlights the need for future intervention studies that promote better diet quality among women during the menopausal stage. Higher ARFS scores were associated with higher nutrient intakes, including higher fibre, beta-carotene, folate, thiamine, niacin, riboflavin, vitamin C, vitamin E, calcium and iron. (Collins et al., 2008). Higher ARFS scores were also consistent with having more optimal macronutrient profiles, in terms of higher percentage energy intake from carbohydrate, protein and monounsaturated fat and a lower percentage energy from total fat and saturated fat (Collins et al., 2008), demonstrating that higher ARFS scores reflect greater adherence to dietary patterns as recommended in the Australian Dietary Guidelines. Thus, from the above results, it can be concluded that women during the menopausal transition have dietary intakes that are not consistent with national recommendations. This finding is consistent with previous studies carried out in Australia which found that it is common to have poor diet quality (Zarrin et al., 2013, McNaughton et al., 2008), particularly among mid-age women.(Ball et al., 2004, Arabshahi et al., 2012, Mishra et al., 2004)

Moreover, the body of work conducted on mid-age women found a group of women who are at greater risk of progressing to overweight or obesity. Those who were postmenopausal, current smokers, physically inactive, of lower education, or had a higher baseline weight were at a greater risk of progressing to overweight or obesity independently over six years. It has been found consistently that smoking and low physical activity is associated with greater prospective weight (Brown et al., 2005, Kimokoti et al., 2010). Taking the findings altogether, my research and that of others highlights that strategies are needed to raise awareness about the worse health outcomes associated with poor diet, sedentary lifestyles, smoking and weight gain (Williams et al., 2007). Adopting healthy lifestyle behaviours, including eating healthy food, not smoking, and being active is essential to maintaining a lifelong healthy weight and lowering the incidence of overweight or obesity, as well as helping those overweight or obese to lose weight (Jakicic & Rogers, 2013, Pate et al., 2015) and reducing the burden of disease (Ekelund et al., 2015). This is consistent with the recommendations from the Australian Dietary Guidelines (NHMRC, 2013b), that eating a variety of healthy foods within a person's energy requirements is needed to achieve and maintain a healthy weight. Also, some studies show that the majority of women at this life-stage are inactive. The current NHMRC (2013a) weight management guidelines recommend increasing physical activity and improving dietary quality while reducing total energy intake, particularly from energy-dense, nutrient-poor 'discretionary' foods in order to help achieve weight stability. Although the ARFS does not capture the TEI from nutrient poor food, my current research can recommend improving the variety of healthful foods together with other health behaviours such as improved physical activity and not smoking in order to optimize wellbeing and general health, especially to prevent greater weight gain at this life stage. This indicates that women can safely be advised to improve their eating habits and follow the national dietary guidelines without risk of exacerbating weight gain.

10.5 Comparison of the findings between the young ALSWH cohort and mid-age women

The research reported in this thesis found that baseline diet quality as measured by ARFS and FAVI is associated with relatively lower six-year weight gain in young age women, but this was not the case in mid-age women. Chapter 9 revealed that improved diet quality as measured by the ARFS was strongly associated with lower weight gain in mid-age women over nine years of follow-up. From these analyses, it can be said that consuming a variety of healthy foods is associated with lower weight gain in women. These analyses also revealed that the trend of weight gain continues in both young and mid-age women and that poor diet quality is common. This is a concern and urgent actions are needed to prevent weight gain, rather than treating it once it has occurred. Intervention studies targeting weight gain prevention are urgently needed to educate women from younger ages, and programs should continue into later stages, including menopause. As my research has shown that even among women in the menopausal life stage, where hormonal changes are a dominant contributor to weight status, improvements in diet are associated with significantly lower weight gain prospectively. From the results of my research, it is recommended for young and mid-age women to consume a wide variety of healthy foods more frequently, especially vegetables and fruit, so that they can prevent greater weight and that these behaviours should be adopted for the lifespan.

10.6 Limitations and strengths of the research

There are some limitations that should be noted in the research presented in this thesis. This systematic review provides evidence from cohort studies which were heterogeneous and inconsistent and therefore could not be pooled in a meta-analysis.

A limitation of the analyses undertaken on the ALSWH data is that both weight status and the dietary data, from which diet quality was derived, are self-reported. Even though the data on body weight status has been shown to be valid (Burton et al., 2010), and dietary intake was derived from a valid FFQ (DQESv2) (Hodge et al., 2000b), this limitation must be acknowledged. However, the impact of self-reported data on weight change may have been moderated by the fact that weight was self-reported at each occasion.

The instruments for assessing diet quality do not capture energy-dense, nutrient-poor foods or portion size, which are important factors impacting on TEI, even though the aim of the ARFS and FAVI are on variety of healthy core foods, rather than nutrient-poor items. In addition, an adjustment for TEI has been done, but this is still an issue in the analyses as the validated FFQ (DQESv2) contains only a limited list of the available food in the market, particularly processed foods and sweetened beverages, and may therefore not provide an accurate estimate for TEI. Although one of the weaknesses is the use of a FFQ, this is what was used in the ALSWH study and was therefore beyond our control. However, FFQs are accepted as standard methodology in epidemiological and cohort studies. Moreover, I have used valid TEI methods in some analyses in order to minimize the impact of mis-reporting of TEI.

Another limitation that should be acknowledged is that the ARFS and FAVI may not be sensitive enough to detect small changes in diet quality which can be statistically significant, or that the diet quality amongst women at this life stage is relatively homogenous making differences difficult to detect if indeed they do exist. Also, there were a large number of women who had missing data on weight and diet and this may have had an impact on the true association between diet and weight. The sub-analyses show that there was no difference between social demographic variables for those who had data on weight and diet and those who had missing data.

However the analyses do have a number of strengths, including the use of the ALSWH data which includes a large, representative sample of Australian women with six to nine years of follow-up data and adjustment for a broad range of confounding variables. I have investigated the relationship between a number of diet quality indexes and weight gain in adults. The strength of the current analyses is that they are the first to examine the relationship between weight change and ARFS scores prospectively. Previously, ARFS has been shown to predict nutrient intakes and health outcomes (Collins et al., 2008). This longitudinal analysis was conducted on a large number of young and mid-age healthy women from the nationally representative ALSWH cohorts, with follow-up for six years. The analyses follow women for a suitable time frame of six to nine years, and used very appropriate statistical tests. There was an adequate follow-up period and number of participants. One analysis explored the change in diet quality, as measured by the ARFS, and weight over a longer follow-up (nine years).

10.7 Implications for future research

Considering the overall evidence from the systematic review and the analyses from the ALSWH, it seems that diet quality indexes based on both food and nutrients, or food only, can better predict weight gain than the indexes which contain nutrient components only. However, definitive statements cannot be made due to an inadequate number of studies using indexes, based on food only. Therefore I recommend further analyses that examine the effect of indexes based on foods only, on changes in weight in both men and women.

In addition, my systematic review clearly highlights heterogeneity in methodology across the studies, in the indexes used to assess the quality of dietary intake, in the numbers of participants, length of the follow-up periods, methods used to report body weight change, and the statistical approaches used. Thus, further prospective studies are needed to consolidate diet quality measurement theory. Further epidemiological research studies are required which use standardized methods, such as; a) testing various indexes based on food components; b) using specific participant inclusion criteria; c) reporting weight gain in kg or as the incidence of overweight or obesity; d) using standard rigorous statistical approaches; and e) extending follow-up periods, when assessing the association between diet quality and weight change in adults. This will facilitate appropriate comparison of results between studies and help to develop recommendations related to confirmation of my results (or otherwise) and allow data to be pooled in a meta-analysis. Further studies will also facilitate the identification of a diet quality tool that captures dietary patterns and has the strongest relationship with body weight status. It would be especially helpful for translation to public health nutrition messages if researchers also tested additional indexes based on food components, so that recommendations targeted at the population level could be constructed in order to promote public wellbeing and health, including healthy weight. Even though researchers should note the differences between countries' eating habits, diet quality instruments can be adapted for use by various countries, and wide use of similar instruments would make international comparisons possible.

In addition, there is a lack of studies evaluating change in diet quality in relation to weight change within cohort studies in both men and women. Change in diet quality may be a key contributor to the development of overweight or obesity, and is likely to be more important than diet quality at baseline. Given that I consistently found, across the available evidence and within my studies, that the majority of people were gaining weight and had poor diet quality, there is an urgent need for research examining the impact of intervention studies to address this international phenomenon and promote wellbeing including healthy weight by consuming dietary intakes of high diet quality. In addition, the majority of the studies reported in the review did not measure changes in diet quality over time, and so further research is also required in this area. The diet quality tools I chose are based on food only. Evaluation of the relationship using additional indices is warranted in future analyses. Examining the prospective impact of promoting higher ARFS and FAVI scores in relation to other health outcomes is required. Given that the majority of women in my studies were found to have poor diet quality scores, further research is required in a group of women who consume the healthiest diet to further evaluate the relationship between those with the highest diet quality and weight change.

10.8 Implications for practice

This thesis revealed that using one of the existing diet quality indexes based on food only, such as ARFS or FAVI may be useful in predicting weight gain. The advantage of using a tool that does not rely on having to wait for nutrient intake assessment before the score can be calculated is that dieticians and other healthcare providers such as GPs, can use these in their practice to efficiently and at low cost predict who is at greater risk of gaining weight. As these tools are mainly based on variety of healthy foods these instruments could also be used with the public to increase their awareness of the importance of more frequently consuming a greater variety of fruit, vegetables, reduced and low fat dairy and nuts and other healthy food choices, which can assist in slowing weight gain in these women. Changing or improving eating habits gradually over time, such as eating a greater variety of vegetables and fruit, can slow the rate of weight gain, which Chapters 5, 6 and 9 of my thesis demonstrate, even though the absolute amount of weight is small. However, it is important to emphasise maintaining healthy eating habits throughout the lifespan.

It is also important to promote public awareness, not just of the nutritional quality of foods chosen, but also of the variety within healthy food groups and frequency of the food consumed, along with other lifestyle choices. My research and the current literature reviewed indicates that the majority of adults, especially women, are at risk of gaining weight and that very few achieved an optimal diet quality score that reflected eating patterns that align with current dietary guidelines. Thus, more ongoing studies are warranted about why dietary guidelines are not achievable in order to prevent the epidemic of excessive weight gain. Because prevention is better than treatment, those who are at greater risk of gaining weight should be targeted early. The results from the mid-age studies found that those who are smokers, are inactive, or of low education, are at greater risk of prospective weight gain and of becoming overweight or obese.

10.9 Final remarks and conclusion

This research systematically provides information and valuable knowledge on the most recent literature reviewed, based on cohort studies of the relationship between diet quality and body weight change in adults. It also provides a snapshot of dietary patterns aligned with National Dietary Guidelines for adults and the trends in body weight change internationally. Taking all the results together, I found that diet quality may be can be a good overall measure that can predict body weight change status over time in adults. Adult women commonly consume diets of poor diet quality and mostly did not comply with national recommendations or dietary guidelines for adults. My research also confirms that weight gain is common in adults generally and in women especially.

This research also examined a novel area, the relationship between diet quality indexes based on food components and body weight status in two age groups of Australian women representing different life stages, and who are at risk of gaining weight. Greater consumption of fruit and vegetables and variety of healthy foods, including low fat dairy, nuts and legumes is associated with lower weight gain in young women, but not mid-age women. However, changing dietary habits to healthier patterns, described as having a greater variety of healthy core foods more frequently, including a variety of reduced and low fat dairy products, fruit, vegetables, nuts and legumes during the menopausal transition, may play an important role in slowing prospective weight gain in populations long-term. Thus, it is recommended that greater frequency and variety in consumption of these healthy foods be promoted to adult populations as a strategy to help improve diet and weight related health. In addition to variety of diet quality improvement, reducing foods and beverages greater in energy density, poor in nutrients can deal with obesity epidemic and facility weight loss.

Appendices

Appendix 1: The article titled: "The association between dietary patterns and weight change in adults over time: a systematic review of studies with follow up"

Appendix removed due to copyright restricions. Aljadani, H., Patterson, A., Sibbritt, D., & Collins, C. (2013). The association between dietary patterns and weight change in adults over time: A systematic review of studies with follow up.. The JBI Database of Systematic Reviews and Implementation Reports , 11(8) , 272 - 316. doi:10.11124/jbisrir-2013-714

Appendix 2: The Book chapter titled "The association between diet quality and weight change in adults over time: A systematic review in perspective studies"

1 The Association Between Diet Quality and Weight Change in Adults Over Time: A Systematic Review of Prospective Cohort Studies

Haya Aljadani, Amanda Patterson, David Sibbritt, and Clare Collins

Key Points

- In general women with unhealthy dietary intakes, as assessed by diet quality scoring tools, gain more weight over time compared to men with unhealthy dietary intake patterns.
- Women with the poorest diet quality gain approximately an additional 300 g/year compared to those assessed as having the highest diet quality.
- Assessing diet quality using differing diet scores or diet indexes can be used to evaluate the variation in annual weight gain. The strength of the relationship between diet quality and weight gain over time does vary depending on the tool used to assess the relationship.
- However there are not enough studies using similar methods to allow a thorough examination of this, and further research is required using different diet quality assessment tools and approaches to determine how reliably they are able to predict for future weight gain in adults.
- Although the current evidence base is not extensive and there is some inconsistency across the findings there is an inverse association between the healthiness of dietary intake and prospective weight gain.
- More research of high methodological quality is needed to examine other lifestyle behaviours of participants with the poorest diet quality in order to try and identify other factors associated with consumption of

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unhealthy foods as well as opportunities to tailor interventions to prevent weight gain in adults.

- Future research studies should consider confounders and interactions between variables when examining the relationship between diet quality and weight gain.

Keywords

Diet index • Diet Quality • Diet score • Weight Change • Weight Gain • Obesity • Longitudinal • Cohort

Abbreviations

BMI	Body mass index
DQI	Diet Quality Index
EI	Energy intake
FFQ	Food Frequency Questionnaire
FNRS	Framingham Nutritional Risk Score
MDP	Mediterranean dietary patterns
MDS	Mediterranean Diet Score
rMDS	Revised Mediterranean Dietary Score
TEI	Total energy intake
WC	Waist circumference

Introduction

Obesity is defined as an excess of body fat. Different methods can be used to determine the degree of adiposity, with body mass index (BMI) being a commonly used indirect method [1]. BMI is defined as weight in kilograms divided by the square of height, in metres. According to the WHO BMI classifications, obesity is defined as BMI ≥ 30 kg/m^2, while overweight is defined as $25 \leq$ BMI < 30 kg/m^2 [2].

Obesity is associated with a decreased quality of life, increased morbidity and reduced life expectancy [3, 4]. Obesity increases the risk of many chronic diseases, including cardiovascular disease (CVD), diabetes, hypertension, metabolic syndrome and dyslipidaemia [5, 6]. It can also increase the risk of some cancers such as cancer of the breast, oesophagus, pancreas, colon and rectum, endometrium, kidney and potentially the gallbladder [7–9]. Studies show that obese people have lower levels of high-density lipoprotein (HDL) with higher levels of total cholesterol, triglycerides and apolipoprotein than nonobese people [10]. A relationship between body weight, body fat and bone mineral density (BMD) has also been suggested with some studies finding increased body fat and waist circumference with decreased BMD [11]. One such study examined 398 subjects aged 44.1 ± 14.2 years with a BMI 35.8 ± 5.8 kg/m^2 and found a significant inverse correlation between BMI and BMD [12].

Obese women are more likely than nonobese women to experience morbidity and to die prematurely due to the adverse effects of overweight and obesity [7]. The same is true of men, especially men with excess abdominal adiposity, which is associated with premature mortality due to CVD [13], along with an increased prevalence of mental health conditions, such as depression [8].

The costs of the adverse effects of obesity on individuals, the health system and to society are enormous. A 2009 US report has predicted that from 2020 to 2025 about $208 billion will be attributed to the costs of lost worker productivity, morbidity and premature death [14]. Furthermore, 1.5 million life-years will be lost, with the total cost of medical care estimated at $46 billion for this same period [14]. In Australia, a recent report estimated that the annual (2004–2005) total direct cost in health care and non-health care per person increased from $1,472 per year (95 % CI, $1,204, 1,740) for those of normal weight to

$2,788 per year (95 % CI, $2,542, 3,035) for those who were obese [15].

The prevalence of obesity has grown rapidly all over the world [16]. A 2006 estimate suggests that obesity affects at least 400 million adults worldwide with an additional 1.6 billion adults (age ≥15 years old) defined as overweight [2]. In Australia, more than half (54 %) of the adults were reported as overweight or obese in the 2004–2005 Australian National Health Survey [17] and this percentage increased to 61.4 % in the 2007–2008 Australian National Health Survey [18].

Today adults are more likely to gain weight at an earlier age than adults in the past [19]. Further, adults currently of an ideal body weight have a 50 % chance of becoming overweight and a 25 % chance of becoming obese over a period of 30 years [20]. Adults gain weight throughout life, especially at specific life stages. For example, men are more likely to gain weight after marriage, whereas women tend to gain weight during pregnancy and during the menopausal transition [21]. Also after giving up smoking and/or changing one's place of residence, weight gain can occur and has been reported for both genders [21]. The specific causes of weight gain are complex and are due to more than one single factor. Epidemiological and experimental studies demonstrate that nutrition behavioural factors such as diet composition, portion size, types of food and eating patterns, as well as snacking lead to weight gain [19].

Diet is a major modifiable factor. Dietary manipulation assists people to successfully lose weight whereas unhealthy dietary patterns or poor dietary quality can contribute to weight gain [22–24]. An excessive calorie intake, above total energy requirements, contributes to obesity and overweight [2]. Some studies have reported that excessive dietary fat and protein intakes are associated with higher BMI. One such study followed a cohort of 31,940 healthy women aged 30–55 years for 8 years and found that prior weight loss and younger age were stronger predictors of subsequent weight gain than dietary intake and that calorie intake was significantly related to past weight gain but did not relate to future weight gain [25]. Other studies suggest that higher intakes of dietary fibre, carbohydrate, vegetables, fruits, vitamin C, carotene and caffeine can be inversely related to BMI, but the studies' findings are mixed [25, 26].

Although major research efforts have been made, the contributions of dietary factors and eating behaviour to the development of excessive body weight have been particularly difficult to identify [27], partly due to the challenges in measuring dietary intake. Further, the contribution of dietary quality has not been studied extensively. Links between dietary intake and weight change are complex because of the multifactorial nature of obesity and overweight, including eating in excess of requirements, together with a poor lifestyle, including lack of physical activity [25, 28]. Further, the environment can affect eating behaviour. For example, people who live near fast-food restaurants have been shown to consume more fast food [29]. On the other hand, people who live near a supermarket tend to eat more healthful foods, especially fruit and vegetables [29]. There are also additional factors that contribute to obesity and overweight such as genetics, ethnicity and age [30, 31].

Little is known about the association between overall or total diet patterns, especially in terms of diet quality, and weight change over time. Diet quality is a measure of the quality of the whole diet and is a concept that aims to assess the quality of an individual's overall eating patterns using various scores or indexes to assess how closely the individual's usual diet is aligned with national dietary guidelines [32]. Therefore, the aim of this review is to identify the best available evidence on the association between diet quality and weight change over time, both short and long term, in cohort or case–control studies, and to summarise what is currently known in this area.

To obtain relevant published studies, a search was performed in two stages: the first stage was a search of four databases: MEDLINE, CINAHL, EMBASE and Scopus. This search was conducted to find cohort or case–control studies, published between 1970 and February 2011 in the English language. The second stage involved manual searches to find additional studies by means of the reference lists of all identified reports and articles.

Keywords included those relating to diet in the adult population (e.g. food patterns, eating behaviours, diet quality, diet index, diet variety, diet patterns) and weight status (e.g. weight gain, BMI, weight change, waist circumference).

The studies selected here include studies with a follow-up period in a longitudinal or case–control study and which assessed dietary intake and weight status in adults aged ≥18 years at baseline.

Dietary intake was the exposure variable with a range of methods used to measure dietary intake, including but not limited to 24-h recalls, multiple day dietary records, food frequency questionnaires (FFQ) or diet histories.

Weight status was the primary outcome and was measured by any of the following methods: weight (kg), BMI, waist circumference (WC) or % body fat.

Participants were all healthy adult males and females aged ≥18 years at baseline.

All longitudinal studies were included where the participants were followed up to determine the association between the overall dietary intake and weight change. A number of methods, including scoring techniques or indexes, were used to evaluate diet quality.

The selection of the included studies was carried out in two stages. The first stage was to retrieve all studies which met the previous criteria based on reading the title and abstract. The second stage was to thoroughly examine all of the retrieved papers. Seven studies were identified and assessed by two independent reviewers in the two stages. In the case of a disagreement about study selection in the first stage, that paper was retrieved. If any disagreement occurred in the second stage, a third independent reviewer was consulted to decide whether the paper should be included or not (Fig. 1.1).

Study quality was assessed using standardised critical appraisal instruments from the Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI).

Figure 1.1 describes the flow of studies meeting the inclusion criteria for this systematic review. Table 1.1 summarises each study's details (i.e. sample size, country and length of follow-up) and participant baseline characteristics. Table 1.2 reports the data extraction for dietary intake within the included studies and how the diet quality score is derived, including how each component or subscale is scored. Table 1.3 summarises the main outcome data related to absolute change in body weight or BMI during follow-up, the statistical analysis and any confounders for which results were adjusted. Table 1.4 reports the significance of the included studies and Table 1.5 the quality of the included studies.

Of 2,304 studies originally identified, seven met all inclusion criteria. These examined the association between overall diet quality and weight change, BMI or obesity incidence and used different methodologies to evaluate dietary patterns. One study [24] used the diet quality index (DQI), two studies [1] used the Framingham Nutritional Risk Score (FNRS) and four studies used different scoring methods to assess adherence to the Mediterranean dietary patterns (MDP).

The total number of participants across the two studies which used FNRS was 2,105 adults (≈67 % female) [1, 33]. Both of these studies were derived from the Framingham Offspring and Spouse Study (FOSS) in the USA, with 16 years of follow-up. The only study that used DQI was also derived from FOSS with 60 % of the participants being female [24]. Two studies were derived from the Seguimiento Universidad de Navarra (SUN) cohort, and different scoring methods were used to evaluate a number of Mediterranean Diet Scoring (MDS) approaches in these studies [34, 35]. Three studies were carried out in Spain [34–36]. Romaguera et al.'s [37] analysing data from the European Prospective Investigation into Cancer—Physical Activity, Nutrition, Alcohol consumption, Cessation of smoking, Eating out of home And obesity (EPIC-PANACEA) Project derived from six cohorts that were established in ten European countries to study the association between adherence to MDP

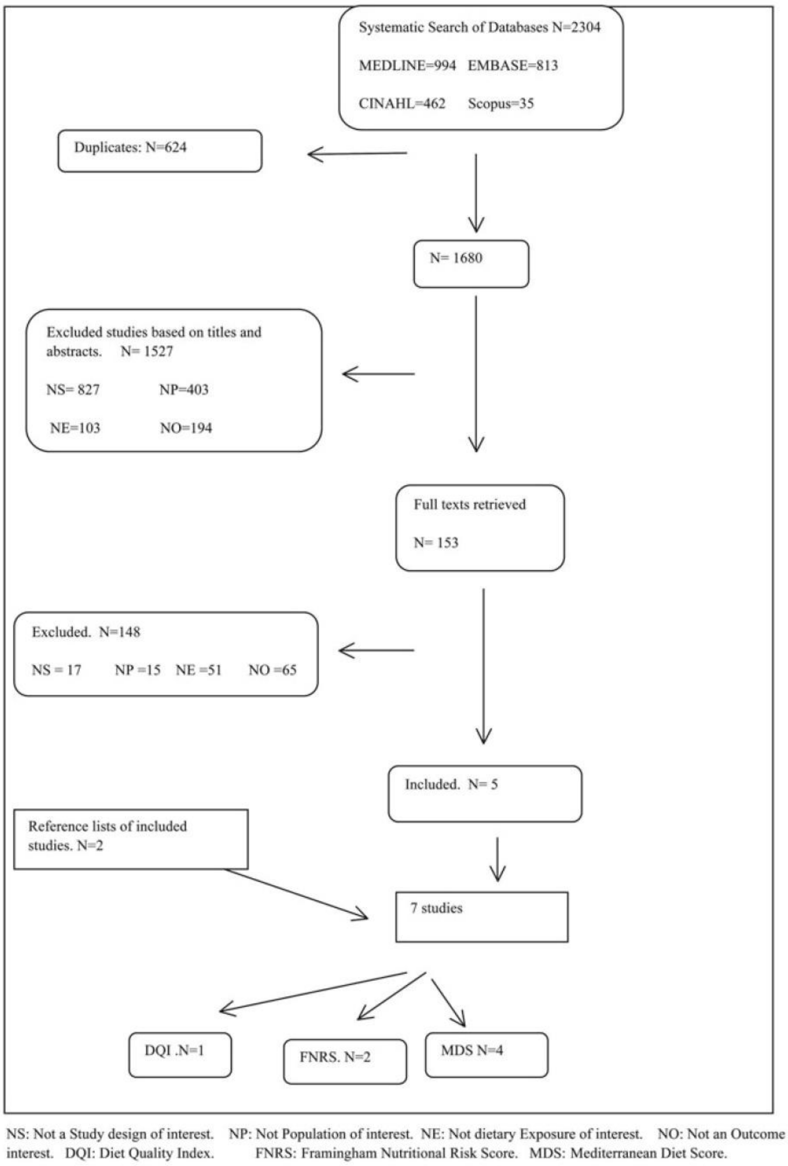


Fig. 1.1 Flowchart of studies identified for inclusion in a systematic review of the relationship between diet quality and weight change in adults over time

and weight change, and incidence of overweight or obesity. Mean participant age across all included studies was ≥25 years and retention rates varied from 58 to 100 % (Table 1.1).

Dietary intake methods used in the seven included studies were 3-day estimated dietary records [21, 32, 33], FFQ [34, 35] and diet history [37] (Table 1.2).

Table 1.1 Characteristics of the studies that examined diet quality

	References	Study design and cohort's name	Population at baseline, *N*, age and gender	BMI at baseline	Country	F/U	Retention	Purpose
1	Quatromoni et al. [24]	Framingham Offspring and Spouse (FOSS) Study	M^{∞}, $F^{\cdot}=2{,}245$ M = 990 F = 1,255, aged 49–56 years	BMI for M in lowest and highest scores of DQI were 27.4 ± 3.7 and 26.9 ± 3 (kg/m^2), respectively; *P* for trend 0.4 And for F were 25.8 ± 5.8 and 25.7 ± 4.3, respectively; *p* for trend 0.0042	USA	8 years	58 %	To assess the relationship between 8-year weight change among Framingham study participants and adherence to the fourth edition of the Dietary Guidelines measured using DQI
2	Kimokoti et al. [1]	Framingham Offspring and Spouse (FOSS) Study	M^{∞}, $F^{\cdot}=1{,}515$ M = 690 F = 825, aged ≥30 years	Mean BMI = 24.7 ± 4.3; 26.8 ± 3.4 kg/m^2 in F and M, respectively	USA	16 years	67 %	(1) Examined patterns of long-term weight change among Framingham men and women over 16 years. (2) Evaluate how diet quality compares with demographic, anthropometric, biological, clinical and other lifestyle factors in predicting weight change in our participants; and (3) impact of these factors, including smoking status, on the association between diet quality and weight change
3	Wolongevicz et al. [33]	The Framingham Offspring and Spouse (FOSS) Study	F = 590 normal weight (BMI < 25 kg/m^2), aged 25–71	Mean BMI across the FNRS tertiles were 22.3, 21.9 and 22 from the lowest to highest tertiles	USA	16 years	100 %	The relationship between diet quality and the development of overweight or obesity in women

4	Beunza et al. [34]	The Seguimiento Universidad de Navarra (SUN) cohort	F, M = 10,376 Mean age 38 years	Mean BMIs were 23.4 ± 3.4, 23.4 ± 3.4, 23.4 ± 3.4 and 23.3 ± 3.4 across baseline MDS from the lowest to highest quartile of MDS	Spain	Mean F/U 5.7 ± 2.2 years	>90 % (for the first 24 months)	The correlation between MDSs and weight gain
5	Sanchez-Villegas et al. [35]	The Seguimiento Universidad de Navarra (SUN) cohort	F, M = 6,319	Mean BMIs were 23.4 ± 3.4, 23.4 ± 3.4, 23.6 ± 3.4 and 23.4 ± 3.4 across baseline MDS from the lowest to highest quartile of MDS	Spain	28 months	90 %	The association between each component at baseline (score_1) and weight or BMI change as outcome. Also overall adherence to the MDP (quartiles of score_1 and outcome)
6	Mendez et al. [36]	The European Prospective Investigation into Cancer and Nutrition (EPIC)—Spain	F = 17,238 M = 10,589 Aged 29–65 years	BMI of participants was >18 and <30 kg/m^2	Spain	Mean of F/U 3.3 years	95 %	To examine whether adherence with MD patterns is associated with obesity incidence for 3 years of follow-up
7	Romaguera et al. [37]	The European Prospective Investigation into Cancer and Nutrition—Physical Activity, Nutrition, Alcohol consumption, Cessation of cmoking, Eating cut of come And obesity (EPIC-PANACEA) project	F, M = 373,803 F = 270,348 M = 103,455 Aged 25–70 years	No data given—all categories of BMI included	Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Spain, Sweden and UK	Median F/U 5 years	Unclear	The association between adherence to MDP and weight change and incidence of overweight or obesity

M male, *F* female, *F/U* follow-up

Table 1.2 Description of dietary intake methods used in included studies

	References	Dietary intake method	Diet quality tool	How the score is derived using the diet quality tool	How the diet quality scores are calculated
1	Quatromoni et al. [24]	3 day estimated food records	Diet quality index (DQI)	5-point DQI to assess adherence to key US dietary recommendations One DQI point was contributed for each of five nutrients if (1) Total fat (<30%kcal) (2) Saturated fat (<10 % kcal) (3) Carbohydrate (>50 % kcal) (4) Cholesterol (<300 mg/day) (5)Sodium (<2,400 mg/day) DQI scores ranged from 0 to 5	Participants classified at baseline within gender across the five points of DQI scores
2	Kimokoti et al. [1]	3 day estimated food records	Framingham Nutritional Risk Score (FNRS)	19 nutrients (1) Total energy (kJ) (2) Protein (% energy) (3) Total fat (% energy) (4) Monounsaturated fat (% energy) (5) Saturated fat (% energy) (6) Alcohol (% energy) (7) Cholesterol (mg/4,184 kJ) (8) Sodium (mg/4,184 kJ) (9) Carbohydrate (%energy) (10) Polyunsaturated fat (% energy) (11) Fibre (g/4,184 kJ) (12) Calcium (mg/4,184 kJ) (13) Selenium (µg/4,184 kJ) (14) Vitamin C (g/4,184 kJ) (15) Vitamin B-6 (g/4,184 kJ) (16) Vitamin B-12 (µg/4,184 kJ) (17) Vitamin E (g/4,184 kJ) (18) Folate (µg/4,184 kJ) (19) Beta-carotene (µg/4,184 kJ)	FNRS had an overall score computed from the mean score of 19 nutrients for each subjects within each gender

3	Wolongevicz et al. [33]	3 day dietary record	Framingham Nutritional Risk Score (FNRS)	19 nutrients (1) Total energy (kJ) (2) Protein (% energy) (3) Total fat (% energy) (4) Monounsaturated fat (% energy) (5) Saturated fat (% energy) (6) Alcohol (% energy) (7) Cholesterol (mg/4,184 kJ) (8) Sodium (mg/4,184 kJ) (9) Carbohydrate (%energy) (10) Polyunsaturated fat (% energy) (11) Fibre (g/4,184 kJ) (12) Calcium (mg/4,184 kJ) (13) Selenium (μg/4,184 kJ) (14) Vitamin C (g/4,184 kJ) (15) Vitamin B-6 (g/4,184 kJ) (16) Vitamin B-12 (μg/4,184 kJ) (17) Vitamin E (g/4,184 kJ) (18) Folate (μg/4,184 kJ) (19) Beta-carotene (μg/4,184 kJ)	Participants were categorised across tertiles of FNRS
4	Beunza et al. [34]	FFQ with 136 food item	MDS-Trichopoulou	There are nine food items—the amount of intake of these food are for M and F, respectively (1) Vegetables 550 and 500 (g/day) (2) Fruit and nuts 360 and 360 (g/day) (3) Legumes 9 and 7 (g/day) (4) Cereals, bread and potatoes 180 and 140 (g/day) (5) Ratio of monounsaturated fatty acids to saturated fatty acids 1.7 and 1.7 (g/day) (6) Moderate alcohol (10–15 g/day) for M and (50–25 g/day) for F (7) Fish 24 and 19 (g/day)	MDS: low score range, 0–3; moderate score, 4–6; high score, 7–9. Participants were categorised into tertile

(continued)

Table 1.2 (continued)

	References	Dietary intake method	Diet quality tool	How the score is derived using the diet quality tool	How the diet quality scores are calculated
				(8) Meat and poultry 120 and 90 (g/day) (9) Dairy products 200 and 190 (g/m) A maximum of 9 points total from the last components	
4	Beunza et al. [34]	FFQ with 136 food item	The Mediterranean Adequacy Index (MAI) proposed by Alberti-Fidanza et al. (2004)	Sum of percentage total energy from the following typical Mediterranean foods (1) Bread (2) Cereal (3) Legumes (4) Potatoes (5) Vegetables (6) Fruit (7) Fish (8) Red wine (9) Vegetable oils	MAI-Alberti-Fidanza Scores: ≤0.95 (lowest); >0.95 to ≤1.31 (moderate); >1.31 to ≤1.84 (high); >1.84 (highest)
				Divided by sum of the percentage total energy from the following nontypical Mediterranean foods (1) Milk (2) Cheese (3) Meat (4) Eggs (5) Animal fat and margarines (6) Sweet beverages (7) Pastries (8) Cookies (9) Sugar	The researchers examined the relationship between these indexes and yearly weight change according to categorical (tertiles or quintiles) of indexes scores
			Mediterranean Diet Quality Index (MDQI) proposed by Scali et al. (2001)	Each of the following items categorised into tertiles and scored from 1 to 3: *Positive* (higher consumption scored 1, medium consumption scored 2, low consumption scored 3)	MDQI-Scali Scores: ≥11 (lowest); 8–10 (moderate); 5–7 (high); ≤4 (highest)

		(1) Vegetables and fruit (g/day) (2) Cereals (bread, pasta, rice and breakfast cereals) (g) (3) Olive oil (mL) (4) Fish (g) *Negative* (higher consumption scored 3, medium consumption scored 2, low consumption scored 1) (1) Meat (g) (2) Saturated fatty acids (% total energy) (3) Cholesterol (mg); the 7 scores were summed (range 0–14): lower score = higher adherence to Mediterranean diet	
	Mediterranean dietary pattern (MDP) proposed by Sánchez-Villegas et al. (2002)	Energy-adjusted intakes of the following items: *Positive* (1) Vegetables (g/day) (2) Fruit (g/day) (3) Legumes (g/day) (4) Cereals incl. bread and potato (g/day) (5) Ratio of monounsaturated fatty acids to saturated fatty acids (6) Moderate alcohol (g/day)—30 for men, 20 for women (not energy adjusted) *Negative* (1) Meat and meat products (g/day) (2) Milk and dairy products (g/day) (3) Trans-fatty acids (g/day) All items standardised as *z*-scores then summed (subtracting negative items) and transformed into % of adherence Score range: 0–100 %	MDP-Sánchez-Villegas Scores: ≤44.23 (lowest); >44.23 to ≤49.47 (moderate); >49.47 to ≤54.97 (high); >54.97 (highest)
	Diet score (DS) proposed by Panagiotakos et al. (2006)	Food items rated 0–5 (reverse for negative items) according to position in Mediterranean diet pyramid:	MDS-Panagiotakos Scores: ≤29 (lowest); 30–33 (moderate); ≥34 (highest)

(continued)

Table 1.2 (continued)

References	Dietary intake method	Diet quality tool	How the score is derived using the diet quality tool	How the diet quality scores are calculated
			Positive (1) Vegetables (times/day or month) (2) Potatoes (times/day or month) (3) Fruit (times/day or month) (4) Legumes (times/day or month) (5) Non-refined cereals (times/day or month) (6) Olive oil (times/day or month) (7) Alcohol (times/day or month) (0 for >700 mL/day, 5 for <300 mL/day) (8) Fish (times/day or month) (9) Poultry (times/day or month) *Negative* (1) Meat and meat products (times/day or month) (2) Full-fat dairy (times/day or month) Score range: 0–55	
		Mediterranean-Style Dietary Pattern Score (MSDPS) recently proposed by Rumawas et al. (2009)	0–10 rating for each item according to its closeness to the goals of the Mediterranean pyramid:	MSDPS-Rumawas Scores: ≤20 (lowest); >20 to 35 (moderate), >35 (highest)
			(1) Vegetables (6 servings/day) (2) Potatoes and other starchy roots (3 servings/week) (3) Fruit (3 servings/day) (4) Legumes, olives and nuts (4 servings/week) (5) Wholegrains (8 servings/day) (6) Sweets (3 servings/week) (7) Dairy products (2 servings/day) (8) Eggs (3 servings/week) (9) Olive oil (as the only fat) (10) Wine (3 glasses/day for M, 1.5 glasses/day for F)	

				(11) Fish (6 servings/week) (12) Poultry (4 servings/week) (13) Meat (1 serving/week) Further adjustment made according to proportion of total energy intake (TEI) provided by consumption of Mediterranean foods Score range: 0–100	
5	Sánchez-Villegas et al. [35]	FFQ with 136 food item	MDS	A maximum of 30 points total from the components (1) Cereals (g/day) (2) Vegetables (g/day) (3) Fruits (g/day) (4) Legumes (g/day) (5) Fish (g/day) (6) Nuts (g/day) (7) Olive oil (g/day) (8) Moderate red wine consumption (g/day) (9) Meat and meat products (g/day) (10) Whole-fat dairy products (g/day)	MDS categorised into quartiles: l ower (<18); moderate (18–19); high (20–21); highest (≥22)
6	Mendez et al. [36]	Diet history with >600 items	MDS	A maximum of 8 points derived from the following components (1) Fish (g/MJ) (2) Vegetables (g/MJ) (3) Fruits and nuts (g/MJ) (4) Legumes (g/MJ) (5) Cereals (g/MJ) (6) Ratio of monounsaturated fat to saturated fat (g/MJ) (7) Moderate ethanol intakes (defined as 5–25 g/day for women, 10–50 g/day for men) (8) Meat (g/MJ)	MDS were categorised in three parts: low (0–3), medium (4–5) and high (6–8)

(continued)

Table 1.2 (continued)

	References	Dietary intake method	Diet quality tool	How the score is derived using the diet quality tool	How the diet quality scores are calculated
7	Romaguera et al. [37]	FFQ	A revised MDS	There are nine components of this score as follows (1) Vegetables (2) Legumes (3) Fruit and nuts (4) Cereals (5) Fish and seafood (6) Olive oil (7) Moderate alcohol consumption (8) Meat and meat products (9) Dairy products Each component was measured in g/1,000 kcal to express ED	The rMED was classified into categories to reflect low (0–6 points), medium (7–10 points) or high (11–18 points) adherence to the MDP

[AU4] **Table 1.3** Description of the outcome measures for the included studies

	References	The outcome	Statistical analysis	Result	Key finding	Confounders
1	Quatromoni et al. [24]	8-year wt gain in lb	Multivariate generalised estimating equations within gender using the mean of DQI score for all participants as the predictor	Participants in the highest DQI quintile gain less wt over 8 years (*P* for trend <0.01). The mean ± SD of wt gain in F in the highest DQI quintile was 3.3 ± 17.4 lb compared with 8.0 ± 13.0 lb gained in those within the lowest DQI quintile. The mean ± SD of wt gain in M in the highest DQI quintile was 2.7 ± 10.1 lb compared with 5.1 ± 13.3 lb those in the lowest DQI quintile	There is significant inverse association between the mean of DQI score for all participant and weight change in both adults; $p = 0.026$ and $p = 0.008$, respectively, for M and F	Age, BMI, physical activity, alcohol intake, smoking cessation, intentional change in diet, postmenopausal, energy intake Note: Smoking cessation was an important predictor of weight gain, accounting for about a 5- to 9-pound difference in weight gain
2	Kimokoti et al. [1]	Wt change in kg	Multivariable linear regression analysis within gender Baseline used FRNS as predictors for weight change during a 16-year follow-up	FNRS was not associated with weight gain in both M and F; $p = 0.16$ and $p = 0.61$, respectively F who were former smokers and who were in the lowest tertile of FRNS gained an additional 5.2 kg compared with former smokers who were in the highest tertile of FNRS; *P* for trend = 0.03	FNRS was not a predictor for wt gain in either M or F	In F: age, wt, physical activity index, FNRS, former smoker and FNRS across smoking category In M: age, wt, wt fluctuation and former smoking and nonsmokers
3	Wolongevicz et al. [33]	Incidence of overweight or obesity; BMI ≥25 kg/m²	Logistic regression model to estimate odds ratio of being overweight or obese	FNRS was associated with incidence of overweight or obesity (*p* for trend = 0.009). Women with lower diet quality were significantly more likely to become overweight or obese; OR, 1.76; CI, 95 %(1.16–2.69) times compared with those with highest diet quality	Higher FNRS was associated with a reduced chance of being overweight or obese	Age, physical activity and smoking status

(continued)

Table 1.3 (continued)

	References	The outcome	Statistical analysis	Result	Key finding	Confounders
4	Beunza et al. [34]	(1) Annual wt gain in kg	(1) Multiple linear regressions were used to estimate the annual means change in body weight across categories of adherence the MD	(1) Participants in the highest tertile of MDS had the lowest average yearly wt gain relative to lowest tertile of MDS −059 kg/year; 95 % CI (−0.111, −0.008 kg/year)	(1) There was a significant inverse association between all MDS and wt change	Age and sex, BMI, physical activity, sedentary behaviour, smoking, snacking and TEI
		(2) Incidence of wt gain (≥3 kg/year or ≥5 kg/year) during the first 2 or 4 years of follow-up	(2) Logistic regression analysis for the first index only and to estimate OR for incidence of weight gain (≥3 or ≥5 kg) during the first 2 or 4 years of follow-up	(2) OR for incident of wt gain for highest tertile relative to lowest tertile OR: CI 95 % (2 years) for ≥3 kg, 0.8 (070, 0.92) OR: CI 95 % (2 years) for ≥5 kg, 0.76 (0.62, 0.92) OR: CI 95 % (4 years) for ≥3 kg, 0.80 (0.71, 0.91) OR: CI 95 % (4 years) for ≥5 kg, 0.76 (0.64, 0.90)	(2) Those in the highest tertile of MDS were less likely to have absolute wt gain relative to those in the lowest tertile	
4	Beunza et al. [34]	(1) Annual wt gain in kg	(1) Multiple linear regressions were used to estimate the annual means change in body weight across categories of adherence the MD	MAI-Alberti-Fidanza Scores >1.84 (highest) had the highest mean wt gain −0.077 (−0.131, −0.022) compared with the lowest ≤0.95	There was a significant inverse association between all MDS and wt change except MDS-Panagiotakos and MSDPS-Rumawas with p for trend 0.30, 0.41, respectively while all other MDS had p for trend <0.05	Age and sex, BMI, physical activity, sedentary behaviour, smoking, snacking and TEI

				MDQI-Scali Scores ≤4 (highest) had the highest mean wt gain −0.102 (−0.194, −0.009) compared with ≥11 (lowest) MDP-Sánchez-Villegas Scores >54.97 (highest) gained −0.061 (−0.116, −0.006) compared with ≤44.23 (lowest)		
				MDS-Panagiotakos ≥34 (highest) gained −0.029 (−0.079, 0.021) compared with ≤29 (lowest) MSDPS-Rumawas Scores >35 (highest) gained −0.028 (−0.094, 0.038) compared with ≤20 (lowest)		
5	Sánchez-Villegas et al. [35]	Wt in kg	(1) Linear regression models were used to assess the association between MD scores at baseline and wt change and BMI change during F/U time (2) Logistic regression to examine the association between baseline of MDS and incidence of overweight or obesity during the F/U time	(1) Participants in the highest quartile of MDS gained less weight (+0.65 kg) (+0.59 to +0.80) compared with those in the lowest quartile (*p* for trend 0.291) (2) Participant in the highest quartile of MDS had smaller increase in BMI +0.23 (+0.12 to +0.33) compared with those in the lowest quartile of MDS (*p* for trend 0.279)	There was not a significant association between MDS and weight gain	Age, gender, BMI, smoking, physical activity, alcohol, EI, change in dietary habits (fruit, vegetables, meat, meat product, fish, olive oil and alcohol) and change in physical activity during F/U time

(continued)

Table 1.3 (continued)

	References	The outcome	Statistical analysis	Result	Key finding	Confounders
6	Mendez et al. [36]	(1) Incidence of obesity (BMI ≥30 kg/m²)	Logistic regression models were used to estimate odds of becoming overweight or obese	(1) Overweight participants in the highest MDS were less likely to become obese OR (95 % CI) of becoming obese for F and M, respectively +0.69, (0.54–0.89) +0.68, (0.53–0.89)	(1) There was inverse significant association between MDS and becoming obese	Underreporting of dietary data, age, physical activity, education, centre, height, smoking status, season, follow-up time, changes in employment status during follow-up, use of special diets, parity and menopause in women and history of chronic diseases (cancer, diabetes or heart diseases) at baseline or follow-up
		(2) Incidence of overweight (BMI ≥25 to <30 kg/m²)		(2) High MD adherence was not associated with overweight incidence in women and men OR (95 % CI) of becoming overweight for F and M, respectively +0.99 (0.78, 1.25) +1.11 (0.81–1.52)	(2) There was no significant association between MDS and incidence of overweight	
7	Romaguera et al. [37]	(1) Wt gain in 5-year F/U	(1) Multiple linear regression between rMED and 5-year wt gain	(1) Those in the highest tertile of rMED had less wt gain −0.16 kg (CI 95 %: −0.24, −0.07) and −0.04 kg (−0.07, −0.02) for the combined results	There is a significant inverse association between MDP and becoming overweight or obese	Sex, age, baseline BMI, follow-up time, educational, physical activity, smoking, TEI and misreporting of EI
		(2) Overweight or obesity incidence in 5-years of F/U (BMI ≥25 kg/m²)	(2) Logistic regression to examine the association between a 2-point increase in rMED and becoming overweight	(2) Overall results showed that a 2-point increase in the rMED was associated with becoming overweight after compounding the result from all the cohorts OR (CI 95 %): 0.97 (0.95, 0.99)		

WT weight, *EI* energy intake

Table 1.4 Conclusions and significance of included studies

	References	Was there an inverse relationship between diet quality and body weight change?	Were the results significant?
1	Quatromoni et al. [24]	Y	Y
2	Kimokoti et al. [1]	N However, there was inverse correlation between women who quit smoking in the lowest FNRS and higher weight gain in women only	N Y in former smokers in the lowest FNRS tertile gain more weight than other in highest tertile
3	Wolongevicz et al. [33]	Y	Y
4	Beunza et al. [34]	Y in 6 diet quality indexes	Y in 4 indexes N in two indexes
5	Sanchez-Villegas et al. [35]	Y	N
6	Mendez et al. [36]	Y of becoming obese N of becoming overweight	Y of becoming obese among the overweight only N of becoming overweight
7	Romaguera et al. [37]	Y	Y

Methods Used to Measure Diet Quality

To evaluate diet quality, the studies examined used a number of different indexes and scores which are described in detail in Table 1.2 and summarised below.

Quatromoni et al. [24] used the DQI to judge the quality of overall dietary intake, with a higher DQI representing greater adherence to the US national dietary guidelines. The DQI score ranges from zero to five, and the five points constitute adherence to percentage energy intake from total fat, saturated fat and carbohydrate (3 points), and the total intakes of cholesterol and sodium (2 points) [24]. The intake levels were set according to the US dietary guidelines [24] and are given in Table 1.2. Each DQI component is awarded a score of either zero or one. If consumption of the nutrient is optimal and within the recommended limits, then a score of one is awarded, otherwise it is scored as zero [38]. Therefore, higher DQI scores are associated with lower total fat, saturated fat, cholesterol and sodium intakes and higher intakes of carbohydrate, representing greater adherence to the Dietary Guidelines for Americans. Thus, it reflects a dietary pattern that contains food rich in carbohydrate and fibre such as fruits and vegetables and lower intakes of foods that are high in sodium and fat [21].

Two [32, 33] studies used the FNRS, which is based on intakes of 19 nutrient components (Table 1.2). These nutrients are classified into three groups according to their relationship with CVD risk as follows: (1) optimal intake profile of selected macronutrients including energy, protein, monounsaturated fat and polyunsaturated fat; (2) increased risk-related nutrients including total fat, saturated fat, cholesterol, alcohol and sodium; (3) protective nutrients including carbohydrate, dietary fibre, calcium, selenium, vitamin C, vitamin B-6, vitamin B-12, vitamin E, folate and beta-carotene [39]. The nutrients included in FNRS are scored in such a way that a person with a more desirable nutrient profile is awarded a lower score. For example, a lower fat or higher vitamin and mineral intake will attract a lower score. Similarly a less desirable nutrient profile is given a higher score, e.g. higher total fat or lower micronutrient intake. Higher monounsaturated fat intake was given a higher score, because the source of these fats was mostly animal products (e.g. beef fat) for participants in the Framingham study [1, 33]. The rank given to individual nutrients was aggregated to give an overall composite risk rank [1].

The Mediterranean Diet Score (MDS) was compiled by Trichopoulou et al. [40]. All four studies included in this review that used the MDS [34–37] used different scoring methods to calculate

Table 1.5 Quality assessment for included studies

	References	(1) Is the sample representative of patients in the population as a whole?	Was everyone assessed at the same follow-up time?	Are the confounding factors identified and strategies to deal with them stated?	Are outcome assessed using objective criteria?	Was follow-up carried out over a sufficient time period?	Were the people who withdrew described and included in the analysis?	Were the outcome measured in reliable way?	Was appropri-ate statistical analysis used?	The total
1	Quatromoni et al. [24]	U	Y	Y	Y	Y	U	Y	Y	2U 6Y
2	Kimokoti et al. [1]	U	Y	Y	Y	Y	U	Y	Y	2U, 6Y
3	Wolongevicz et al. [33]	U	Y	Y	Y	Y	U	Y	Y	2U, 6Y
4	Beunza et al. [34]	N	N	Y	N	Y	U	Y	Y	1U, 3N, 4Y
5	Sanchez-Villegas et al. [35]	N	Y	Y	N	Y	U	Y	Y	1U, 2N, 5Y
6	Mendez et al. [36]	Y	Y	Y	N	Y	U	Y	Y	1U, 1N, 6Y
7	Romaguera et al. [37]	N	N	Y	N	Y	U	N	Y	1U, 4N, 2Y
	The total	3U, 1Y, 3N	1N, 6Y	7Y	3Y 4N	7Y	7U	1N, 6Y	7Y	

U unclear, *N* no, *Y* yes

adherence to the Mediterranean Diet Pattern (MDP). Each one referenced the MDS, even though they varied in the actual method. In general, the Mediterranean Diet Pattern includes regular consumption of vegetables, fruit, legumes, cereals, nuts, fish and foods rich in olive oil, as well as a low in intake of foods high in saturated fat, dairy products, meat and poultry [40].

The MDS as used in the paper by Beunza et al. [34] considered the intake of nine food items (Table 1.2), which were classified into (1) positive components (vegetables, fruit, nuts, legumes, cereals, moderate alcohol and fish) and (2) negative components (meat and poultry, dairy products) [34]. The score assigned to each component was based on both the nature of the food component and the quantity of that food consumed in relation to the median value for all subjects under consideration [41]. A score of zero was assigned to a positive component if the individual's consumption was less than the gender-specific median consumption [42]. A score of one was awarded if the food item was positive and consumption was greater than the gender-specific median. The opposite procedure was followed in case of negative components. A score of zero was awarded if the consumption was greater than the gender-specific median and one if consumption of the negative component was less than the relevant median [34, 42].

The MDS as used by Sanchez-Villegas et al. [35] was defined a priori and considered the intake of ten food item components. These foods were classified into two groups: (1) beneficial food items which included cereals, vegetables, fruits, legumes, fish, nuts, olive oil and moderate red wine and (2) detrimental food items which included meat, meat products and whole-fat dairy products [35]. The total score range was 10–30 points. To compute the score for each participant, a rank system was applied to each component. First, each item was classified into tertiles and scored from 1 to 3 from the lowest to the highest tertile for beneficial food items and then 1–3 from the highest to lowest tertile for detrimental food components. The ten components scores were summed for each participant. Thus, a maximum of 30 points reflects the highest MDS and the greatest adherence to MDP, while a score of 10 points reflects the lowest adherence [35].

The MDS used by Mendez et al. [36] collected the dietary intake data from a diet history, which generated a list of approximately 600 food items. This MDS score is similar to a previous one [34] and classified food items into (1) beneficial foods including fish, vegetables, fruits, legumes, cereals and the ratio of monounsaturated saturated fat and (2) detrimental food items, including moderate alcohol intake and meat. Milk and dairy products were not considered in this index. A score of zero was assigned to a component if it was beneficial and if the individual's consumption was less than the gender-specific median consumption of that particular food for all individuals in the study. The opposite procedure was followed in the case of detrimental foods, with a score of zero awarded if consumption was more than the gender-specific median and a score of one given if consumption was less than the relevant median [36].

Researchers for the Romaguera et al. [37] paper used a revised Mediterranean Diet Pattern [43] evaluated using a Relative Mediterranean Diet Score (rMed). This rMed differs from the original MDS and comprises nine nutritional components which characterise MDP. Components like vegetables, legumes, fruit, nuts, cereals, seafood and fish, moderate alcohol consumption and olive oil are rated as beneficial foods, while meat and meat products and dairy products are rated as detrimental. All food items in this score are expressed in units as grams/1,000 kcal. Each component in this index is scored as tertiles, except for alcohol and olive oil. Scores of 0, 1 and 2 were given from the lowest to the highest tertile for the beneficial food items. The detrimental components of meat/meat products and dairy were given 0, 1 or 2 from the highest to the lowest tertile. Thus, higher intakes of beneficial foods and lower intakes of detrimental foods contributed more to the score, reflecting greater adherence to Mediterranean patterns. For olive oil, a zero score was given to nonconsumers, 1 to those with consumption below the median level and 2 to those with consumption greater than or equal to the median. Regarding alcohol, a score of 2 was given to those with a moderate alcohol consumption, ranging from 10 to <50 g/day for men and 5 to <25 g/day for women. Consumption outside of this range for alcohol scored zero. The rMed score ranged from 0 (lowest adherence to MDP) to 18 (highest adherence to MDP). Further evaluation classified the score 0–6 as low adherence, 7–10 as medium and 11–18 as high adherence to MDP [43].

The Implications of Diet Quality on Weight Change

This systematic review aimed to synthesise the best evidence available on the relationship between diet quality and weight change in adults within cohort studies. There were only seven studies included that assessed dietary quality using a dietary quality score or index from an initial search generating 2,304 citations from a comprehensive search of the four most relevant databases, specific for the research question. This review indicates that the relationship between diet quality and weight gain is important. Using the DQI tool, the mean diet quality score at baseline was shown to be a strong predictor of prospective weight gain [24]. Another study [34] found that the risk of having a specific amount of weight gain (≥3 or ≥5 kg) during follow-up periods of 2 and 4 years was higher among those in the lowest tertile of MDS compared to those in the highest tertile. Moreover, there were significant associations between annual weight gain in adults using all four indexes of MDP [34]. However, in the same study, the authors also evaluated another two indexes to generate MDPs and found that there were no relationships between these two indexes and annual weight gain [34]. In addition, two other diet quality indexes [1, 35] found no relationship between diet quality and weight gain over time. More specifically, evaluation of FNRS at baseline with prospective weight gain within gender demonstrated a strong interaction with smoking status in both genders [1]. In this study women who quit smoking and also had the poorest diet quality, as evaluated by FNRS, had higher weight gain than those in the highest FRNS tertile. A significant association was found between having lower diet quality, as determined by FNRS or rMDS, and a higher risk of becoming overweight or obese [33, 37] Moreover, a significant risk of becoming obese was demonstrated among those who were overweight and in the lowest tertile of diet quality score, but there was no greater risk of becoming overweight among those with the poorest diet quality [36].

Quality of the Studies

From Table 1.5 it was identified that most studies have confounders and although this is a potential risk of bias, the majority adjusted for at least the major confounders in the statistical analysis. It was unclear from the population descriptions whether some of the researchers used a representative sample or not, but at least three studies used non-representative population samples. Three studies reported analyses were conducted in the USA [21, 32, 33] from the same cohort and three studies were carried out in Spain [34–36], so although they may each be representative within countries, internationally they are not.

Limitations of the Studies

Within the included studies, the reporting of confounders and statistical adjustment for them is the most common weakness. The most commonly reported confounders were similar and included age, BMI, physical activity, education and income (Table 1.3).

One of the most important confounders that is rarely addressed is changes in dietary intake during the follow-up period, especially when follow-up times are extensive, as there is no guarantee of stability of dietary intake and behaviours over time. This means that weight gain could also have been influenced by other factors apart from baseline diet. There are other important confounders, such as misreporting of energy intake, and the only study to adjust for underreporting was Mendez et al. [36].

Further, use of a 3-day food record has been identified as commonly associated with underreporting of dietary intake [24].

The finding of this systematic review demonstrates that within cohort studies examining weight change over time, dietary intake has not commonly been categorised using a diet quality score or dietary index in adults. Due to the small number of studies in this area, further research is needed. Moreover, this is an important field warranting more research because diet is an important determinant of weight change. In addition, there is limited research identifying which are the most useful tools to assess diet quality as a predictor of weight change in adults within longitudinal studies.

The results from the studies in Table 1.1 are heterogeneous and use different methodologies to evaluate both dietary intake and the outcome of body weight. In general, four studies out of the total of seven found an inverse association between diet quality and weight change, both as absolute weight gain or as a change in weight status category. This means that consuming a higher quality diet, or one which is consistent with healthier eating habits and dietary intakes, that aligns more closely with national dietary guidelines does lead to smaller amounts of weight gain. However, two studies found this association in multivariate models only among specific groups of participants who were overweight at baseline or women who were former smokers and also had the poorest dietary intake as scored by FNRS or MDS [1, 36] (Table 1.4).

The first three studies in Table 1.1 [1, 24, 33] were evaluations using differing methodologies but performed on the same FOSS cohort. Each used different criteria for including participants; different methods to assess diet quality (DQI or FNRS), varied in how the weight change was defined; different methods to report the weight change outcomes; and differing approaches to the statistical analysis. However, across the studies, women with the poorest diet quality gained an additional 1,040 g compared to men with the poorest dietary intake over time [24].

On average, adults in the lowest diet quality category gain additional weight (59–1,090 g) compared to those who had eating patterns consistent with higher diet quality over follow-up periods of 1–8 years duration.

Conclusions

In conclusion, the current evidence is insufficient to set benchmarks for optimal diet quality in order to prevent weight gain. However, aspiring to diet quality scores that reflect adherence to national dietary guidelines appears prudent. Although we cannot determine whether lower diet quality, as assessed by scores or indexes, could definitely lead to higher weight gain due to the limitations of the evidence in this area currently, it is clear from the available evidence that there is a strong association between higher weight gain and poor diet quality. Further, smoking status, especially in women, and baseline BMI in adults were important confounders that should be considered in future studies, along with any interactions between them and dietary intake.

Recommendations for Researchers

Further studies are required that use a number of different methods within the one cohort to measure diet quality as predictors of weight gain in adults. This approach would ideally be repeated across a number of nationally representative population cohorts to examine how robust any relationships are internationally or whether any of the approaches is more applicable.

Although there have been a considerable number of studies that have examined the relationship between macronutrient or energy intakes and weight change over time, it is clear from this systematic review that there is a lack of studies examining overall diet quality or total dietary patterns. Such an approach would better characterise the relationship between weight change and diet quality in adults over time and facilitate development of food-based guidelines targeting the prevention of weight gain.

References

1. Kimokoti RW, Newby PK, Gona P, Zhu L, Jasuja GK, Pencina MJ, et al. Diet quality, physical activity, smoking status, and weight fluctuation are associated with weight change in women and men. J Nutr. 2010;140:1287–93.
2. World Health Organization. Obesity and overweight. http://www.who.int/mediacentre/factsheets/fs311/en/. Accessed Mar 2011.
3. Kushner RF, Foster GD. Obesity and quality of life. Nutrition. 2000;16:947–52.
4. Peeters A, Barenderegt JJ, Willekens F, Johan PM, Mamun AA, Bonneux L. Obesity in adulthood and its consequences for life expectancy: a life-table analysis. Ann Intern Med. 2003;138:24–32.
5. Cameron AJ, Dunstan DW, Owen N, Zimmet PZ, Barr EL, Tonkin AM, et al. Health and motality consequences of abdominal obesity: evidence from AusDiab study. Med J Aust. 2009;191:202–8.
6. Lijing LY, Daviglus ML, Liu K, Stamler J, Wang R, Pirzada A, et al. Midlife body mass index and hospitalization and mortality in older age. JAMA. 2006;295:290–8.
7. Hu FB. Overweight and obesity in women: health risks and consequences. J Womens Health. 2003;12:163–72.
8. Sanchez-Villegas A, Adriano MP, Beunza JJ, Guillen-Grima F, Toledo E, et al. Childhood and young adult overweight/obesity and incidence of depression in the SUN Project. Obesity. 2010;18:1443–8.
9. World Cancer Research Fund International/American Institute for Cancer Research. Food, nutrition, physical activity, and the prevention of cancer: a global perspective. http://www.dietandcancerreport.org/downloads/chapters/chapter_08.pdf. Accessed Apr 2011.
10. Hu D, Hannah J, Gray RS, Jablonski KA, Henderson JA, Robbins DC, et al. Effects of obesity and body fat distribution on lipids and lipoproteins in nondiabetic American Indians: the Strong Heart Study. Obesity. 2000;8:411–21.
11. Lee DC, Kim KC, Shin DH, Lee SY, Im JA. Relation between obesity and bone mineral density and vertebral fractures in Korean postmenopausal women. Yonsei Med J. 2010;51:857–63.
12. Greco EA, Fornari R, Rossi F, Santiemma V, Prossomariti G, Annoscia C, et al. Is obesity protective for osteoporosis? Evaluation of bone mineral density in individuals with high body mass index. Int J Clin Pract. 2010;64:817–20.
13. Larsson B, Svardsudd K, Welin L, Wilhelmsen L, Bjorntorp P, Tibblin G. Abdominal adipose tissue distribution, obesity, and risk of cardiovascular disease and death: 13 year follow up of participants in the study of men born in 1913. Br Med J. 1984; 288:1401–4.
14. Lightwood J, Bibbins-Domingo K, Coxson P, Wang C, Williams L, Goldman L. Forecasting the future economic burden of current adolescent overweight: an estimate of the Coronary Heart Disease Policy Model. Am J Public Health. 2009;99:2230–7.
15. Colagiuri S, Lee CMY, Colagiuri R, Magliana D, Shaw JE, Zimmet PZ, et al. The cost of overweight and obesity in Australia. Med J Aust. 2010;192:260–4.
16. Kolotikin RL, Meter K, Williams GR. Quality of life and obesity. Obes Rev. 2001;2:219–29.
17. Australian Burean of Statistics. Overweight and obesity in adults, Australia, 2004–05. (ABS4719.0). http://www.abs.gov.au. Accessed May 2011.
18. Australian Burean of Statistics. National Health Survey: summary of results 2007–2008. (ABS 4364.0). http://www.abs.gov.au. Accessed May 2011.
19. McCrory MA, Suen VMM, Roberts SB. Biobehavioral influences on energy intake and adult weight gain. J Nutr. 2002;132:3830S–4.
20. Tang JW, Kushner RF, Thompson J, Baker DW. Physician counseling of young adults with rapid weight gain: a retrospective cohort study. BMC Fam Pract. 2010;11:31.
21. Yanovski JA, Yanovski SZ, Sovik KN, Nguyen TT, O'Neil PM, Sebring NG. A prospective study of holiday weight gain. N Engl J Med. 2000;342:861–7.
22. Drapeau V, Despras J-P, Bouchard C, Allard L, Fournier G, Leblanc C, et al. Modifications in food-group consumption are related to long-term body-weight changes. Am J Clin Nutr. 2004;80:29–37.
23. Foreyt JP, Goodrick GK. Evidence for success of behavior modification in weight loss and control. Ann Intern Med. 1993;119:698–701.
24. Quatromoni PA, Pencina M, Cobain MR, Jacques PF, D'Agostino RB. Dietary quality predicts adult weight gain: findings from the Framingham Offspring Study. Obesity. 2006;14:1383–91.
25. Colditz GA, Willett WC, Stampfer MJ, London SJ, Segal MR, Speizer FE. Patterns of weight change and their relation to diet in a cohort of healthy women. Am J Clin Nutr. 1990;51:1100–5.
26. Bes-Rastrollo M, Martinez-Gonzalez MA, Sanchez-Villegas A, de la Fuente Arrillaga C, Martinez JA. Association of fiber intake and fruit/vegetable consumption with weight gain in a Mediterranean population. Nutrition. 2006;22:504–11.
27. Schulz M, Kroke A, Liese AD, Hoffmann K, Bergmann MM, Boeing H. Food groups as predictors for short-term weight changes in men and women of the EPIC-Potsdam cohort. J Nutr. 2002;132:1335–40.
28. Fogelholm M, Kukkonen-Harjula K. Does physical activity prevent weight gain—a systematic review. Obes Rev. 2000;1:95–111.
29. Kapinos KA, Yakusheva O. Environmental influences on young adult weight gain: evidence from a natural experiment. J Adolesc Health. 2011;48:52–8.
30. Loos RJF, Bouchard C. Obesity—is it a genetic disorder? J Intern Med. 2003;254:401–25.
31. Roberts SB, Williamson DF. Causes of adult weight gain. J Nutr. 2002;132:3824S–5.

32. Wirt A, Collins CE. Diet quality–what is it and does it matter? Public Health Nutr. 2009;12:2473–92.
33. Wolongevicz DM, Zhu L, Pencina MJ, Kimokoti RW, Newby PK, D'Agostino RB, et al. Diet quality and obesity in women: the Framingham Nutrition Studies. Br J Nutr. 2010;103:1223–9.
34. Beunza JJ, Toledo E, Hu FB, Bes-Rastrollo M, Serrano-Martínez M, Sánchez-Villegas A, et al. Adherence to the Mediterranean diet, long-term weight change, and incident overweight or obesity: the Seguimiento Universidad de Navarra (SUN) cohort. Am J Clin Nutr. 2010;92:1484–93.
35. Sanchez-Villegas A, Bes-Rastrollo M, Martinez-Gonzalez M, Serra-Majem L. Adherence to a Mediterranean dietary pattern and weight gain in a follow-up study: the SUN cohort. Int J Obes. 2006;30:350–8.
36. Mendez MA, Popkin BM, Jakszyn P, Berenguer A, Tormo MJ, Sanchez MJ, et al. Adherence to a Mediterranean diet is associated with reduced 3-year incidence of obesity. J Nutr. 2006;136:2934–8.
37. Romaguera D, Norat T, Vergnaud A, Mouw T, May AM, Agudo A, et al. Mediterranean dietary patterns and prospective weight change in participants of the EPIC-PANACEA project. Am J Clin Nutr. 2010;92:912–21.
38. Drewnowski A, Henderson SA, Driscoll A, Rolls BJ. The Dietary Variety Score: assessing diet quality in healthy young and older adults. J Am Diet Assoc. 1997;97:266–71.
39. Kimokoti RW, Newby PK, Gona P, Zhu L, Campbell WR, D'Agostino RB, et al. Stability of the Framingham Nutritional Risk Score and its component nutrients over 8 years: the Framingham Nutrition Studies. Eur J Clin Nutr. 2012;66(3):336–44.
40. Trichopoulou A, Costacou T, Bamia C, Trichopoulos D. Adherence to a Mediterranean diet and survival in a Greek population. N Engl J Med. 2003;348:2599–608.
41. Willett WC, Sacks F, Trichopoulou A, Drescher G, Ferro-Luzzi A, Helsing E, et al. Mediterranean diet pyramid: a cultural model for healthy eating. Am J Clin Nutr. 1995;61:1402S–6.
42. Simopoulos AP, Visioli F. More on Mediterranean diets. New York: Basel/Karger; 2007.
43. Romaguera D, Norat T, Mouw T, May AM, Bamia C, Slimani N, et al. Adherence to the Mediterranean diet is associated with lower abdominal adiposity in European men and women. J Nutr. 2009;139:1728–37.

Appendix 3: The Dietary Questionnaire for Epidemiological Studies Version 2 (DQESv2), Food Frequency Questioners (FFQ)

This section is about your **usual** eating habits **over the PAST 12 MONTHS.** Where possible, give only **one answer per question** for the type of food you eat **most often.** *(If you can't decide which type you have most often, answer for the types you usually eat.)*

50 How many pieces of FRESH fruit do you usually eat per day? *(Count 1/2 cup of diced fruit, berries or grapes as one piece)*

- I don't eat fruit
- Less than 1 piece of fruit per day
- 1 piece of fruit per day
- 2 pieces of fruit per day
- 3 pieces of fruit per day
- 4 or more pieces of fruit per day

51 How many different vegetables do you usually eat per day? *(Count all types, fresh, frozen or tinned.)*

- Less than 1 vegetable per day
- 1 vegetable per day
- 2 vegetables per day
- 3 vegetables per day
- 4 vegetables per day
- 5 vegetables per day
- 6 or more vegetables per day

52 What type of milk do you usually use?

- A None
- B Full cream milk
- C Reduced fat milk
- D Skim milk
- E Soya milk

53 How much milk do you usually use per day? *(Include flavoured milk and milk added to tea, coffee, cereal etc.)*

- None
- Less than 250 ml *(1 large cup or mug)*
- Between 250 and 500 ml *(1-2 cups)*
- Between 500 and 750 ml *(2-3 cups)*
- 750 ml *(3 cups)* or more

54 What type of bread do you usually eat?

- A I don't eat bread
- B High fibre white bread
- C White bread
- D Wholemeal bread
- E Rye bread
- F Multi-grain bread

55 How many slices of bread do you usually eat per day? *(Include all types, fresh or toasted and count one bread roll as 2 slices.)*

- Less than 1 slice per day
- 1 slice per day
- 2 slices per day
- 3 slices per day
- 4 slices per day
- 5-7 slices per day
- 8 or more slices per day

56 Which spread do you usually put on bread?

- A I don't usually use any fat spread
- B Margarine of any kind
- C Polyunsaturated margarine
- D Monounsaturated margarine
- E Butter and margarine blends
- F Butter

57 On average, how many teaspoons of sugar do you usually use per day? *(Include sugar taken with tea and coffee and on breakfast cereal etc.)*

- None
- 1 to 4 teaspoons per day
- 5 to 8 teaspoons per day
- 9 to 12 teaspoons per day
- More than 12 teaspoons per day

58 On average, how many eggs do you usually eat per week?

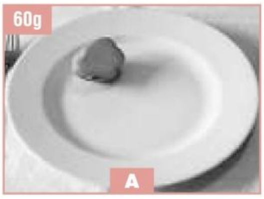
- I don't eat eggs
- Less than 1 egg per week
- 1 to 2 eggs per week
- 3 to 5 eggs per week
- 6 or more eggs per week

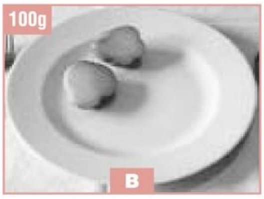
59 What types of cheese do you usually eat?

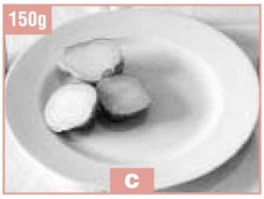
- A I don't eat cheese
- B Hard cheeses, eg parmesan, romano
- C Firm cheeses, eg cheddar, edam
- D Soft cheeses, eg camembert, brie
- E Ricotta or cottage cheese
- F Cream cheese
- G Low fat cheese

For each food shown on this page, indicate **how much on average you would usually have eaten at main meals during the PAST 12 MONTHS.** When answering each question, think of the **amount** of that food you usually ate, even though you may rarely have eaten the food on its own. If you usually ate more than one helping, choose the serving size closest to the **total amount** you ate.

60 When you ate potato, did you usually eat: ○ I never ate potato

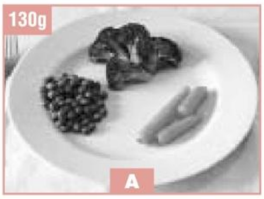


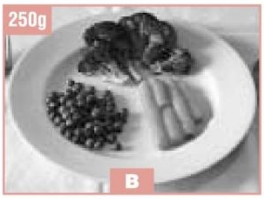


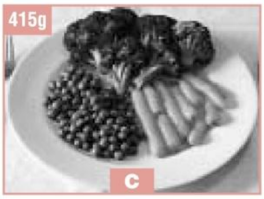


○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

61 When you ate vegetables, did you usually eat: ○ I never ate vegetables

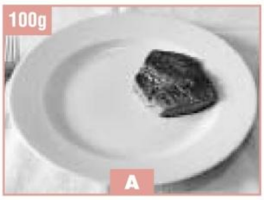


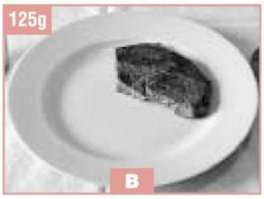


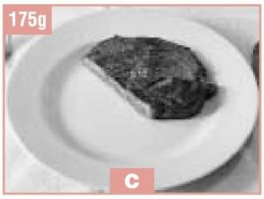


○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

62 When you ate steak, did you usually eat: ○ I never ate steak

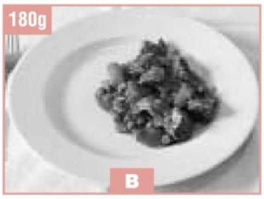


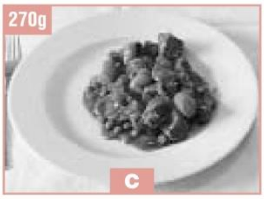




○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

63 When you ate meat *or* vegetable casserole, did you usually eat: ○ I never ate casserole





○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

64 Over the LAST 12 MONTHS, on average, how often did you eat the following foods?
(Mark one on each line)

Times you have eaten:	Never	Less than once per month	1-3 times per month	1 time per week	2 times per week	3-4 times per week	5-6 times per week	1 time per day	2 times per day	3 or more times per day
Cereal, Foods, Sweets & Snacks										
A All Bran										
B Sultana Bran™, FibrePlus™, Branflakes™										
C Weet Bix™, Vita Brits™, Weeties™										
D Cornflakes, Nutrigrain™, Special K™										
E Porridge										
F Muesli										
G Rice										
H Pasta or noodles *(include lasagne)*										
I Crackers, crispbreads, dry biscuits										
J Sweet biscuits										
K Cakes, sweet pies, tarts and other sweet pastries										
L Meat pies, pasties, quiche and other savoury pastries										
M Pizza										
N Hamburger with a bun										
O Chocolate										
P Flavoured milk drink *(cocoa, Milo™ etc)*										
Q Nuts										
R Peanut butter or peanut paste										
S Corn chips, potato crisps, Twisties™ etc										
T Jam, marmalade, honey or syrups										
U Vegemite™, Marmite™ or Promite™										
Dairy Products, Meat & Fish										
A Cheese										
B Ice-cream										
C Yoghurt										
D Beef										
E Veal										
F Chicken										
G Lamb										
H Pork										
I Bacon										
J Ham										
K Corned beef, luncheon meats or salami										
L Sausages or frankfurters										
M Fish, steamed, grilled or baked										
N Fish, fried *(include take-away)*										
O Fish, tinned *(salmon, tuna, sardines etc)*										
Fruit										
A Tinned or frozen fruit *(any kind)*										
B Fruit juice										
C Oranges or other citrus fruit										
D Apples										
E Pears										
F Bananas										
G Watermelon, rockmelon *(cantaloupe)*, honeydew etc										
H Pineapple										
I Strawberries										
J Apricots										
K Peaches or nectarines										
L Mango or paw paw										
M Avocado										

64 Continued... Over the LAST 12 MONTHS, on average, how often did you eat the following foods? *(Mark one on each line)*

Times you have eaten:	Never	Less than once per month	1-3 times per month	1 time per week	2 times per week	3-4 times per week	5-6 times per week	1 time per day	2 times per day	3 or more times per day
Vegetables (including fresh, frozen and tinned)										
A Potatoes roasted or fried *(include hot chips)*	○	○	○	○	○	○	○	○	○	○
B Potatoes cooked without fat	○	○	○	○	○	○	○	○	○	○
C Tomato sauce, tomato paste or dried tomatoes	○	○	○	○	○	○	○	○	○	○
D Fresh or tinned tomatoes	○	○	○	○	○	○	○	○	○	○
E Peppers *(capsicum)*	○	○	○	○	○	○	○	○	○	○
F Lettuce, endive, or other salad greens	○	○	○	○	○	○	○	○	○	○
G Cucumber	○	○	○	○	○	○	○	○	○	○
H Celery	○	○	○	○	○	○	○	○	○	○
I Beetroot	○	○	○	○	○	○	○	○	○	○
J Carrots	○	○	○	○	○	○	○	○	○	○
K Cabbage or Brussels sprouts	○	○	○	○	○	○	○	○	○	○
L Cauliflower	○	○	○	○	○	○	○	○	○	○
M Broccoli	○	○	○	○	○	○	○	○	○	○
N Silverbeet or spinach	○	○	○	○	○	○	○	○	○	○
O Peas	○	○	○	○	○	○	○	○	○	○
P Green beans	○	○	○	○	○	○	○	○	○	○
Q Bean sprouts or alfalfa sprouts	○	○	○	○	○	○	○	○	○	○
R Baked beans	○	○	○	○	○	○	○	○	○	○
S Soy beans, soy bean curd or tofu	○	○	○	○	○	○	○	○	○	○
T Other beans *(include chick peas, lentils etc)*	○	○	○	○	○	○	○	○	○	○
U Pumpkin	○	○	○	○	○	○	○	○	○	○
V Onion or leeks	○	○	○	○	○	○	○	○	○	○
W Garlic *(not garlic tablets)*	○	○	○	○	○	○	○	○	○	○
X Mushrooms	○	○	○	○	○	○	○	○	○	○
Y Zucchini	○	○	○	○	○	○	○	○	○	○

65 Over the LAST 12 MONTHS, how often did you drink beer, wine and/or spirits? *(Mark one on each line)*

If you do NOT drink alcohol, mark here → ○ and go to Q68

Times that you drank:	Never	Less than once per month	1-3 days per month	1 day per week	2 days per week	3 days per week	4 days per week	5 days per week	6 days per week	Every day
A Beer *(low alcohol)*	○	○	○	○	○	○	○	○	○	○
B Beer *(full strength)*	○	○	○	○	○	○	○	○	○	○
C Red wine	○	○	○	○	○	○	○	○	○	○
D White wine *(include sparkling wines)*	○	○	○	○	○	○	○	○	○	○
E Fortified wines, port, sherry etc	○	○	○	○	○	○	○	○	○	○
F Spirits, liqueurs etc	○	○	○	○	○	○	○	○	○	○

Appendix 4: The Australian Recommended Food Score (ARFS) questioners in the ALSWH survey

Questions 64 to 74 are modified from the Cancer Council of Victoria Food Frequency Questionnaire and are used with permission.

This section is about your **usual** eating habits over the **LAST TWELVE MONTHS**. Where possible, give only **one answer per question** for the type of food you eat **most often** (if you can't decide which type you have most often, answer for the types you usually eat).

Q64 How many pieces of FRESH fruit do you usually eat per day?
(Count ½ cup diced fruit, berries or grapes as one piece)

- I don't eat fruit ☐
- Less than 1 piece of fruit per day ☐
- 1 piece of fruit per day ☐
- 2 pieces of fruit per day ☐
- 3 pieces of fruit per day ☐
- 4 pieces of fruit per day ☐
- 5 or more pieces of fruit per day ☐

Q65 How many DIFFERENT vegetables do you usually eat per day?
(Count all types, fresh, frozen or tinned)

- Less than 1 vegetable per day ☐
- 1 vegetable per day ☐
- 2 vegetables per day ☐
- 3 vegetables per day ☐
- 4 vegetables per day ☐
- 5 vegetables per day ☐
- 6 or more vegetables per day ☐

Q66 How many SERVES of vegetables do you usually eat each day?
(A serve = half a cup of cooked vegetables or a cup of salad vegetables)

- None ☐
- 1 serve ☐
- 2 serves ☐
- 3 serves ☐
- 4 serves ☐
- 5 serves or more ☐

Q67 What type of milk do you usually use?

- **a** None ☐
- **b** Full cream milk ☐
- **c** Reduced fat milk ☐
- **d** Skim milk ☐
- **e** Soya milk ☐

Q68 How much milk do you usually use per day?
(Include flavoured milk and milk added to tea, coffee, cereal etc)

- None ☐
- Less than 250ml *(1 large cup or mug)* ☐
- Between 250ml and 500ml *(1-2 cups)* ☐
- Between 500ml and 750ml *(2-3 cups)* ☐
- 750ml *(3 cups)* or more ☐

Q69 What type of bread do you usually eat?

- **a** I don't eat bread ☐
- **b** High fibre white bread ☐
- **c** White bread ☐
- **d** Wholemeal bread ☐
- **e** Rye bread ☐
- **f** Multi-grain bread ☐

Q70 How many slices of bread do you usually eat per day? *(Include all types, fresh or toasted and count one bread roll as 2 slices)*

- Less than 1 slice per day ☐
- 1 slice per day ☐
- 2 slices per day ☐
- 3 slices per day ☐
- 4 slices per day ☐
- 5-7 slices per day ☐
- 8 or more slices per day ☐

Q71 Which spread do you usually put on bread?

- **a** I don't use any fat spread ☐
- **b** Margarine of any kind ☐
- **c** Polyunsaturated margarine ☐
- **d** Monounsaturated margarine ☐
- **e** Butter and margarine blends ☐
- **f** Butter ☐

Q72 On average, how many eggs do you usually eat per week?

- I don't eat eggs ☐
- Less than 1 egg per week ☐
- 1 to 2 eggs per week ☐
- 3 to 5 eggs per week ☐
- 6 or more eggs per week ☐

Q73 What types of cheese do you usually eat?

- **a** I don't eat cheese ☐
- **b** Hard cheeses eg parmesan, romano ☐
- **c** Firm cheeses eg cheddar, edam ☐
- **d** Soft cheeses eg camembert, brie ☐
- **e** Ricotta or cottage cheese ☐
- **f** Cream cheese ☐
- **g** Low fat cheese ☐

Q74a Over the LAST 12 MONTHS, on average, how often did you eat the following foods?
(Mark one on each line)

		Never	Less than once a week	Once a week or more
a	All-Bran™	☐	☐	☐
b	Sultana Bran™, Fibre Plus™, Branflakes™	☐	☐	☐
c	Weet Bix™, Vita Brits™, Weeties™	☐	☐	☐
d	Cornflakes, Nutrigrain™, Special K™	☐	☐	☐
e	Porridge	☐	☐	☐
f	Muesli	☐	☐	☐
g	Rice	☐	☐	☐
h	Pasta or noodles *(include lasagne)*	☐	☐	☐
i	Nuts	☐	☐	☐
j	Peanut butter or peanut paste	☐	☐	☐
k	Vegemite™, Marmite™, Promite™	☐	☐	☐
l	Tinned or frozen fruit *(any kind)*	☐	☐	☐
m	Oranges or other citrus fruit	☐	☐	☐
n	Apples	☐	☐	☐
o	Pears	☐	☐	☐
p	Bananas	☐	☐	☐
q	Watermelon, rockmelon, honeydew etc	☐	☐	☐
r	Pineapple	☐	☐	☐
s	Strawberries	☐	☐	☐
t	Apricots	☐	☐	☐
u	Peaches or nectarines	☐	☐	☐
v	Mango or paw paw	☐	☐	☐
w	Avocado	☐	☐	☐
x	Fruit or vegetable juice	☐	☐	☐
y	Potatoes cooked without fat	☐	☐	☐
z	Tomato sauce, tomato paste or dried tomatoes	☐	☐	☐
aa	Fresh or tinned tomatoes	☐	☐	☐
bb	Peppers *(capsicum)*	☐	☐	☐
cc	Lettuce, endive or other salad greens	☐	☐	☐
dd	Cucumber	☐	☐	☐
ee	Celery	☐	☐	☐
ff	Beetroot	☐	☐	☐
gg	Carrots	☐	☐	☐
hh	Cabbage or Brussels sprouts	☐	☐	☐
ii	Cauliflower	☐	☐	☐
jj	Broccoli	☐	☐	☐
kk	Silverbeet or spinach	☐	☐	☐
ll	Peas	☐	☐	☐
mm	Green beans	☐	☐	☐

		Never	Less than once a week	Once a week or more
nn	Bean sprouts or alfalfa sprouts	☐	☐	☐
oo	Baked beans	☐	☐	☐
pp	Soya beans, soy bean curd or tofu	☐	☐	☐
qq	Other beans *(include chick peas, lentils etc)*	☐	☐	☐
rr	Pumpkin	☐	☐	☐
ss	Onions or leeks	☐	☐	☐
tt	Garlic *(not garlic tablets)*	☐	☐	☐
uu	Mushrooms	☐	☐	☐
vv	Zucchini	☐	☐	☐

Q74b Over the LAST 12 MONTHS, on average, how often did you eat the following foods?
(Mark one on each line)

		Never	Less than once a week	Once a week	2-4 times per week	5 or more times per week
a	Cheese	☐	☐	☐	☐	☐
b	Ice cream	☐	☐	☐	☐	☐
c	Yoghurt	☐	☐	☐	☐	☐
d	Beef	☐	☐	☐	☐	☐
e	Veal	☐	☐	☐	☐	☐
f	Chicken	☐	☐	☐	☐	☐
g	Lamb	☐	☐	☐	☐	☐
h	Pork	☐	☐	☐	☐	☐
i	Fish, steamed, grilled or baked	☐	☐	☐	☐	☐
j	Fish, tinned *(salmon, tuna, sardines etc)*	☐	☐	☐	☐	☐

Q75 How often do you currently smoke cigarettes or any tobacco products?
(Mark one only)

Daily ☐ ← Go to Q76
At least weekly *(but not daily)* ☐ ← Go to Q77
Less often than weekly ☐
Not at all ☐ ← Go to Q78

Q76 If you smoke daily, on average how many cigarettes do you smoke EACH DAY?
PRINT the number in the box

[| |] cigarettes per day ← Go to Q80

Q77 If you smoke, but not daily, on average how many cigarettes do you smoke PER WEEK?
PRINT the number in the box

[| |] cigarettes per week

Q78 Have you ever smoked DAILY?
(Mark one only)

Yes ☐
No ☐ ← If No, go to Q80

Q79 At what age did you finally stop smoking DAILY?
PRINT age in the box

[|] years old

Appendix 5: Statement of contribution and collaboration for Chapter 3

I attest that Research Higher Degree candidate Haya Aljadani contributed to the following paper:

H. Aljadani, A. Patterson, D. Sibbritt and C. Collins (2015). "Diet Quality and Weight Change in Adults Over Time: A Systematic Review of Cohort Studies." Current Nutrition Reports 4(1): 88-101.

In the following way:

Aljadani contributed to the conception and design of the study, completed the literature review, data extraction and drafted the initial paper. Professor Collins, Dr Patterson, and Professor Sibbritt contributed to the study design, interpretation of the results and the drafting and revision of this manuscript within their capacity as PhD supervisors.

Professor Clare Collins Date: 17/7/15

17/7/2015

Dr Amanda Patterson Date:

Professor David Sibbritt Date: 14/07/15

17/7/2015

Mrs Haya Aljadani Date:

Professor Robert Callister

Assistant Dean Research Training Date: 20.07.2015

Appendix 6: Statement of contribution and collaboration for Chapter 5

I attest that Research Higher Degree Candidate Haya Aljadani contributed to the paper entitled:

H. Aljadani, A. Patterson, D. Sibbritt, M. J. Hutchesson, M. E. Jensen and C. E. Collins (2013). "Diet Quality, Measured by Fruit and Vegetable Intake, Predicts Weight Change in Young Women." Journal of Obesity 2013: 10.

In the following way:

Aljadani was responsible for the conception of the study, data analysis, and drafted the initial paper under the supervision of Professor Collins, Dr Patterson, and Professor Sibbritt. All authors contributed to study design, interpretation of the results and the drafting and revision of this manuscript. In addition, Professor Sibbritt assisted in reviewing the statistical analyses.

Professor Clare Collins Date: 17/7/2015

Dr Amanda Patterson Date: 17/7/2015

Professor David Sibbritt Date: 14/07/15

Dr Melinda Hutchesson Date: 17/7/2015

Dr Megan Jensen Date: 17/7/2015

Mrs Haya Aljadani Date: 17/7/2015

Professor Robert Callister

Assistant Dean Research Training Date: 20.07.2015

Appendix 7: Statement of contribution and collaboration for Chapter 6

I attest that Research Higher Degree Candidate (Haya M Aljadani) contributed to the preparation of the paper entitled:

H. Aljadani, L. Al-Oboudi, A. Patterson, D. Sibbritt, and C. E. Collins. "Frequency and variety of healthy foods, fruit and vegetables predicts lower six year weight gain in young women".

In the following way:

Aljadani was responsible for the conception, design of the study, and drafted the initial paper under the supervision of Professor Collins, Dr Patterson and Professor Sibbritt. All authors contributed to study design, interpretation of the results, the drafting and revision of this manuscript.

Professor Clare Collins Date: 17/7/2015

Dr Amanda Patterson Date: 17/7/2015

Professor David Sibbritt Date: 14/07/15

Professor Latifah Al-Oboudi Date

Mrs Haya Aljadani Date: 17/7/2015

Professor Robert Callister
Assistant Dean Research Training Date: 20.07.2015

I attest that Research Higher Degree Candidate (Haya M Aljadani) contributed to the preparation of the paper entitled:

H. Aljadani, L. Al-Oboudi, A. Patterson, D. Sibbritt, and C. E. Collins. "Frequency and variety of healthy foods, fruit and vegetables predicts lower six year weight gain in young women".

In the following way:

Aljadani was responsible for the conception, design of the study, and drafted the initial paper under the supervision of Professor Collins, Dr Patterson and Professor Sibbritt. All authors contributed to study design, interpretation of the results, the drafting and revision of this manuscript.

Professor Clare Collins Date:

Dr Amanda Patterson Date:

Professor David Sibbritt Date:

Professor Latifah Al-Oboudi Date: 22/07/2015

Mrs Haya Aljadani Date:

Professor Robert Callister

Assistant Dean Research Training Date:

Appendix 8: Statement of contribution and collaboration for Chapter 7

I attest that Research Higher Degree Candidate Haya Aljadani contributed to the publication entitled:

H. Aljadani, D. Sibbritt, A. Patterson and C. E. Collins (2013). "The Australian Recommended Food Score did not predict weight gain in middle-aged Australian women during six years of follow-up." The Australian and New Zealand Journal of Public Health 37(4): 322-328.

In the following way:

Aljadani contributed to the study design, data analysis and manuscript preparation. Professor Collins, Dr Patterson, and Professor Sibbritt contributed to the study design, interpretation of the results and the drafting and revision of this manuscript within their capacity as PhD supervisors.

Professor Clare Collins Date: 17/7/2015

Dr Amanda Patterson Date: 17/7/2015

Professor David Sibbritt Date: 14/07/15

Mrs Haya Aljadani Date: 17/7/2015

Professor Robert Callister
Assistant Dean Research Training Date: 20.07.2015

Appendix 9: Statement of contribution and collaboration for Chapter 8

I attest that Research Higher Degree Candidate (Haya Aljadani) contributed to the publication entitled:

H. Aljadani, A. Patterson, D. Sibbritt and C. E. Collins (2013). " Diet quality and six year risk of overweight and obesity amongst mid-age Australian women who were initially in the healthy weight range". It is under review in the Health Promotion Journal of Australia.

In the following way:

Aljadani contributed to the conception and design of the study, data analysis, and drafted the initial paper. Professor Collins, Dr Patterson, and Professor Sibbritt contributed to the study design, interpretation of the results and the drafting and revision of this manuscript within their capacity as PhD supervisors.

Professor Clare Collins Date: 17/7/2015

17/7/2015

Dr Amanda Patterson Date:

Professor David Sibbritt Date: 14/07/15

17/7/2015

Mrs Haya Aljadani Date:

Professor Robert Callister

Assistant Dean Research Training Date: 20.07.2015

Appendix 10: Statement of contribution and collaboration for Chapter 9

I attest that Research Higher Degree Candidate Haya Aljadani contributed to the paper/publication entitled:

H. Aljadani, A. Patterson, D. Sibbritt and C. E. Collins. "Prospective changes in diet quality in mid-age Australian women and its association with weight change during nine years of follow-up." Under review in the J of Public Health, It was submitted on the 29th of July 2015.

In the following way:

Aljadani contributed to the conception and design of the study, data analysis and drafted the initial paper study. Professor Collins, Dr Patterson, and Professor Sibbritt contributed to the study design, interpretation of the results and the drafting and revision of this manuscript within their capacity as PhD supervisors.

Professor Clare Collins Date: 17/7/2015

Dr Amanda Patterson Date: 17/7/2015

Professor David Sibbritt Date: 14/07/15

Mrs Haya Aljadani Date: 17/7/2015

Professor Robert Callister

Assistant Dean Research Training Date: 20.07.2015

Appendix11: Statement of contribution and collaboration for the 2013 systematic review reported as appendix 1

I attest that Research Higher Degree Candidate Haya M Aljadani contributed to the paper/publication entitled:

H. Aljadani, A. Patterson, D. Sibbritt and C. E. Collins (2013). "The association between dietary patterns and weight change in adults over time: A systematic review of studies with follow up." JBI Database of Systematic Reviews and Implementation Reports 11(8).

In the following way:

Aljadani was responsible for the conception and design of the study, completed the literature review, data extraction and drafted the initial paper. Professor Collins, Dr Patterson, and Professor Sibbritt contributed to the study design, interpretation of the results and the drafting and revision of this manuscript within their capacity as PhD supervisors.

Professor Clare Collins Date: 17/7/2015

Dr Amanda Patterson Date: 17/7/2015

Professor David Sibbritt Date: 14/07/15

Mrs Haya Aljadani Date: 17/7/2015

Professor Robert Callister
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Appendix 12: Statement of contribution and collaboration for the book chapter reported as appendix 2

I attest that Research Higher Degree Candidate (Haya M Aljadani) contributed to the paper/publication entitled:

H. Aljadani, A. Patterson, D. Sibbritt and C. E. Collins (2013). The association between diet quality and weight change in adults over time: A systematic review in perspective studies. Diet quality- an evidence approach. L. L. a. V. P. Victor R Preedy. New York, Springer. 2: 3 - 27.

In the following way:

Aljadani was responsible for the conception and design of the study, completed the literature review, data extraction and drafted the initial paper under the supervision Professor Collins, Dr Patterson, and Professor Sibbritt. All Co-authors contributed to the study design, interpretation of the results and the drafting and revision of this manuscript within their capacity as PhD supervisors.

Professor Clare Collins Date: 17/7/2015

Dr Amanda Patterson Date: 17/7/2015

Professor David Sibbritt Date: 14/07/15

Mrs Haya Aljadani Date: 17/7/2015

Professor Robert Callister
Assistant Dean Research Training Date: 20.07.2015

References:

Abo, S. 2012. Australian health survey: first results, 2011-12. *Canberra: Australian Bureau of Statistics*.

Abrams, S. A., Griffin, I. J. & Davila, P. M. 2002. Calcium and zinc absorption from lactose-containing and lactose-free infant formulas. *The American Journal of Clinical Nutrition,* 76**,** 442-446.

Access Economics. 2008. The growing cost of obesity in 2008: three years on. Available: http://www.diabetesaustralia.com.au/PageFiles/7830/FULLREPORTGrowingCostOfObesity2008.pdf.

Adamson, L., Brown, W., Byles, J., Chojenta, C., Dobson, A., et al. 2007. Women's weight : findings from the Australian longitudinal study on women's health: The University of Newcastle;The University of Queensland. Available: http:wwwalswhorgau.

Aljadani, H., Patterson, A., Sibbritt, D. & Collins, C. 2015. Diet Quality and Weight Change in Adults Over Time: A Systematic Review of Cohort Studies. *Current Nutrition Reports,* 4**,** 88-101.

Aljadani, H., Patterson, A., Sibbritt, D. & Collins, C. E. 2013a. The association between dietary patterns and weight change in adults over time: a systematic review of studies with follow up. *JBI Database of Systematic Reviews and Implemntation Reports,* 11.

Aljadani, H., Patterson, A., Sibbritt, D., Hutchesson, M. J., Jensen, M. E., et al. 2013b. Diet Quality, Measured by Fruit and Vegetable Intake, Predicts Weight Change in Young Women. *Journal of Obesity,* 2013**,** 10.

Aljadani, H. M., Patterson, A., Sibbritt, D. & Collins, C. E. 2013c. The association between diet quality and weight change in adults over time: a systematic review of prospective cohort studie. *In:* VICTOR R PREEDY, L. L. A. V. P. (ed.) *Diet quality- an evidence approach.* New York: Springer.

Aljadani, H. M., Sibbritt, D., Patterson, A. & Collins, C. E. 2013d. The Australian Recommended Food Score did not predict weight gain in mid-age Australian women during six year of follow-up. *The Australian and New Zealand Journal of Public Health* 37**,** 322-28.

Appel, L. J. 2003. Lifestyle Modification as a Means to Prevent and Treat High Blood Pressure. *Journal of the American Society of Nephrology,* 14**,** S99-S102.

Arabshahi, S., Van Der Pols, J. C., Williams, G. M., Marks, G. C. & Lahmann, P. H. 2012. Diet quality and change in anthropometric measures: 15-year longitudinal study in Australian adults. *British Journal of Nutrition,* 107**,** 1376-1385.

Arvaniti, F. & Panagiotakos, D. B. 2008. Healthy Indexes in Public Health Practice and Research: A Review. *Critical Reviews in Food Science and Nutrition,* 48**,** 317-327.

Asghari, G., Mirmiran, P., Rashidkhani, B., Asghari-Jafarabadi, M., Mehran, M., et al. 2012. The association between diet quality indices and obesity: Tehran Lipid and Glucose Study. *Arch Iran Med.,* 15**,** 599-605.

Assmann, K. E., Lassale, C., Galan, P., Hercberg, S. & Kesse-Guyot, E. 2014. Dietary Quality and 6-Year Anthropometric Changes in a Sample of French Middle-Aged Overweight and Obese Adults. *PLOs,* 9.

Au, N., Hauck, K. & Hollingsworth, B. 2012. Employment, work hours and weight gain among middle-aged women. *International Journal of Obesity*.

Australian Bureau of Statistics. 2005. *4719.0 - Overweight and Obesity in Adults, Australia* [Online]. Available: http://www.abs.gov.au/ausstats.

Australian Bureau of Statistics. 2008. *Overweight and obesity in adults, Australia* [Online]. Available: http://www.abs.gov.au.

Australian Government 2013a. *Australian Recommendations of the Clinical Management of Overweight and Obesity.* Canberra, National Health and Medical Research Council.

Australian Government 2013b. *Nutrient Reference Values for Australia and New Zealand: Including Recommended Dietary Intakes*. Canberra, Department of Health and Ageing, National Health and Medical Research Council.

Australian Health Survey 2012. *National Health Survey: First Results. KeyFindings* Canberra, Australian Burean of Statistics.

Australian Institute of Health and Welfare 2007. Australian Diet Quality Index Project. Canberra: AIHW

Australian Institute of Health and Welfare. 2011. National Health Priority Areas.

Australian Institute of Health and Welfare. 2014. *Causes of overweight and obesity.* [Online]. Available: http://www.aihw.gov.au/overweight-and-obesity/causes/ [Accessed 30 Nov 2014].

Australian Longitudinal Study on Women's Health. 2015. *Study Overview* [Online]. Available: http://www.alswh.org.au/ [Accessed 3 May 2015.

Azadbakht, L. & Esmaillzadeh, A. 2011. Dietary diversity score is related to obesity and abdominal adiposity among Iranian female youth. *Public Health Nutrition,* 14**,** 62-69.

Ball, K., Brown, W. & Crawford, D. 2002. Who does not gain weight? Prevalence and predictors of weight maintenance in young women. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity,* 26**,** 1570-8.

Ball, K., Mishra, G. D. & Crawford, D. 2003. Social factors and obesity: an investigation of the role of health behaviours. *Int J Obes Relat Metab Disord,* 27**,** 394-403.

Ball, K., Mishra, G. D., Thane, C. W. & Hodge, A. 2004. How well do Australian women comply with dietary guidelines? *Public Health Nutrition,* 7**,** 443-452.

Barbaresko, J., Koch, M., Schulze, M. B. & Nöthlings, U. 2013. Dietary pattern analysis and biomarkers of low-grade inflammation: a systematic literature review. *Nutrition Reviews,* 71**,** 511-527.

Bazelmans, C., De Henauw, S., Matthys, C., Dramaix, M., Kornitzer, M., et al. 2006. Healthy Food and Nutrient Index and All Cause Mortality. *European Journal of Epidemiology,* 21**,** 145-152.

Beunza, J.-J., Toledo, E., Hu, F. B., Bes-Rastrollo, M., Serrano-Martínez, M., et al. 2010. Adherence to the Mediterranean diet, long-term weight change, and incident overweight or obesity: the Seguimiento Universidad de Navarra (SUN) cohort. *The American journal of clinical nutrition*.

Bezerra, I. & Sichieri, R. 2011. Household food diversity and nutritional status among adults in Brazil. *International Journal of Behavioral Nutrition and Physical Activity,* 8**,** 1-7.

Black, A. E. 2000. Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity,* 24**,** 1119-1130.

Blümel, J. E., Castelo-Branco, C., Rocangliolo, M. E., Bifa, L., Tacla, X., et al. 2001. Changes in body mass index around menopause: a population study of Chilean woman. *Menopause,* 8**,** 239-244.

Blumfield, M., Hure, A., Macdonald-Wicks, L., Patterson, A., Smith, R., et al. 2011. Disparities exist between National food group recommendations and the dietary intakes of women. *BMC Women's Health,* 11**,** 37.

Boeing, H., Bechthold, A., Bub, A., Ellinger, S., Haller, D., et al. 2012. Critical review: vegetables and fruit in the prevention of chronic diseases. *European Journal of Nutrition,* 51**,** 637-663.

Boggs, D. A., Rosenberg, L., Rodríguez-Bernal, C. L. & Palmer, J. R. 2013. Long-Term Diet Quality Is Associated with Lower Obesity Risk in Young African American Women with Normal BMI at Baseline. *The Journal of Nutrition,* 143**,** 1636-1641.

Brown, W., Bryson, L., Byles, J., Dobson, A., Lee, C., et al. 1998. Women's Health Australia: recruitment for a national longitudinal cohort study. *Women & Health,* 28**,** 23 - 40.

Brown, W., Bryson, L., Byles, J., Dobson, A., Manderson, L., et al. 1996. Women's Health Australia: Establishment of The Australian Longitudinal Study on Women's Health. *Journal of Women's Health,* 5**,** 467-472.

Brown, W. J. & Bauman, A. E. 2000. Comparison of estimates of population levels of physical activity using two measures. *Australian and New Zealand journal of public health,* 24**,** 520-525.

Brown, W. J. & Trost, S. G. 2003. Life transitions and changing physical activity patterns in young women. *American Journal of Preventive Medicine,* 25**,** 140-143.

Brown, W. J., Trost, S. G., Bauman, A., Mummery, K. & Owen, N. 2004. Test-retest reliability of four physical activity measures used in population surveys. *Journal of Science and Medicine in Sport,* 7**,** 205-215.

Brown, W. J., Williams, L., Ford, J. H., Ball, K. & Dobson, A. J. 2005. Identifying the energy gap: magnitude and determinants of 5-year weight gain in midage women. *Obesity research,* 13**,** 1431-41.

Buckland, G., Bach, A. & Serra-Majem, L. 2008. Obesity and the Mediterranean diet: a systematic review of observational and intervention studies. *Obesity Reviews,* 9**,** 582-593.

Buijsse, B., Feskens, E. J., Schulze, M. B., Forouhi, N. G., Wareham, N. J., et al. 2009. Fruit and vegetable intakes and subsequent changes in body weight in European populations: results from the project on Diet, Obesity, and Genes (DiOGenes). *American Journal of Clinical Nutrition,* 90**,** 202-209.

Burke, B. B., Va. Kirkwood, Sb. Stuart, Hc. 1943. Nutrition Studies During Pregnancy. *American Journal of Obstetrics and Gynecology,* 46**,** 38-52.

Burton, N. W., Brown, W. & Dobson, A. 2010. Accuracy of body mass index estimated from self-reported height and weight in mid-aged Australian women. *Australian and New Zealand journal of public health,* 34**,** 620-3.

Cameron, A. J., Dunstan, D. W., Owen, N., Zimmet, P. Z., Barr, E. L., et al. 2009. Health and motality consequences of abdominal obesity : Evidence from AusDiab study. *Medical Journal of Australia,* 191**,** 202-208.

Centers for Disease Control and Prevention. 2004. *Prevalence of overweight and obesity among adults with diagnosed diabetes—United States* [Online]. Available: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5345a2.htm.

Chou, S.-Y., Grossman, M. & Saffer, H. 2004. An economic analysis of adult obesity: results from the Behavioral Risk Factor Surveillance System. *Journal of Health Economics,* 23**,** 565-587.

Colagiuri, S., Lee, C. M. Y., Colagiuri, R., Magliana, D., Shaw, J. E., et al. 2010. The cost of overweight and obesity in Australia. *Medical Journal of Australia,* 192**,** 260-264.

Collins, C., Burrows, T., Rollo, M., Boggess, M., Watson, J., et al. 2015. The Comparative Validity and Reproducibility of a Diet Quality Index for Adults: The Australian Recommended Food Score. *Nutrients,* 7**,** 785-798.

Collins, C. E., Patterson, A. & Fitzgerald, D. 2011. Higher Diet Quality Does Not Predict Lower Medicare Costs but Does Predict Number of Claims in Mid-Aged Australian Women. *Nutrients,* 3**,** 40-48.

Collins, C. E., Young, A. F. & Hodge, A. 2008. Diet quality is associated with higher nutrient intake and self-rated health in mid-aged women. *Journal of the American College of Nutrition,* 27**,** 146-157.

Committee on Diet and Health, F. a. N. B. 1989. Diet and health: implications for reducing chronic disease Washington, DC: National Research Council.

Compernolle, S., De Cocker, K., Abbott, G., Verloigne, M., Cardon, G., et al. 2015. Do sedentary behaviors mediate associations between socio-demographic characteristics and BMI in women living in socio-economically disadvantaged neighborhoods? *The International Journal of Behavioral Nutrition and Physical Activity,* 12**,** 48.

Compston, J., Watts, N., Chapurlat, R., Cooper, C., Boonen, S., et al. Obesity Is Not Protective against Fracture in Postmenopausal Women: GLOW. *AMERICAN JOURNAL OF MEDICINE; NOV, 2011, 124 11, p1043-p1050, 8p*.

Dahl, A. K., Hassing, L. B., Fransson, E. I. & Pedersen, N. L. 2010. Agreement between self-reported and measured height, weight and body mass index in old age—a longitudinal study with 20 years of follow-up. *Age and Ageing,* 39**,** 445-451.

De Irala-Estevez, J. & Groth, M. 2000. A systematic review of socio-economic differences in food habits in Europe: consumption of fruit and vegetables. *European Journal of Clinical Nutrition,* 54**,** 706.

De Jersey, S. J., Nicholson, J. M., Callaway, L. K. & Daniels, L. A. 2012. A prospective study of pregnancy weight gain in Australian women. *Australian and New Zealand Journal of Obstetrics and Gynaecology,* 52**,** 545-551.

Department of Primary Industries and Energy and Department of Human Services and Health 1994. Rural, remote and metropolitan areas classification: 1991 Census edition. Canberra: Australian Government Publishing Service.

Devaux, M. & Sassi, F. 2013. Social inequalities in obesity and overweight in 11 OECD countries. *The European Journal of Public Health,* 23**,** 464-469.

Diaz, M. E. 2002. Hypertension and obesity. *Journal of human hypertension,* 16 Suppl 1**,** S18-22.

Dietary Guidelines for Australian Adults. 2003. *A Guide to Healthy Eating* [Online]. Canberra, Australia. Available: http://www.health.gov.au/internet/main/publishing.nsf/Content/health-pubhlth-strateg-food-guide-index.htm [Accessed 20 Nov 2011.

Dietary Guidelines for Australian Adults 2013. "A Guide to Healthy Eating." *In:* HEALTH (ed.). Canberra.

Ebrahimi-Mameghani, M., Scott, J. A., Der, G., Lean, M. E. J. & Burns, C. M. 2007. Changes in weight and waist circumference over 9 years in a Scottish population. *Eur J Clin Nutr,* 62**,** 1208-1214.

Eckert, D. J. & Malhotra, A. 2008. Pathophysiology of Adult Obstructive Sleep Apnea. *Proc Am Thorac Soc,* 5**,** 144-153.

Edefonti, V., Randi, G., La Vecchia, C., Ferraroni, M. & Decarli, A. 2009. Dietary patterns and breast cancer: a review with focus on methodological issues. *Nutrition Reviews,* 67**,** 297-314.

Ekelund, U., Ward, H. A., Norat, T., Luan, J. A., May, A. M., et al. 2015. Physical activity and all-cause mortality across levels of overall and abdominal adiposity in European men and women: the European Prospective Investigation into Cancer and Nutrition Study (EPIC). *American Journal of Clinical Nutrition,* 101**,** 613-621.

Ello-Martin, J. A., Roe, L. S., Ledikwe, J. H., Beach, A. M. & Rolls, B. J. 2007. Dietary energy density in the treatment of obesity: a year-long trial comparing 2 weight-loss diets. *The American journal of clinical nutrition,* 85**,** 1465-1477.

Fernandez, E., D'avanzo, B., Negri, E., Franceschi, S. & La Vecchia, C. 1996. Diet diversity and the risk of colorectal cancer in northern Italy. *Cancer Epidemiology Biomarkers & Prevention,* 5**,** 433-436.

Fernandez, E., Negri, E., La Vecchia, C. & Franceschi, S. 2000. Diet Diversity and Colorectal Cancer. *Preventive Medicine,* 31**,** 11-14.

Fine, J. T., Colditz, G. A., Coakley, E. H. & Et Al. 1999. A prospective study of weight change and health-related quality of life in women. *JAMA,* 282**,** 2136-2142.

Fitzgerald, A. L., Dewar, R. A. & Veugelers, P. J. 2002. Diet quality and cancer incidence in Nova Scotia, Canada. *Nutrition & Cancer,* 43**,** 127-132.

Flegal, K. M. 1999. The obesity epidemic in children and adults: current evidence and research issues. *Medicine & Science in Sports & Exercise,* 31**,** S509.

Forget, G., Doyon, M., Lacerte, G., Labonté, M., Brown, C., et al. 2013. Adoption of American Heart Association 2020 Ideal Healthy Diet Recommendations Prevents Weight Gain in Young Adults. *Journal of the Academy of Nutrition and Dietetics,* 113**,** 1517-1522.

Fransen, H. P. & Ocké, M. C. 2008. Indices of diet quality. *Current Opinion in Clinical Nutrition & Metabolic Care,* 11**,** 559-565 10.1097/MCO.0b013e32830a49db.

Fung, T. T., Hu, F. B., Mccullough, M. L., Newby, P. K., Willett, W. C., et al. 2006. Diet Quality Is Associated with the Risk of Estrogen Receptor–Negative Breast Cancer in Postmenopausal Women. *The Journal of Nutrition,* 136**,** 466-472.

Galliano, D. & Bellver, J. 2013. Female obesity: short- and long-term consequences on the offspring. *Gynecological Endocrinology,* 29**,** 626-631.

George, S. M., Ballard-Barbash, R., Manson, J. E., Reedy, J., Shikany, J. M., et al. 2014. Comparing Indices of Diet Quality With Chronic Disease Mortality Risk in Postmenopausal Women in the Women's Health Initiative Observational Study: Evidence to Inform National Dietary Guidance. *American Journal of Epidemiology*.

Gerber, M. 2001. The Comprehensive Approach to Diet: A Critical Review. *The Journal of Nutrition,* 131**,** 3051S-3055S.

Gerber, M. J., Scali, J. D., Michaud, A., Durand, M. D., Astre, C. M., et al. 2000. Profiles of a Healthful Diet and its Relationship to Biomarkers in a Population Sample from Mediterranean Southern France. *Journal of the American Dietetic Association,* 100**,** 1164-1171.

Grafenauer, S. J., Tapsell, L. C., Beck, E. J. & Batterham, M. J. 2014. Development and validation of a Food Choices Score for use in weight-loss interventions. *British Journal of Nutrition,* 111**,** 1862-1870.

Greco, E. A., Fornari, R., Rossi, F., Santiemma, V., Prossomariti, G., et al. 2010. Is obesity protective for osteoporosis? Evaluation of bone mineral density in individuals with high body mass index. *International Journal of Clinical Practice,* 64**,** 817-820.

Grønbæk, M. 2009. The positive and negative health effects of alcohol- and the public health implications. *Journal of Internal Medicine,* 265**,** 407-420.

Guelinckx, I., Devlieger, R., Beckers, K. & Vansant, G. 2008. Maternal obesity: pregnancy complications, gestational weight gain and nutrition. *Obesity Reviews,* 9**,** 140-150.

Guenther, P. M., Casavale, K. O., Reedy, J., Kirkpatrick, S. I., Hiza, H. a. B., et al. 2013. Update of the Healthy Eating Index: HEI-2010. *Journal of the Academy of Nutrition and Dietetics,* 113**,** 569-580.

Guenther, P. M., Reedy, J., Krebs-Smith, Reeve, B. B. & Basiotis, P. P. 2008. Development of the Healthy Eating Index-2005. *Journal of the American Dietetic Association.* USA.

Guenther, P. M., Reedy, J., Krebs-Smith, S.M., R., B.B., & Basiotis, P. P. 2007. Development and Evaluation of the Healthy Eating Index-2005. Available: http://www.cnpp.usda.gov/HealthyEatingIndex.htm. [Accessed 10 sep 2014].

Guthrie, J. R., Dennerstein, L. & Dudley, E. C. 1999. Weight gain and the menopause: a 5-year prospective study. *Climacteric,* 2**,** 205-211.

Haby, M. M., Markwick, A., Peeters, A., Shaw, J. & Vos, T. 2012. Future predictions of body mass index and overweight prevalence in Australia, 2005–2025. *Health Promotion International,* 27**,** 250-260.

Haines, P. S., Siega-Riz, A. M. & Popkin, B. M. 1999. The Diet Quality Index Revised: A Measurement Instrument for Populations. *Journal of the American Dietetic Association,* 99**,** 697-704.

Hall, J. N., Moore, S., Harper, S. B. & Lynch, J. W. Global Variability in Fruit and Vegetable Consumption. *American Journal of Preventive Medicine,* 36**,** 402-409.e5.

Hann, C. S., Rock, C. L., King, I. & Drewnowski, A. 2001. Validation of the Healthy Eating Index with use of plasma biomarkers in a clinical sample of women. *The American journal of clinical nutrition,* 74**,** 479-486.

Harnack, L., Nicodemus, K., Jacobs, D. R. & Folsom, A. R. 2002. An evaluation of the Dietary Guidelines for Americans in relation to cancer occurrence. *The American journal of clinical nutrition,* 76**,** 889-896.

Haya Aljadani & Amanda Patterson, D. S., Clare E. Collins. 2015. Diet Quality and Weight Change in Adults Over Time: A Systematic Review of Cohort Studies. *Current Nutrition Reports* [Online], 10.1007/s13668-014-0115-1.

He, F. J., Nowson, C. A., Lucas, M. & Macgregor, G. A. 2007. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *J Hum Hypertens,* 21**,** 717-728.

Hiza, H. a. B., Casavale, K. O., Guenther, P. M. & Davis, C. A. 2013. Diet Quality of Americans Differs by Age, Sex, Race/Ethnicity, Income, and Education Level. *Journal of the Academy of Nutrition and Dietetics,* 113**,** 297-306.

Hodge, A., Patterson, A., Brown, W., Ireland, P. & Giles, G. 2000a. The Anti Cancer Council of Victoria FFQ: relative validity of nutrient intakes compared with weighed food records in young to middle-aged women in a study of iron supplementation. *Australian and New Zealand journal of public health,* 24**,** 576 - 583.

Hodge, A., Patterson, A. J., Brown, W. J., Ireland, P. & Giles, G. 2000b. The Anti Cancer Council of Victoria FFQ: relative validity of nutrient intakes compared with weighed food records in young to middle-aged women in a study of iron supplementation. *Australian and New Zealand journal of public health,* 24**,** 576-83.

Hsiao, P. Y., Jensen, G. L., Hartman, T. J., Mitchell, D. C., Nickols-Richardson, S. M., et al. 2011. Food Intake Patterns and Body Mass Index in Older Adults: A Review of the Epidemiological Evidence. *Journal of Nutrition in Gerontology and Geriatrics,* 30**,** 204-224.

Hu, D., Hannah, J., Gray, R. S., Jablonski, K. A., Henderson, J. A., et al. 2000. Effects of obesity and body fat distribution on lipids and lipoproteins in nondiabetic American Indians: The Strong Heart Study. *Obesity,* 8**,** 411-421.

Hu, F. B. 2002. Dietary pattern analysis: a new direction in nutritional epidemiology. *Current Opinion in Lipidology,* 13**,** 3-9.

Hu, F. B. 2003. Overweight and obesity in women: Health risks and consequences. *Journal of Womens Health,* 12**,** 163-172.

Huijbregts, P., Feskens, E., Räsänen, L., Fidanza, F., Nissinen, A., et al. 1997. *Dietary pattern and 20 year mortality in elderly men in Finland, Italy, and the Netherlands: longitudinal cohort study*.

Huijbregts, P. P. C. W. & Feskens, E. J. M. 1998. Dietary patterns and cognitive function in elderly men in Finland, Italy and the Netherlands. *European Journal of Clinical Nutrition,* 52**,** 826.

Hure, A., Young, A., Smith, R. & Collins, C. 2009. Diet and pregnancy status in Australian women. *Public Health Nutrition,* 12**,** 853-861.

Hutchesson, M. J., Hulst, J. & Collins, C. E. Weight Management Interventions Targeting Young Women: A Systematic Review. *Journal of the Academy of Nutrition and Dietetics*.

Ireland, P., Jolley, D., Giles, G., O'dea, K., Powles, J., et al. 1994. Development of the Melbourne FFQ: a food frequency questionnaire for use in an Australian prospective study involving an ethnically diverse *Asia Pacific Journal of Clinical Nutrition,* 3**,** 19 - 31.

Jain, D., Khuteta, R., Chaturvedi, V. & Khuteta, S. 2012. Effect of Body Mass Index on Pregnancy Outcomes in Nulliparous Women Delivering Singleton Babies: Observational Study. *The Journal of Obstetrics and Gynecology of India,* 62**,** 429-431.

Jakicic, J. M. & Rogers, R. J. 2013. The Importance of Physical Activity for Losing Weight, Maintaining Weight, and Preventing Weight Gain. *President's Council on Physical Fitness & Sports Research Digest,* 14**,** 1-9.

Jancey, J., Dos Remedios Monteiro, S., Dhaliwal, S., Howat, P., Burns, S., et al. 2014. Dietary outcomes of a community based intervention for mothers of young children: a randomised controlled trial. *International Journal of Behavioral Nutrition and Physical Activity,* 11**,** 120.

Jung, U. J. & Choi, M.-S. 2014. Obesity and Its Metabolic Complications: The Role of Adipokines and the Relationship between Obesity, Inflammation, Insulin Resistance, Dyslipidemia and Nonalcoholic Fatty Liver Disease. *International Journal of Molecular Sciences,* 15**,** 6184-6223.

Jungheim, E. S., Travieso, J. L. & Hopeman, M. M. 2013. Weighing the impact of obesity on female reproductive function and fertility. *Nutrition Reviews,* 71**,** S3-S8.

Kahn, H. S., Tatham, L. M., Rodriguez, C., Calle, E. E., Thun, M. J., et al. 1997. Stable behaviors associated with adults' 10-year change in body mass index and likelihood of gain at the waist. *American Journal of Public Health,* 87**,** 747-754.

Kaluza, J., Hakansson, N., Brzozowska, A. & Wolk, A. 2007. Diet quality and mortality: a population-based prospective study of men. *European Journal of Clinical Nutrition,* 63**,** 451-457.

Kant, A. K. 1996. Indexes of Overall Diet Quality: A Review. *Journal of the American Dietetic Association,* 96**,** 785-791.

Kant, A. K. 2004. Dietary patterns and health outcomes. *Journal of the American Dietetic Association,* 104**,** 615-635.

Kant, A. K. 2010. Dietary patterns: biomarkers and chronic disease risk. *Applied Physiology, Nutrition & Metabolism,* 35**,** 199-206.

Kant, A. K. & Graubard, B. I. 2005. A Comparison of Three Dietary Pattern Indexes for Predicting Biomarkers of Diet and Disease. *Journal of the American College of Nutrition,* 24**,** 294-303.

Kant, A. K., Schatzkin, A., Graubard, B. I. & Schairer, C. 2000. A prospective study of diet quality and mortality in women. *JAMA,* 283**,** 2109-2115.

Kant, A. K. & Thompson, F. E. 1997. Measures of overall diet quality from a food frequency questionnaire: National Health Interview Survey, 1992. *Nutrition Research,* 17**,** 1443-1456.

Kawachi, I. 1999. Physical and psychological consequences of weight gain. *Journal of Clinical Psychiatry,* 60**,** 5-9.

Kennedy, E. 2004. Dietary Diversity, Diet Quality, and Body Weight Regulation. *Nutrition Reviews,* 62**,** S78-S81.

Kennedy, E. T., Ohls, J., Carlson, S. & Fleming, K. 1995. The Healthy Eating Index: Design and Applications. *Journal of the American Dietetic Association,* 95**,** 1103-1108.

Kim, J. Y., Yang, Y. J., Yang, Y. K., Oh, S. Y., Hong, Y. C., et al. 2011. Diet quality scores and oxidative stress in Korean adults. *European Journal of Clinical Nutrition,* 65**,** 1271-1278.

Kim, S., Haines, P. S., Siega-Riz, A. M. & Popkin, B. M. 2003. The Diet Quality Index-International (DQI-I) Provides an Effective Tool for Cross-National Comparison of Diet Quality as Illustrated by China and the United States. *The Journal of Nutrition,* 133**,** 3476-3484.

Kimokoti, R. W., Newby, P. K., Gona, P., Zhu, L., Jasuja, G. K., et al. 2010. Diet quality, physical activity, smoking status, and weight fluctuation are associated with weight change in women and men. *Journal of Nutrition,* 140**,** 1287-1293.

Kivimäki, M., Batty, G. D., Singh-Manoux, A., Nabi, H., Sabia, S., et al. 2009. *Association between common mental disorder and obesity over the adult life course*.

Knoops, K. T. B., Groot De, L. C., Fidanza, F., Alberti-Fidanza, A., Kromhout, D., et al. 2006. Comparison of three different dietary scores in relation to 10-year mortality in elderly European subjects: the HALE project. *Eur J Clin Nutr,* 60**,** 746-755.

Koh, G. A., Scott, J. A., Woodman, R. J., Kim, S. W., Daniels, L. A., et al. 2014. Maternal feeding self-efficacy and fruit and vegetable intakes in infants. Results from the SAIDI study. *Appetite***,** 44.

Kolotikin, R. L., Meter, K. & Williams, G. R. 2001. Quality of life and obesity. *Obesity Reviews,* 2**,** 291-229.

Kopelman, P. G. 2000. Obesity as a medical problem. *Nature,* 404**,** 635-643.

Krauss, R. M., Winston, M., Fletcher, B. J. & Grundy, S. M. 1998. Obesity : Impact on Cardiovascular Disease. *Circulation,* 98**,** 1472-1476.

Lagiou, P., Trichopoulos, D., Sandin, S., Lagiou, A., Mucci, L., et al. 2006. Mediterranean dietary pattern and mortality among young women: a cohort study in Sweden. *British Journal of Nutrition,* 96**,** 384-392.

Lamichhane, A. P., Liese, A. D., Urbina, E. M., Crandell, J. L., Jaacks, L. M., et al. 2014. Associations of dietary intake patterns identified using reduced rank regression with markers of arterial stiffness among youth with type 1 diabetes. *Eur J Clin Nutr*.

Lane, M., Zander-Fox, D. L., Robker, R. L. & Mcpherson, N. O. Peri-conception parental obesity, reproductive health, and transgenerational impacts. *Trends in Endocrinology & Metabolism,* 26**,** 84-90.

Lara, J. J., Scott, J. A. & Lean, M. E. J. 2004. Intentional mis-reporting of food consumption and its relationship with body mass index and psychological scores in women. *Journal of Human Nutrition & Dietetics,* 17**,** 209-18.

Larsson, B., Svardsudd, K., Welin, L., Wilhelmsen, L., Bjorntorp, P., et al. 1984. Abdominal adipose tissue distribution, obesity, and risk of cardiovascular disease and death: 13 year follow up of participants in the study of men born in 1913. *British Medical Journal,* 288**,** 1401-4.

Lassale, C., Fezeu, L., Andreeva, V. A., Hercberg, S., Kengne, A. P., et al. 2012. Association between dietary scores and 13-year weight change and obesity risk in a French prospective cohort. *International Journal of Obesity*.

Lavoie, M.-E., Faraj, M., Strychar, I., Doucet, É., Brochu, M., et al. 2013. Synergistic associations of physical activity and diet quality on cardiometabolic risk factors in overweight and obese postmenopausal women. *British Journal of Nutrition,* 109**,** 605-614.

Lazarou, C. & Newby, P. K. 2011. Use of dietary indexes among Children in developed countries. *Advances in Nutrition,* 2**,** 295-303.

Ledoux, T. A., Hingle, M. D. & Baranowski, T. 2011. Relationship of fruit and vegetable intake with adiposity: a systematic review. *Obesity Reviews,* 12**,** e143-e150.

Lee, C., Dobson, A. J., Brown, W. J., Bryson, L., Byles, J., et al. 2005. Cohort Profile: The Australian Longitudinal Study on Women's Health. *International Journal of Epidemiology,* 34**,** 987-991.

Lee, D. C., Kim, K. C., Shin, D. H., Lee, S. Y. & Im, J. A. 2010. Relation between obesity and bone mineral density and vertebral fractures in Korean postmenopausal women. *Yonsei Medical Journal,* 51**,** 857-863.

Lewis, J., Milligan, G. & Hunt, A. 1995. NUTTAB95 Nutrient Data Table for Use in Australia.

Lightwood, J., Bibbins-Domingo, K., Coxson, P., Wang, C., Williams, L., et al. 2009. Forecasting the future economic burden of current adolescent overweight: An estimate of the Coronary Heart Disease Policy Model. *American Journal of Public Health,* 99**,** 2230-2237.

Lijing, L. Y., Daviglus, M. L., Liu, K., Stamler, J., Wang, R., et al. 2006. Midlife body mass index and hospitalization and mortality in older age. *JAMA,* 295**,** 290-298.

Lorefat, B., Ganowiak, W., Wissing, U., Granerus, A. K. & Unosson, M. 2006. Food habits and intake of nutrients in elderly patients with Parkinson's disease. *Gerontology,* 52**,** 160-8.

Macfarlane, A., Abbott, G., Crawford, D. & Ball, K. 2010. Personal, social and environmental correlates of healthy weight status amongst mothers from socioeconomically disadvantaged neighborhoods: findings from the READI study. *International Journal of Behavioral Nutrition and Physical Activity,* 7**,** 23.

Mai, V., Kant, A. K., Flood, A., Lacey, J. V., Schairer, C., et al. 2005. Diet quality and subsequent cancer incidence and mortality in a prospective cohort of women. *International Journal of Epidemiology,* 34**,** 54-60.

Mamun, A. A., Mannan, M. & Doi, S. a. R. 2014. Gestational weight gain in relation to offspring obesity over the life course: a systematic review and bias-adjusted meta-analysis. *Obesity Reviews,* 15**,** 338-347.

Marshall, S., Burrows, T. & Collins, C. E. 2014. Systematic review of diet quality indices and their associations with health-related outcomes in children and adolescents. *Journal of Human Nutrition & Dietetics,* 27**,** 577-598.

Martin, J. E., Hure, A. J., Macdonald-Wicks, L., Smith, R. & Collins, C. E. 2014. Predictors of post-partum weight retention in a prospective longitudinal study. *Maternal & Child Nutrition,* 10**,** 496-509.

Mcardle, M. A., Finucane, O. M., Connaughton, R. M., Mcmorrow, A. M. & Roche, H. M. 2013. Mechanisms of Obesity-Induced Inflammation and Insulin Resistance: Insights into the Emerging Role of Nutritional Strategies. *Frontiers in Endocrinology,* 4**,** 52.

Mccarron, D. & Reusser, M. 2000. The power of food to improve multiple cardiovascular risk factors. *Current Atherosclerosis Reports,* 2**,** 482-486.

Mccrory, M. A., Suen, V. M. M. & Roberts, S. B. 2002. Biobehavioral influences on energy intake and adult weight gain. *Journal of Nutrition,* 132**,** 3830S-3834S.

Mccullough, M. L., Feskanich, D., Rimm, E. B., Giovannucci, E. L., Ascherio, A., et al. 2000a. Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in men. *American Journal of Clinical Nutrition,* 72**,** 1223-1231.

Mccullough, M. L., Feskanich, D., Stampfer, M. J., Giovannucci, E. L., Rimm, E. B., et al. 2002. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *The American journal of clinical nutrition,* 76**,** 1261-1271.

Mccullough, M. L., Feskanich, D., Stampfer, M. J., Rosner, B. A., Hu, F. B., et al. 2000b. Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in women. *American Journal of Clinical Nutrition,* 72**,** 1214-22.

Mcnaughton, S. A., Ball, K., Crawford, D. & Mishra, G. D. 2008. An index of diet and eating patterns is a valid measure of diet quality in an Australian population. *The Journal of nutrition,* 138**,** 86-93.

Mcnaughton, S. A., Bates, C. J. & Mishra, G. D. 2012. Diet Quality Is Associated with All-Cause Mortality in Adults Aged 65 Years and Older. *The Journal of Nutrition,* 142**,** 320-325.

Mcnaughton, S. A., Dunstan, D. W., Ball, K., Shaw, J. & Crawford, D. 2009. Dietary Quality Is Associated with Diabetes and Cardio-Metabolic Risk Factors. *The Journal of Nutrition,* 139**,** 734-742.

Mendez, M. A., Popkin, B. M., Jakszyn, P., Berenguer, A., Tormo, M. J., et al. 2006. Adherence to a Mediterranean diet is associated with reduced 3-year incidence of obesity. *Journal of Nutrition,* 136**,** 2934-8.

Meyer, K. A., Sijtsma, F. P. C., Nettleton, J. A., Steffen, L. M., Van Horn, L., et al. 2013. Dietary patterns are associated with plasma F2-isoprostanes in an observational cohort study of adults. *Free Radical Biology and Medicine,* 57**,** 201-209.

Michels, K. B. & Wolk, A. 2002. A prospective study of variety of healthy foods and mortality in women. *International Journal of Epidemiology,* 31**,** 847-854.

Miller, P. E., Lesko, S. M., Muscat, J. E., Lazarus, P. & Hartman, T. J. 2010. Dietary Patterns and Colorectal Adenoma and Cancer Risk: A Review of the Epidemiological Evidence. *Nutrition and Cancer,* 62**,** 413-424.

Milte, C. M., Thorpe, M. G., Crawford, D., Ball, K. & Mcnaughton, S. A. 2015. Associations of diet quality with health-related quality of life in older Australian men and women. *Experimental Gerontology,* 64**,** 8-16.

Mishra, G., Ball, K., Patterson, A., Brown, W., Hodge, A., et al. 2004. Socio-demographic inequalities in the diets of mid-aged Australian women. *Eur J Clin Nutr,* 59**,** 185-195.

Mishra, G. D., Ajm, D., Schoenaker, Mihrshahi, S. & Dobson, A. J. 2014. How do women's diets compare with the new Australian dietary guidelines? .

Mishra, G. D., Mcnaughton, S. A., Ball, K., Brown, W. J., Giles, G. G., et al. 2010. Major dietary patterns of young and middle aged women: results from a prospective Australian cohort study. *European Journal of Clinical Nutrition,* 64**,** 1125-33.

Morrison, M. K., Koh, D., Lowe, J. M., Miller, Y. D., Marshall, A. L., et al. 2012. Postpartum diet quality in Australian women following a gestational diabetes pregnancy. *European Journal of Clinical Nutrition,* 66**,** 1160-1165.

Murphy, S. P., Davis, M. A., Neuhaus, J. M. & Lein, D. 1996. Dietary quality and survival among middle-aged and older adults in the NHANES I epidemiologic follow-up study. *Nutrition Research,* 16**,** 1641-1650.

Murray, C. J. L., Ezzati, M., Flaxman, A. D., Lim, S., Lozano, R., et al. 2012. GBD 2010: design, definitions, and metrics. *The Lancet,* 380**,** 2063-2066.

National Health and Medical Research Council 2003. Dietary Guidelines for Australian Adults. Canberra NHMRC.

National Health and Medical Research Council 2013a. Australian Dietary Guidelines. *In:* COUNCIL, N. H. A. M. R. (ed.). Canberra: National Health and Medical Research Council.

National Health and Medical Research Council 2013b. Dietary Guidelines for Australian Adults. Canberra: National Health and Medical Research Council.

National Health and Medical Research Council and New Zealand Ministry of Health. *Nutrient Reference Values for Australia and New Zealand - Including Recommended Dietary Intakes.* [Online]. Canberra: Australian Government Department of Health and Ageing, . Available: http://www.nrv.gov.au/disease/index.htm [Accessed 12th of August 2013].

Newby, P., Hu, F. B., Rimm, E. B., Smith-Warner, S. A., Feskanich, D., et al. 2003a. Reproducibility and validity of the Diet Quality Index Revised as assessed by use of a food-frequency questionnaire. *The American journal of clinical nutrition,* 78**,** 941-949.

Newby, P. K., Muller, D., Hallfrisch, J., Qiao, N., Andres, R., et al. 2003b. Dietary patterns and changes in body mass index and waist circumference in adults. *American Journal of Clinical Nutrition,* 77**,** 1417-25.

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., et al. 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, 766.

Norman, J. E., Bild, D., Lewis, C. E., Liu, K. & West, D. S. 2003. The impact of weight change on cardiovascular disease risk factors in young black and white adults: the CARDIA study. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity,* 27**,** 369-376.

Nutrition and Your Health 1990. *Dietary Guidelines for Americans, 3rd ed*. Washington, US Dept of Agriculture/Dept of Health and Human Services,Home and Garden Bulletin.

Nutrition and Your Health 1995. Dietary Guidelines for Americans: Home and Garden Bulletin Washington DC:U.S. Departments of Agriculture and Health and Human Services.

Nutrition and Your Health 2000. Dietary guidelines for Americans. 5th ed. Washington, DC: US Department of Agriculture, US Department of Health and Human Services,.

Osler, M., Andreasen, A. H., Heitmann, B., Hoidrup, S., Gerdes, U., et al. 2002. Food intake patterns and risk of coronary heart disease: A prospective cohort study examining the use of traditional scoring techniques. *European Journal of Clinical Nutrition,* 56**,** 568-574.

Osler, M., Heitmann, B. L., Gerdes, L. U., Jørgensen, L. M. & Schroll, M. 2001. Dietary patterns and mortality in Danish men and women: a prospective observational study. *British Journal of Nutrition,* 85**,** 219-225.

Osler, M. & Schroll, M. 1997. Diet and mortality in a cohort of elderly people in a north European community. *International Journal of Epidemiology,* 26**,** 155-9.

Oude Griep, L., Wang, H. & Chan, Q. 2013. Empirically Derived Dietary Patterns, Diet Quality Scores, and Markers of Inflammation and Endothelial Dysfunction. *Current Nutrition Reports,* 2**,** 97-104.

Panagiotakos, D. B., Pitsavos, C. & Stefanadis, C. 2006. Dietary patterns: A Mediterranean diet score and its relation to clinical and biological markers of cardiovascular disease risk. *Nutrition, Metabolism and Cardiovascular Diseases,* 16**,** 559-568.

Pate, R. R., Ross, S. E. T., Liese, A. D. & Dowda, M. 2015. Associations among Physical Activity, Diet Quality, and Weight Status in US Adults. *Medicine & Science in Sports & Exercise,* 47**,** 743-750.

Patterson, R. E., Haines, P. S. & Popkin, B. M. 1994. Diet quality index: Capturing a multidimensional behavior. *Journal of the American Dietetic Association,* 94**,** 57-64.

Petrogianni, M., Kanellakis, S., Kallianioti, K., Argyropoulou, D., Pitsavos, C., et al. 2013. A multicomponent lifestyle intervention produces favourable changes in diet quality and cardiometabolic risk indices in hypercholesterolaemic adults. *Journal of Human Nutrition and Dietetics,* 26, 596-605.

Popkin, B. M. 2004. The Nutrition Transition: An Overview of World Patterns of Change. *Nutrition Reviews,* 62, S140-S143.

Popkin, B. M. & Gordon-Larsen, P. 2004. The nutrition transition: worldwide obesity dynamics and their determinants. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity,* 28 Suppl 3, S2-9.

Quatromoni, P. A., Pencina, M., Cobain, M. R., Jacques, P. F. & D'agostino, R. B. 2006. Dietary quality predicts adult weight gain: Findings from the Framingham Offspring Study. *Obesity,* 14, 1383-91.

Randi, G., Edefonti, V., Ferraroni, M., La Vecchia, C. & Decarli, A. 2010. Dietary patterns and the risk of colorectal cancer and adenomas. *Nutrition Reviews,* 68, 389-408.

Robinson, S. M., Crozier, S. R., Harvey, N. C., Barton, B. D., Law, C. M., et al. 2015. Modifiable early-life risk factors for childhood adiposity and overweight: an analysis of their combined impact and potential for prevention. *The American Journal of Clinical Nutrition*.

Rolls, B. J., Ello-Martin, J. A. & Tohill, B. C. 2004. What Can Intervention Studies Tell Us about the Relationship between Fruit and Vegetable Consumption and Weight Management? *Nutrition Reviews,* 62, 1-17.

Romaguera, D., Norat, T., Mouw, T., May, A. M., Bamia, C., et al. 2009. Adherence to the Mediterranean diet is associated with lower abdominal adiposity in European men and women. *Journal of Nutrition,* 139, 1728-37.

Romaguera, D., Norat, T., Vergnaud, A., Mouw, T., May, A. M., et al. 2010. Mediterranean dietary patterns and prospective weight change in participants of the EPIC-PANACEA project. *American Journal of Clinical Nutrition,* 92, 912-921.

Román-Viñas, B., Ribas Barba, L., Ngo, J., Ángel Martínez-González, M., Wijnhoven, T. M. A., et al. 2009. Validity of dietary patterns to assess nutrient intake adequacy. *British Journal of Nutrition,* 101, S12-S20.

Salehi-Abargouei, A., Maghsoudi, Z., Shirani, F. & Azadbakht, L. 2013. Effects of Dietary Approaches to Stop Hypertension (DASH)-style diet on fatal or nonfatal cardiovascular diseases—Incidence: A systematic review and meta-analysis on observational prospective studies. *Nutrition,* 29, 611-618.

Sanchez-Villegas, A., Adriano, M. P., Juan, J., Beunza, Guillen-Grima, F., et al. 2010. Childhood and young adult overweight/obesity and incidence of depression in the SUN Project. *Obesity,* 18**,** 1443-1448.

Sanchez-Villegas, A., Bes-Rastrollo, M., Martinez-Gonzalez, M. & Serra-Majem, L. 2006. Adherence to a Mediterranean dietary pattern and weight gain in a follow-up study: The SUN cohort. *International Journal of Obesity,* 30**,** 350-358.

Sartorelli, D. S., Franco, L. J. & Cardoso, M. A. 2008. High intake of fruits and vegetables predicts weight loss in Brazilian overweight adults. *Nutrition Research,* 28**,** 233-238.

Savage, J. S., Marini, M. & Birch, L. L. 2008. Dietary energy density predicts women's weight change over 6 y. *American Journal of Clinical Nutrition,* 88**,** 677-84.

Schofield, W. N. 1985. Predicting basal metabolic rate, new standards and review of previous work. *Human Nutrition. Clinical Nutrition,* 39 Suppl 1**,** 5-41.

Schulze, M. B., Fung, T. T., Manson, J. E., Willett, W. C. & Hu, F. B. 2006. Dietary patterns and changes in body weight in women. *Obesity,* 14**,** 1444-53.

Schulze, M. B. & Hoffmann, K. 2006. Methodological approaches to study dietary patterns in relation to risk of coronary heart disease and stroke. *British Journal of Nutrition,* 95**,** 860-869.

Seymour, J. D., Calle, E. E., Flagg, E. W., Coates, R. J., Ford, E. S., et al. 2003. Diet Quality Index as a Predictor of Short-term Mortality in the American Cancer Society Cancer Prevention Study II Nutrition Cohort. *American Journal of Epidemiology,* 157**,** 980-988.

Simopoulos, A. P. & Visioli, F. 2007. *More on Mediterranean diets*. Basel ; New York, Karger.

Slattery, M., Berry, T. D., Potter, J. & Caan, B. 1997. Diet diversity, diet composition, and risk of colon cancer (United States). *Cancer Causes & Control,* 8**,** 872-882.

Slattery, M. L. 2010. Analysis of dietary patterns in epidemiological researchThis paper is one of a selection of papers published in the CSCN–CSNS 2009 Conference, entitled Are dietary patterns the best way to make nutrition recommendations for chronic disease prevention? *Applied Physiology, Nutrition, and Metabolism,* 35**,** 207-210.

Smith, A., Kellett, E. & Schmerlaib, Y. A. 1998. Australian Guide to Healthy Eating. Canberra: Commonwealth Department of Health and Family Services.

Smith, S. A., Hulsey, T. & Goodnight, W. 2008. Effects of Obesity on Pregnancy. *Journal of Obstetric, Gynecologic, and Neonatal Nursing,* 37**,** 176-184.

Sofi, F., Abbate, R., Gensini, G. F. & Casini, A. 2010. Accruing evidence on benefits of adherence to the Mediterranean diet on health: an updated systematic review and meta-analysis. *The American journal of clinical nutrition,* 92**,** 1189-1196.

Søgaard, A. J., Holvik, K., Omsland, T. K., Tell, G. S., Dahl, C., et al. 2014. Abdominal obesity increases the risk of hip fracture. A population-based study of 43 000 women and men aged 60-79 years followed for 8 years. Cohort of Norway. *Journal Of Internal Medicine*.

Statacorp 2011. Stata Statistical Software: . 11.1 ed. College Station, TX: StataCorp LP.

Sternfeld, B., Wang, H., Quesenberry, C. P., Abrams, B., Everson-Rose, S. A., et al. 2004. Physical Activity and Changes in Weight and Waist Circumference in Midlife Women: Findings from the Study of Women's Health Across the Nation. *American Journal of Epidemiology,* 160**,** 912-922.

Sun, Q., Townsend, M. K., Okereke, O. I., Franco, O. H., Hu, F. B., et al. 2009. Adiposity and weight change in mid-life in relation to healthy survival after age 70 in women: prospective cohort study. *BMJ,* 339.

Sundararajan, K., Campbell, M. K., Choi, Y.-H. & Sarma, S. 2014. The Relationship Between Diet Quality and Adult Obesity: Evidence from Canada. *Journal of the American College of Nutrition,* 33**,** 1-17.

Tataranni, P. A., Harper, I. T., Snitker, S., Del Parigi, A., Vozarova, B., et al. 2003. Body weight gain in free-living Pima Indians: Effect of energy intake vs expenditue. *International Journal of Obesity,* 27**,** 1578-1583.

The Food Guide Pyramid 1992. Washington, DC: US Dept of Agriculture, Human Nutrition Information Service. Home and Garden Bulletin.

Toft, U., Kristoffersen, L. H., Lau, C., Borch-Johnsen, K. & Jorgensen, T. 2006. The Dietary Quality Score: validation and association with cardiovascular risk factors: the Inter99 study. *Eur J Clin Nutr,* 61**,** 270-278.

Togo, P., Osler, M., Sørensen, T. I. & Heitmann, B. L. 2001. Food intake patterns and body mass index in observational studies. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity,* 25**,** 1741-1751.

Tooze, J. A., Krebs-Smith, S. M., Troiano, R. P. & Subar, A. F. 2012. The accuracy of the Goldberg method for classifying misreporters of energy intake on a food frequency questionnaire and 24-h recalls: comparison with doubly labeled water. *European Journal of Clinical Nutrition,* 66**,** 569-576.

Trichopoulou, A., Costacou, T., Bamia, C. & Trichopoulos, D. 2003. Adherence to a Mediterranean Diet and Survival in a Greek Population. *New England Journal of Medicine,* 348**,** 2599-2608.

Trichopoulou, A., Kouris-Blazos, A., Wahlqvist, M. L., Gnardellis, C., Lagiou, P., et al. 1995. Diet and overall survival in elderly people. *BMJ : British Medical Journal,* 311**,** 1457-1460.

Tucker, K. L. 2010. Dietary patterns, approaches, and multicultural perspectiveThis is one of a selection of papers published in the CSCN–CSNS 2009 Conference, entitled Can we identify culture-specific healthful dietary patterns among diverse populations undergoing nutrition transition? *Applied Physiology, Nutrition, and Metabolism,* 35**,** 211-218.

Ursin, G., Ziegler, R. G., Subar, A. F., Graubard, B. I., Haile, R. W., et al. 1993. Dietary Patterns Associated with a Low-Fat Diet in the National Health Examination Follow-up Study: Identification of Potential Confounders for Epidemiologic Analyses. *American Journal of Epidemiology,* 137**,** 916-927.

Vadiveloo, M., Dixon, L. B. & Parekh, N. 2013. Associations between dietary variety and measures of body adiposity: a systematic review of epidemiological studies. *British Journal of Nutrition,* 109**,** 1557-1572.

Verger Eo, M. F., Holmes Ba, Paineau D, Huneau J-F. 2012. Evaluation of a Diet Quality Index Based on the Probability of Adequate Nutrient Intake (PANDiet) Using National French and US Dietary Surveys. *PLoS ONE [Electronic Resource],* 7.

Vioque, J., Weinbrenner, T., Castello, A., Asensio, L. & Garcia De La Hera, M. 2008. Intake of fruits and vegetables in relation to 10-year weight gain among Spanish adults. *Obesity,* 16**,** 664-70.

Waijers, P. M. C. M., Feskens, E. J. M. & Ocké, M. C. 2007. A critical review of predefined diet quality scores. *British Journal of Nutrition,* 97**,** 219-231.

Wane, S., Van Uffelen, J. G. & Brown, W. 2010. Determinants of weight gain in young women: a review of the literature. *Journal of women's health,* 19**,** 1327-40.

Weinstein, S. J., Vogt, T. M. & Gerrior, S. A. 2004. Healthy eating index scores are associated with blood nutrient concentrations in the third National Health and Nutrition Examination Survey. *Journal of the American Dietetic Association,* 104**,** 576-584.

Willett, W. C., Sacks, F., Trichopoulou, A., Drescher, G., Ferro-Luzzi, A., et al. 1995. Mediterranean diet pyramid: a cultural model for healthy eating. *The American journal of clinical nutrition,* 61**,** 1402S-1406S.

Williams, L., Germov, J. & Young, A. 2007. Preventing weight gain: a population cohort study of the nature and effectiveness of mid-age women's weight control practices. *International journal of obesity,* 31**,** 978-86.

Williams, L. T., Hollis, J. L., Collins, C. E. & Morgan, P. J. 2014. Can a relatively low-intensity intervention by health professionals prevent weight gain in mid-age women[quest] 12-Month outcomes of the 40-Something randomised controlled trial. *Nutrition & Diabetes,* 4**,** e116.

Williams, L. T., Young, A. F. & Brown, W. J. 2006. Weight gained in two years by a population of mid-aged women: how much is too much? *International Journal of Obesity,* 30, 1229-1233.

Wing, R. R., Matthews, K. A., Kuller, L. H., Meilahn, E. N. & Plantinga, P. L. 1991. WEight gain at the time of menopause. *Archives of Internal Medicine,* 151, 97-02.

Wirfält, E., Drake, I. & Wallström, P. 2013. What do review papers conclude about food and dietary patterns? *Food & Nutrition Research*.

Wirt, A. & Collins, C. E. 2009. Diet quality--what is it and does it matter? *Public Health Nutrition,* 12, 2473-92.

Wolongevicz, D. M., Zhu, L., Pencina, M. J., Kimokoti, R. W., Newby, P. K., et al. 2010. Diet quality and obesity in women: the Framingham Nutrition Studies. *British Journal of Nutrition,* 103, 1223-9.

World Cancer Research Fund International 2007. *Food, nutrition, physical activity, and the prevention of cancer: A global Perspective*. Washington, American Institute for Cancer Research.

World Health Organization. 2008. WHO Statistical Information System (WHOSIS). Available: http://www.who.int/whosis/indicators/compendium/2008/1pou/en/.

World Health Organization. 2010. *Global Strategy on Diet, Physical Activity and Health.* [Online]. Available: http://www.who.int/dietphysicalactivity/fruit/en/ [Accessed 30 Nov 2014].

World Health Organization. 2013a. Controlling the global obesity epidemic Available: http://www.who.int/nutrition/topics/obesity/en/ [Accessed 12 February 2013].

World Health Organization. 2013b. *Obesity and overweight* [Online]. Available: http://www.who.int/mediacentre/factsheets/fs311/en/.

World Health Organization 2014. *Global Status Report on Noncommunicable Disease*. Switzerland.

Yannakoulia, M., Panagiotakos, D., Pitsavos, C., Lentzas, Y., Chrysohoou, C., et al. 2009. Five-year incidence of obesity and its determinants: the ATTICA Study. *Public Health Nutrition,* 12, 36-43.

Yu, D., Zhang, X., Xiang, Y.-B., Yang, G., Li, H., et al. 2014. Adherence to dietary guidelines and mortality: a report from prospective cohort studies of 134,000 Chinese adults in urban Shanghai. *The American journal of clinical nutrition,* 100, 693-700.

Yu, Z., Han, S., Zhu, J., Sun, X., Ji, C., et al. 2013. Pre-pregnancy body mass index in relation to infant birth weight and offspring overweight/obesity: a systematic review and meta-analysis. *Plos One,* 8, e61627-e61627.

Zamora, D., Gordon-Larsen, P., Jacobs, D. R. & Popkin, B. M. 2010. Diet quality and weight gain among black and white young adults: the Coronary Artery Risk Development in Young Adults (CARDIA) Study (1985–2005). *The American journal of clinical nutrition,* 92**,** 784-793.

Zarrin, R., Ibiebele, T. I. & Marks, G. C. 2013. Development and validity assessment of a diet quality index for Australians. *Asia Pacific Journal of Clinical Nutrition,* 22**,** 177-187.

Zhvania, N., Ratiani, L. & Avaliani, S. 2012. Peculiarities of cardiovascular disease in women. *Georgian Medical News***,** 30-7.