

**The impact of food subsidy programs on the health of
disadvantaged populations**

**An evaluation of subsidised fruit and vegetables in a rural
Aboriginal medical service**

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Contents

Contents	i
List of Figures.....	v
List of Tables	vi
Abbreviations	viii
Abstract.....	ix
Declaration.....	xi
Acknowledgements	xii
Contribution of study investigators.....	xv
Thesis Overview	1
1 Introduction.....	2
1.1 Health Outcomes and Nutrition	2
1.1.1 The Rise of Non-Communicable Disease	2
1.1.2 Epidemiology of Nutrition-related risk factors	4
1.1.3 Cardiovascular Disease and Nutrition	12
1.1.4 Cancer and Nutrition	14
1.1.5 Short-term benefits of improved nutrition.....	15
1.1.6 Maternal and Fetal Nutrition	21
1.1.7 Fruit and Vegetable intake and Health outcomes	24
1.2 Methods of Nutritional Assessment.....	27
1.2.1 Dietary Assessment techniques	27
1.2.2 The challenge of reducing error in dietary assessment.....	29
1.2.3 Dietary assessment studies involving children	30
1.2.4 Dietary assessment in Aboriginal and Torres Strait Islander people.....	30
1.2.5 Biomarkers.....	31
1.3 Promoting Healthy Nutrition.....	39
1.3.1 Determinants of dietary behaviour	39
1.3.2 Socio-economic status and Diet	41
1.3.3 Promoting healthy nutrition in Aboriginal and Torres Strait Islander communities.....	45
1.3.4 Population-based strategies to promote healthy nutrition.....	46
1.4 Summary and Rationale for the Thesis	50
1.4.1 Rationale.....	51
2 Food subsidy programs and the health and nutritional status of disadvantaged families in high income countries: a systematic review	54

2.1	Introduction.....	54
2.2	Methods.....	56
2.2.1	Criteria for studies included in the review.....	56
2.2.2	Outcomes	57
2.2.3	Search strategy.....	58
2.2.4	Data synthesis and analysis	58
2.2.5	Assessment of risk of bias in included studies	59
2.3	Results	59
2.3.1	Scope of included studies	62
2.3.2	Risk of bias in included studies	62
2.3.3	Interventions and Outcomes	62
2.3.4	Impact of food subsidy programs	68
2.4	Discussion.....	81
2.4.1	Conclusions	85
3	Methods.....	86
3.1	Participants.....	86
3.1.1	Location- Regional Australia.....	86
3.1.2	Local Aboriginal Communities	87
3.2	Study design.....	89
3.2.1	Fruit and vegetable program.....	89
3.2.2	Evaluation design	90
3.2.3	Outcome measures.....	91
3.2.4	Eligibility criteria.....	93
3.2.5	Recruitment Strategy	93
3.2.6	Sample size calculations.....	94
3.2.7	Timeline of evaluation.....	94
3.3	Data Collection	96
3.3.1	Pathology samples	96
3.3.2	Dietary recall	96
3.3.3	Anthropometric measurements.....	96
3.3.4	Clinical audit.....	97
3.4	Analysis	98
3.4.1	Blood specimens.....	98
3.4.2	Statistical analysis.....	99
3.4.3	Validity of the self-reported dietary data.....	100
3.5	Ethics.....	100

4	Nutritional impacts of the fruit and vegetable program	102
4.1	Introduction.....	102
4.2	Methods.....	103
4.2.1	Study design and data collection	103
4.2.2	Data analysis.....	103
4.2.3	Ethics	104
4.3	Results	104
4.3.1	Baseline demographic characteristics of participants.....	104
4.3.2	Baseline levels of biomarkers.....	105
4.3.3	Nutrient intake at baseline	106
4.3.4	Impact of the fruit and vegetable program on biomarkers and fruit and vegetable intake	111
4.4	Discussion.....	120
4.4.1	Conclusions	124
5	Impact of subsidised fruit and vegetables and folate fortification	125
5.1	Introduction.....	125
5.2	Methods.....	125
5.3	Results	126
5.4	Discussion.....	132
6	The fruit and vegetable program and health outcomes	135
6.1	Introduction.....	135
6.2	Methods.....	136
6.2.1	Study design	136
6.2.2	Statistical analysis.....	136
6.3	Results	137
6.3.1	Demographics	137
6.3.2	Anthropometric changes associated with the fruit and vegetable program...	137
6.3.3	Health outcomes after fruit and vegetable program participation for 12 months	140
6.3.4	Changes in anaemia, iron status and vitamin D after fruit and vegetable program	144
6.4	Discussion.....	146
6.4.1	Conclusions	150
7	The fruit and vegetable program: development, implementation and evaluation	151
7.1	Introduction.....	151

7.2	The establishment of the Bulgarr fruit and vegetable program.....	151
7.2.1	The role of the Bulgarr Fruit and Vegetable committee.....	154
7.3	Considerations in the design of the program evaluation.....	154
7.3.1	Obtaining ethics approval and balancing community needs	154
7.3.2	Impact of the choice of study design	156
7.3.3	The expansion of the fruit and vegetable program - a multi-site evaluation.	156
7.4	Community feedback from the focus groups	157
7.5	Food subsidy programs in Native American communities in the USA	159
7.6	Food subsidy programs and concerns about sustainability, dependence and equity.....	161
7.7	Conclusions.....	162
8	Discussion.....	164
8.1	Introduction.....	164
8.2	Key findings.....	164
8.3	Strengths and limitations of the study	165
8.4	Comparison with previous research.....	170
8.5	Implications for policy and practice.....	173
8.6	Implications for future research.....	176
8.7	Conclusion	178
	References.....	179
Appendix A.	Medline Search Strategy.....	218
Appendix B	Sample Size calculations	222
Appendix C	Dietary Assessment form.....	224
Appendix D	F&V program Health record Audit	229
Appendix E	Fruit & Vegetable Program - Produce List	231
Appendix F	Focus group themes/questions	232

List of Figures

Figure 2.1 Flow-chart of search results.....	61
Figure 2.2 Forest plot of the impact of food subsidy programmes on birth weight outcomes (WIC studies).....	81
Figure 3.1 Map of New South Wales (Main study location indicated by arrow)	87
Figure 3.2 Map of Northern NSW with arrows indicating study communities	88
Figure 3.3 The fruit and vegetable subsidy program and components of the evaluation .	92
Figure 3.4 Timeline of the duration of the fruit and vegetable program in each community and timing of evaluation assessments.	95
Figure 4.1 Macronutrient intake per megajoule before and after the fruit and vegetable program	118
Figure 5.1 Change in RBC folate z-scores by community before and after 12 months of the fruit and vegetable program	128
Figure 5.2 Scatterplot of change in fruit and vegetable intake by change in RBC folate z-score	129
Figure 5.3 Scatterplot of mean fruit and vegetable intake by change in RBC folate z-score	130
Figure 5.4 Scatterplot of mean bread intake versus change in RBC folate z-score.....	131

List of Tables

Table 1.1. Age specific mortality rates for Indigenous and Non-Indigenous Australians 2006-2010	4
Table 1.2. Prevalence of nutrition-related risk factors in Australia.	5
Table 1.3. Proportion of Australian children's meeting current dietary guidelines, 2007 ..	8
Table 2.1 Characteristics of included studies (in chronological order).....	65
Table 2.2 Nutritional and health outcomes associated with comprehensive food subsidy programs	72
Table 2.3 Nutritional and health outcomes in limited food subsidy programs	79
Table 4.1 Baseline demographic characteristics of participating children.....	105
Table 4.2 Baseline biomarkers of Aboriginal children 0-17 years	106
Table 4.3 Macronutrient intake by age category and sex at baseline.....	108
Table 4.4 Micronutrient intake by age category and sex at baseline	109
Table 4.5 Biomarkers before and after the fruit and vegetable program	112
Table 4.6 Biomarker changes among F&V program participants overall and by individual communities.....	113
Table 4.7 Fruit and vegetable intake before and after fruit and vegetable program	114
Table 4.8 Changes in fruit and vegetable intake among fruit and vegetable program participants by community.....	115
Table 4.9 Macronutrient intake before and after fruit and vegetable program	117
Table 4.10 Change in macronutrients per megajoule among fruit and vegetable participants.....	119
Table 5.1 Red cell folate before and after 12 months on the fruit and vegetable program by community	127
Table 5.2 Linear regression model of change in F&V intake and baseline RBC folate as predictors of change in RBC folate.....	132
Table 5.3 Linear regression model of mean bread intake and baseline RBC folate as predictors of the change in RBC folate.....	132
Table 6.1 Proportion of children aged 2-17 years classified as underweight, normal weight, overweight or obese by age at baseline.....	138
Table 6.2 Proportion of children aged 2-17 years classified as underweight, normal weight, overweight or obese by age at 12 month follow-up.....	139

Table 6.3 Anthropometric changes among fruit and vegetable program participants at 12 month follow-up.....	140
Table 6.4 Change in health outcomes among fruit and vegetable program participants by community	143
Table 6.5 Changes in haemoglobin, iron status and vitamin D levels in fruit and vegetable program participants	145
Table 6.6 Proportion of children with low haemoglobin, ferritin, iron and vitamin D before and after participation in the fruit and vegetable program	146

Abbreviations

Abbreviation	Definition
AHR	Adjusted hazard ratio
AMS	Aboriginal Medical Service
BMI	Body mass index
BMR	Basal metabolic rate
BNMAC	Bulgarr Ngaru Medical Aboriginal Corporation
CRP	C-reactive protein
CVS	Cardiovascular
EAR	Estimated average requirement
EI	Energy intake
EPIC	European Prospective Investigation into Cancer and Nutrition
F&V	Fruit and vegetable
FFQ	Food frequency questionnaire
HDL	High density lipoprotein
HPLC	High pressure liquid chromatography
IUGR	Intra-uterine growth retardation
LDL	Low density lipoprotein
NHANES III	The third National Health and Nutrition Examination Survey
PUFA	Polyunsaturated fatty acids
RBC	Red blood cell
RCF	Red cell folate
RCT	Randomised controlled trial
RDA	Recommended dietary allowance
RR	Relative risk
SES	Socio-economic status
WIC	Special Supplemental Nutrition Program for Women, Infants and Children

Abstract

Nutrition is a significant factor underpinning people's health. Australian surveys have shown that social disadvantage correlates with poorer health outcomes, higher rates of chronic disease and lower adherence to nutrition guidelines. This is reflected in the life expectancy gap between Aboriginal and Torres Strait Islander people and non-Indigenous Australians. In this context effective interventions to improve nutrition are important to inform nutrition policy development. Subsidising healthy foods for those on low incomes is one strategy that has not been widely trialled in Australia.

To contribute to the evidence base for healthy food subsidies, this thesis reports on (i) the evaluation of a program of subsidised fruit and vegetables for disadvantaged Aboriginal families at three rural Aboriginal Health Services, and (ii) a systematic review of food subsidy programs in high income countries.

The evaluation was conducted on the Bulgarr Ngaru Medical Aboriginal Corporation fruit and vegetable program that incorporates subsidised fruit and vegetables with preventive health screening and nutrition promotion. A before and after study design was used to assess the impact on the nutritional and health status of participating children. The nutritional assessments included 24-hour dietary recalls and measurement of biomarkers of fruit and vegetable intake in bloods. Health outcomes were assessed with retrospective clinical record audits and anthropometric data. Focus groups and key informant interviews were used to document the implementation and sustainability of the program.

A cohort of 57 new families was recruited for this evaluation. Baseline assessment in 149 children showed low fruit and vegetable consumption. Twelve month follow-up of 129 children showed significant increases in β -cryptoxanthin ($p=0.027$), vitamin C ($p=0.013$), lutein-zeaxanthin ($p=0.026$) and red cell folate, although self-reported fruit and vegetable intake was unchanged. There were also significant decreases in episodes of illness (14%, $p=0.037$), hospital attendances (25%, $p=0.017$) and oral antibiotics (34%, $p=0.001$) during participation in the program. The success of the evaluation depended on the ongoing relationships between the health services and the Aboriginal communities and the practical nature of the intervention.

The systematic review identified limited high quality evidence, mostly from the Special Supplemental Nutrition Program for Woman, Infants and Children in the United States,

that food subsidies improve the nutritional intake of pregnant and postnatal women and result in small but significant improvements in birth outcomes. However, the number of controlled studies investigating food subsidies in the United States and other countries is increasing.

The improvements in biomarkers of fruit and vegetable intake and short-term health outcomes demonstrated in this study, though not conclusive, indicate the need for a more controlled study of healthy food subsidies in Australia. This, together with an economic analysis, would facilitate a thorough assessment of the costs and benefits of subsidising healthy foods. The most important implication of this thesis is the potential reduction in chronic disease rates, if food subsidy programs lead to sustainable increases in fruit and vegetable intake. Thus, food subsidies could, if effective, reduce the social inequalities in health by improving the nutrition of disadvantaged Australians, particularly Aboriginal and Torres Strait Islander people.

Declaration

I declare that this thesis presents work carried out by myself and does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, is clearly acknowledged.

A handwritten signature in black ink, appearing to read 'A. Black', written in a cursive style.

Andrew Peter Black

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Contribution of study investigators

My three primary supervisors in this thesis, Professor Kerin O’Dea, Dr Hassan Vally and Dr Peter Morris were all involved in planning the study design. With their support, the candidate took the lead role in decisions regarding the study design, and the negotiations with local stakeholders and ethics committees. As the only researcher based in the Clarence Valley, the candidate was responsible for supervising or undertaking all aspects of the study. The candidate was primarily responsible for the data analysis with support and advice from each of the three supervisors and from Professor Adrian Esterman and Professor Mark Daniel. Dr Karen Walker and Ms Jia Hwa Lee entered diet recall data into Foodworks and provided basic and supplementary data outputs.

Dr Julie Brimblecombe, Dr Helen Eyles, Professor O’Dea, Dr Vally and Dr Morris were co-authors in the systematic review. They contributed to designing the protocol and edited the manuscript. The candidate had primary responsibility for implementing the protocol, including designing the search strategy, undertaking the search, selecting studies for inclusion (with Dr Brimblecombe), analyzing the results and drafting the manuscript/chapter.

Thesis Overview

The introductory chapter of this thesis reviews the relationship between health outcomes and nutrition, with a focus on Australia including Aboriginal and Torres Strait Islander people. It also summarises techniques for the assessment of dietary intake and nutritional status. The promotion of healthy nutrition, highlighting the role of economic measures, is discussed. The chapter concludes with the rationale and aims of the thesis.

Chapter 2 is a systematic review of food subsidy programs for disadvantaged families in high income countries. This review highlights the limited evidence from high quality studies of these programs. It also includes a discussion of the nutritional impact of these programs and their potential to improve the health status of disadvantaged populations.

An evaluation of a fruit and vegetable subsidy program in three rural Aboriginal medical services in Australia is documented in Chapters 3-7. Chapter 3 describes the methods of the before and after study design involving a cohort of Aboriginal children. The context, location and an outline of the fruit and vegetable subsidy program are also presented in Chapter 3. The nutritional and health outcomes data from the evaluation are presented in Chapters 4-6. These chapters are structured as manuscripts to facilitate dissemination. Chapter 4 reports on the nutritional impacts of the program including self-reported dietary intake and biomarkers. Chapter 5 analyses the changes in red cell folate, which were complicated due to the simultaneous introduction of mandatory folate fortification of bread-making flour in Australia. Chapter 6 compares the changes in health status and in the frequency of episodes of illness before and after the fruit and vegetable program using clinical audit data. Finally, chapter 7 describes the development and implementation of both the program and the evaluation using data from direct observation, interviews and focus groups. There is also a description of the operation of food subsidy programs in Native American communities in the USA based on my personal observations during a study trip.

The discussion in Chapter 8 summarises the main findings of the fruit and vegetable program evaluation, highlighting the strengths and weakness of the study. It relates this study to previous nutrition promotion research and discusses the implications for policy in this area and recommendations for future research priorities.

1 Introduction

This literature overview provides the context and relevant background material which informs the later chapters in the thesis. Section 1.1 describes the relationship between nutrition and health outcomes, including the epidemiology of common non-communicable diseases and nutrition-related risk factors, shorter term health outcomes, the benefits of healthy lifestyles, maternal and fetal nutrition and the links between fruit and vegetable intake and health outcomes. Section 1.2 summarises nutritional assessment techniques including dietary assessment and biomarkers. Section 1.3 discusses the promotion of healthy nutrition focusing on dietary behaviour, socio-economic status and diet and fiscal measures to promote healthy eating. Section 1.4 summarises the preceding sections and the rationale for the thesis.

1.1 Health Outcomes and Nutrition

There have been dramatic increases in chronic non-communicable diseases particularly diabetes mellitus and obesity in recent decades. This has generated increasing interest in the underlying causes of these worldwide trends. Nutrition has been emphasised as a key mediating factor in the pathophysiological, environmental, social and cultural factors contributing to this rise in chronic diseases.

1.1.1 The Rise of Non-Communicable Disease

The Global Burden of Disease studies emphasised the importance of chronic non-communicable diseases in all countries, as these diseases caused 58.5% of deaths globally in 2001.¹ This is despite the awareness of the problem in high income countries and the resources that have been devoted to promoting healthy lifestyles. In developing

or low and middle income countries, the epidemiological transition has firmly established these non-communicable diseases as the major causes of mortality and morbidity.

The Global Burden of Disease studies have also highlighted the major risk factors underlying the burden of disease. Nutrition-related risk factors including high blood pressure, high blood glucose, overweight/obesity, high cholesterol and low fruit and vegetable intake are responsible for 28% of deaths globally each year.² In this context, nutrition-related risk factors are defined as those factors in which nutritional intake is the risk factor (e.g. low fruit and vegetable intake or high intake of saturated fat) or is recognised to have a significant role in the development of the risk factor (e.g. high cholesterol). There is much that could be done to ameliorate the high prevalence of these risk factors and thus reduce their contribution to mortality and morbidity.

In Australia, the major causes of death are even more dominated by chronic non-communicable diseases.³ The leading causes of mortality in 2007 were: all cancers 32.3% (males), 26.0% (females), and cardiovascular disease 31.3% (males), 36.5% (females). Diabetes mellitus caused 2.7% of deaths in males and 2.8% deaths in females and is likely linked with an increasing proportion of deaths from CVD. Nutrition-related factors including high blood pressure, high body mass, high cholesterol and low fruit and vegetable intake were estimated to cause 23% of the burden of disease in Australia in 2003.⁴

1.1.1.1 Mortality and Disadvantage in Indigenous Australians

It is well established that Indigenous Australians experience higher rates and earlier onset of many of these chronic diseases.^{5, 6} The high prevalence of chronic non-communicable disease has been the focus of the Closing the Gap campaign which highlights the difference in life expectancy between Indigenous and non-Indigenous Australians.⁷ There are significant challenges in presenting data on Indigenous Australians health due to problems with Indigenous identification in different states and data-sets.⁵ The difference in mortality outcomes is best illustrated by comparing age-specific mortality rates which emphasize the much higher rates of younger Indigenous people dying from these chronic diseases (**Table 1.1**).

Table 1.1. Age specific mortality rates for Indigenous and Non-Indigenous Australians 2006-2010^{8*}

Age	Age-specific death rates		Rate-ratio
	Indigenous Australians	Non-Indigenous Australians	Indigenous/Non-Indigenous
0 years	8.0	4.3	1.9
1–4 years	45.4	19.7	2.3
5–14 years	19.3	9.3	2.1
15–24 years	97.6	38.9	2.5
25–34 years	199.3	56.7	3.5
35–44 years	436.9	98.7	4.4
45–54 years	810.3	224.5	3.6
55–64 years	1,559.8	525.1	3.0
65 years and over	4,876.1	3,910.0	1.3

*Data from New South Wales, Queensland, Northern Territory and South Australia.

It can be seen in **Table 1.1** that Indigenous Australians aged 25-64 years die at 3-4.5 times the rate of Non-Indigenous Australians. Underlying these mortality data are higher levels of morbidity and higher prevalence of certain risk factors, particularly smoking.⁹

1.1.2 Epidemiology of Nutrition-related risk factors

Major nutrition-related risk factors are all highly prevalent in the adult population in Australia (**Table 1.2**). The inclusion of clinical and laboratory measurements to assess risk factors in the AusDiab study resulted in higher prevalence figures if compared to self-report. For example, the self-reported prevalence of hypertension in adults was 9% in the National Health Survey 2007-2008.¹⁰ The National Health Survey 2007-2008 did not undertake any laboratory measurements. Updated prevalence data for cholesterol and hypertension will be obtained in the Australian Health Survey 2011-2013 which is currently underway.

Table 1.2. Prevalence of nutrition-related risk factors in Australia.

Risk Factor	Source of data	Prevalence	Definition & Age
Obesity	National Health Survey, 2007/8 ³	25%	BMI $\geq 30\text{kg/m}^2$ Age $\geq 18\text{yo}$
High blood cholesterol	AusDiab Study, 2000 ³	51%	Total Cholesterol $> 5.5\text{mmol/L}$ Age $\geq 25\text{yo}$
Low fruit and vegetables	National Health Survey, 2007/8 ³	94%	Not meeting dietary guidelines – 2 serves fruit and 5 serves vegetables/day Age $> 15\text{yo}$
High BP	AusDiab Study, 2000 ³	30%	Systolic BP $> 140\text{mmHg}$ Diastolic BP $> 90\text{mmHg}$ Or taking medication Age $\geq 25\text{yo}$

The high prevalence of these risk factors in Australia is consistent with prevalence observed in other similar countries. In the USA, the age-adjusted prevalence of hypertension in adults was 29.9% in 2005-2008.¹¹ In the UK, 32% of males 16 years and over and 29% of females 16 years and over had hypertension in 2008.¹² In a European Union survey in 2006, the prevalence of self-reported hypertension in adults ranged from 11% in Ireland to 29% in Bulgaria, with a mean of 24% in the 27 member countries.¹²

High blood cholesterol was 58% in males 16 years and over and 61% for females 16 years and over in 2008 in the UK.¹² In the USA, the prevalence of high cholesterol was 16.2% among adults 20 years and over.¹³ This was based on a level of 240mg/dL, which is equivalent to 6.2mmol/L, whereas the cut-off used in the UK is 5.0mmol/L and 5.5mmol/L in Australia.

International comparisons of obesity prevalence depend on use of a standard definition for obesity ($\text{BMI} \geq 30\text{kg/m}^2$) and whether measured data or self-reported data were used in the survey. In the UK, the prevalence of obesity was 25% in males 16 years and over and 28% in females 16 years and over in 2008.¹² In the USA, 34% of the adult population 20 years and over was obese in 2008 (32% of males and 36% of females).¹³ Among countries in the Organization for Economic Co-operation and Development (OECD), Japan (3.4%) and Korea (3.8%) have by far the lowest prevalence of obesity in adults using measured height and weight data. In other OECD countries using measured height and weight, the prevalence of obesity ranges from 16.9% in the Slovak Republic to 33.8% in the USA. In OECD countries, using self-reported height and weight data, the prevalence of obesity ranges from 8.1% in Switzerland to 21% in Wales.¹⁴

1.1.2.1 Nutritional Intake in Australian Adults

The most recent national nutrition survey of Australian adults was the National Nutrition Survey in 1995. The Australian Health Survey 2011-2013 which is currently being undertaken will include dietary data from both adults and children. The mean self-reported energy intake among Australian adults ≥ 19 years in 1995 was 11,050 kJ/day for men and 7481 kJ/day for women. As a proportion of total energy intake, total fat intake was 32.5%, saturated fat 12.7% and total sugars 20.2% in Australian adults in 1995.¹⁵ The low intake of fruit and vegetables is highlighted in Table 2. In the National Health Survey 2007-2008, 56% of females and 48% of males 15 years or older consumed recommended daily fruit intake while 10% of females and 7% of males 15 years or older consumed recommended daily vegetable intake.¹⁶ Rangan et al reported on the consumption of 'extra' foods (as described in the Australian Guide to Healthy Eating) in adults in the 1995 national nutrition survey.¹⁷ They found that these 'extra' foods or energy-dense, nutrient-poor foods contributed 36% of total energy intake, 41% of total and saturated fat but only 20% of selected micronutrients. These 'extra' foods have been designated 'discretionary' foods in the draft revised Australian dietary guidelines to differentiate them from core foods;¹⁸ they include foods such as fried potatoes, margarine, cakes and muffins, beer, sugar-sweetened soft drinks and meat pies.¹⁷

The draft revised Australian dietary guidelines recommend that saturated fat intake should be no higher than 10% total energy and added sugars intake should also be

limited to 10% to promote healthy weight and adequate intake of nutrient-dense foods. The recommendations for fruit and vegetable intake are unchanged. The guidelines recommend achieving and maintaining a healthy weight emphasizing the need to balance energy intake and with energy requirements and/or growth. The increase in total energy intake in adults, evident between the 1983 and 1995 national nutrition surveys, is sufficient to explain the increase in mean body weight. Despite improvements in some important nutritional behaviours, significant challenges remain to improve nutritional intake, which could ultimately lead to better population health outcomes.¹⁸

1.1.2.2 Nutritional Intake in Children

The 2007 Australian National Children's Nutrition and Physical Activity Survey provided updated information about nutritional intake of Australian children aged 2-16 years.¹⁹ This data came from two 24 hour recalls completed by 4487 children randomly selected from across Australia. With reference to the Australian Guide to Healthy Eating, very few children consumed recommended levels of vegetables, a minority met recommendations for total sugar, saturated fat or cereals and a minority of 12-16 year old children had adequate intake of calcium (**Table 1.3**). Most children in all age groups met the estimated average requirements (EAR) for major micronutrients except calcium in children aged 9-16 and magnesium in 14-16 year old children. Sodium consumption exceeded the recommended upper level of intake in all age groups.¹⁹

The prevalence of overweight and obesity have also been rapidly increasing among Australian children although there have been some data to suggest that the rate of increase has slowed in recent years.²⁰ The 2007 Australian National Children's Nutrition and Physical Activity Survey found among 2-16 year old children that 17% of children were overweight, 6% were obese, 72% were normal weight and 5% were underweight.¹⁹

Table 1.3. Proportion of Australian children's meeting current dietary guidelines, 2007.¹⁹

Recommendation	Age Group			
	2-3 years	4-8 years	9-13 years	14-16 years
≥1-3 serves fruit/day excluding juice	(68)*	61	51	1
≥2-4 serves veg/day excluding potato	(5)	3	2	0
≥3-4 serves cereal/day	(5)	20	11	25
% >EAR protein, iron, zinc	99-100	100	99-100	93-100
% >EAR for calcium	99	89	55,31 [†]	38
% >Adequate intake of fluid	53	54	57	46
<10% energy from saturated fat	16	19	19	22
% <20% energy from total sugars	21	39	33	39

*Percentage in brackets based on recommendation for 4-7 year olds as no national guidelines for this age group.

[†]% for 9-11yo and 12-13yo respectively as there are different EARs for these age groups.

The classifications are based on international standard cut-offs of BMI for age.²¹ There are even higher rates of obesity among children in the UK and the USA. In the Health Survey of England in 2006, 14% of 2-15yo children were overweight and 16% were

obese.²² In the USA, the prevalence of overweight was 15% and obesity was 17% among children 2-19 years old in 2007-8.²³ All of these survey used physical measurements to calculate BMI which minimizes the bias introduced by using self-reported data.

The rapid increase in prevalence of overweight and obesity in both adults and children reflects increasing adiposity and importantly increased risk of the metabolic syndrome, cardiovascular disease, diabetes mellitus and other health problems.²⁴ However, there has been debate about the extent of the risk associated with being overweight as a child.^{25, 26} More recent data showed that risk factors for chronic disease were significantly more common in both overweight and obese adolescent children. In this study of 496 Australian Year 10 students, elevated insulin, alanine aminotransferase, gamma-glutamyltransferase, C-reactive protein, blood pressure and low HDL-cholesterol were significantly associated with overweight and obesity in adolescent boys. Elevated insulin, C-reactive protein and low HDL-cholesterol were significantly associated with overweight and obesity in adolescent girls. The presence of two or more risk factors was significantly higher in obese boys (74% vs. 8%, $p < 0.001$) and girls (44% vs. 5%, $p < 0.001$) compared to non-overweight children.²⁷

1.1.2.3 Nutritional Intake in Aboriginal and Torres Strait Islander Australians

There are limited population data on the dietary intake of Indigenous Australians. Neither the 1995 National Nutrition Survey or the 2007 Australian National Children's Nutrition and Physical Activity Survey reported data by Indigenous status. Fruit and vegetable intake was collected in the 2004/5 National Aboriginal and Torres Strait Islander Health Survey. Among Indigenous Australians ≥ 12 years old, 95% reported eating vegetables daily and 86% reported eating fruit daily; intake was significantly higher in non-remote than remote areas (98% versus 85% for vegetables and 88% versus 80% for fruit). Among Indigenous Australians in non-remote areas, 42% met Australian dietary guidelines for fruit intake and 10% for vegetables intake. Fruit intake was significantly lower, while vegetable intake was similar to non-Indigenous Australians.⁵ These self-reported data contrast with the lower intake of fruit and vegetables reported using the store-turnover method in remote areas.²⁸

Existing data on nutritional intake of Indigenous Australian adults are mostly from remote areas. A 2008 study from Townsville of 100 overweight mostly female

Indigenous adults was the first to report on nutritional intake among those from an urban area.²⁹ The 24-hour recall data indicated poor nutrient density with intake of vitamins A, B1, B2, B3, C, folate, magnesium, calcium, phosphorus, iron and zinc all below the EAR and significantly lower intake of vitamins A, B3, C, potassium, magnesium, iron and fibre, but significantly higher intake of protein and cholesterol compared to Australian adults in the 1995 National Nutrition Survey. Food consumption by this group of urban Aboriginal and Torres Strait Islander adults reflected Western dietary patterns, with limited intake of traditional foods. The intake of white bread, red and processed meat, added sugar and added butter was higher than that reported in the 1995 National Nutrition Survey.²⁹ This is consistent with an earlier study of urban and rural Indigenous Australians in Victoria, which found significantly higher frequency of use of salt and dripping in cooking and more frequent intake of takeaway food compared to non-Indigenous adults in the same locations.³⁰

In the 2008 National Aboriginal and Torres Strait Islander Social Survey, among Indigenous Australian children aged 1-14 years, 59% ate fruit daily and 53% ate vegetables daily. In non-remote areas, 4-7 year olds were significantly more likely to meet recommended fruit and vegetable intake (62% for fruit and 60% for vegetables) than 12-14 year olds (21% for fruit and 19% for vegetables).⁵ There are limited other data on non-remote Indigenous Australian children. In a study of 157 children aged 5-12 years (46% Aboriginal and Torres Strait Islander) in Townsville, 97.4% had inadequate intake of 1 or more core food groups with no difference between Indigenous and non-Indigenous children. Indigenous children were significantly less likely than non-Indigenous children to meet recommended intake of dairy foods (31% vs. 52%), vegetables (33% vs. 53%) and meat/meat alternatives (68% vs. 85%) but had similar proportions meeting recommended intake of fruit (65% vs. 59%) and bread/cereals (71% vs. 74%).³¹ Gwynn et al reported on the nutritional intake of 215 children aged 10-12 years (38% Aboriginal) from rural NSW.³² Aboriginal children had significantly higher intake compared to non-Indigenous children of total energy, carbohydrate, glycemic load and total fat, but similar intake of protein and micronutrients. Intake of calcium, magnesium, and fibre was inadequate and sodium intake was above recommended levels in both Aboriginal and Non-Indigenous children.

The limited data suggests that the nutritional intake of non-remote Aboriginal and Torres Strait Islander people is characterized by inadequate intake of F&V and many

important nutrients. However, this reflects similar patterns for non-Indigenous people in the same communities. These data have not reported or been adjusted for socioeconomic status (SES) which has an important impact on dietary intake (see section 1.3.2). The impact of low SES is likely to be a relevant factor mediating dietary intake in Aboriginal and Torres Strait Islander people.

1.1.2.4 Obesity and Disadvantage

The prevalence of obesity is higher among Aboriginal and Torres Strait Islander people and certain ethnic groups in Australia. The National Aboriginal and Torres Strait Islander Health Survey 2004/5 sampled a nationally representative sample of 10,439 Indigenous Australians of all ages. Among Indigenous Australian adults, 25.7% were overweight, 28.4% were obese, 26.8% were acceptable weight and 3.2% were underweight. In comparison, among non-Indigenous Australian adults 32.6% were overweight and 16.2% were obese in the National Health Survey 2004-5.³³ Missing BMI data were more common among the Indigenous sample (16% versus 8%) which suggested that the proportion of obese Indigenous adults may have been even greater.

Among Australian children, the prevalence of obesity varies with ethnicity. However, the data for Indigenous children have shown variable prevalence in different areas. A national survey of 7889 Australian schoolchildren aged 5-18 years in 2006 found an overall rate of obesity of 6.4%.²⁵ Males aged 12-18 years had significantly higher proportion of obesity compared to females. In this study, a significantly lower proportion of Caucasian and Asian children were obese and a much higher proportion of Pacific Islander and Arabic children were obese (around 20%). A higher proportion of Aboriginal and Torres Strait Islander boys 6-11 years (8.6%) and girls 12-18 years (9.1%) were obese compared to Caucasian children. However, the numbers of children in all non-Caucasian ethnic groups were small and significant trends were reported only for the overall comparison. A cross-sectional study of 2266 primary school age children in NSW with 55% Aboriginal children found an overall obesity rate of 7.1% with no significant difference between Aboriginal and non-Indigenous children.³⁴ In a cross-sectional study of 158 Torres Strait Islander children aged 5-17 years, 15% were obese and 31% were overweight.³⁵ In this study, in the overall sample 27% were hypertensive, 43% had acanthosis nigricans and 17% met criteria for the metabolic syndrome, while in the overweight/obese group, 56% had increased fasting insulin and 33% met criteria for the metabolic syndrome.

Obesity has also been associated with low SES among children. In the national survey of Australian school children discussed above, the proportion of obese students from low SES schools, middle SES schools and high SES schools was 8.8%, 6.3% and 4.3% respectively (Chi squared test for trend for obesity by SES=32.7, $p<0.001$).²⁵ However, another study comparing data from surveys of 7-15 year old NSW schoolchildren in 1985, 1997 and 2004 found no statistically significant difference in rate of change in obesity prevalence by SES.³⁶ A New Zealand study of 9,107 high school children aged 13-17 years found 10% obese and 24% overweight. There was a significant association between BMI and local area SES ($p<0.001$) and ethnicity ($p<0.001$) and a significant interaction between low SES and BMI among Maori, Pacific Islander and Caucasian children.³⁷

1.1.3 Cardiovascular Disease and Nutrition

The high prevalence of cardiovascular disease globally emphasises the importance of primary and secondary prevention strategies to reduce its impact. The main potentially reversible risk factors for cardiovascular disease include smoking, dyslipidaemia, obesity, hypertension, diabetes and insulin resistance, physical inactivity, increased thrombosis, high inflammatory markers, high homocysteine and impaired fetal nutrition. Observational studies, including longitudinal cohort studies, and animal models have firmly established the association between reduced risk of cardiovascular disease and increased intake of many foods and nutrients including fish, wholegrain cereals, fruit and vegetables, nuts, garlic, moderate alcohol consumption, fibre, ω -3 PUFAs and antioxidant nutrients. These studies have also established the increased risk of cardiovascular disease associated with dietary cholesterol and trans-unsaturated fatty acids. It is possible to understand the effect of many of these foods by their actions on these risk factors.³⁸

The most important nutrition related risk factor is dyslipidaemia. The oxidation of LDL facilitates the deposition of cholesterol in atheromatous plaques. Although genetic factors play a role in cholesterol levels, high saturated fat intake also increases LDL-cholesterol while high intake of ω -6 PUFAs reduces LDL-cholesterol.³⁸ High intake of refined carbohydrates, particularly fructose, also contributes to dyslipidaemia, specifically increase triglycerides and reduced HDL-cholesterol.³⁹ Dietary antioxidants

including vitamin C, vitamin E, carotenoids and flavonoids may reduce LDL oxidation and thus decrease cardiovascular (CVS) disease.³⁸

Thrombosis on ruptured atheromatous plaques is an important step in the pathophysiology of cardiovascular disease. Thus, increased intake of ω 3-PUFAs which reduce platelet aggregation has an inhibitory effect on thrombogenesis. Other dietary factors, such as low saturated fat intake, high PUFA to saturated fat ratio and high fibre intake, which reduce clotting factors may also contribute to reducing thrombosis.³⁸

Hypertension is a highly prevalent CVS disease risk factor. One of the most important dietary factors affecting blood pressure is sodium intake. It has been estimated that reducing sodium intake to below 3000mg (50 mmol)/day would reduce mean systolic blood pressure sufficiently to decrease stroke incidence by 26% and ischaemic heart disease by 15%.⁴⁰ Other dietary factors have also been shown to reduce blood pressure including increased F&V intake and low fat dairy intake; these are most effective when combined with low sodium and have the largest effect when blood pressure is raised.⁴¹

Diabetes, insulin resistance and obesity, particularly central obesity, all increase the risk of CVS disease. These conditions are also mutually reinforcing. Dietary factors increase the risk of developing insulin resistance and Type 2 diabetes, particularly high intake of saturated fat and refined carbohydrates, low intakes of fibre and low glycaemic index foods.³⁸ High intake of F&V, specifically green leafy vegetables and fruit, has also been associated with reduced risk of developing Type 2 diabetes, particularly in women.^{42, 43} Obesity increases dyslipidaemia and hypertension in addition to insulin resistance. Weight loss reduces these conditions and metabolic changes.³⁸

Clinical trials have reinforced these findings from observational studies. There is strong evidence that decreasing saturated fat and increasing polyunsaturated fats, particularly ω -3 PUFAs, reduces cardiovascular disease and overall mortality. The Lyon Diet Heart study, a RCT comparing the Mediterranean diet plus ω -3 PUFA-rich margarine with the standard French diet resulted in a marked reduction in mortality in patients after a myocardial infarction.⁴⁴ The Mediterranean diet involves high intake of F&V, legumes, bread and olive oil, moderate alcohol and limited meat and dairy foods. Other dietary patterns, including vegetarian diets, that reduce saturated fat and meat, promote high intake of F&V, whole grains, fat from unmodified vegetable oils, protein from fish, nuts

and seeds and avoiding excessive weight gain have been shown to reduce cardiovascular disease.³⁸

1.1.4 Cancer and Nutrition

As for cardiovascular disease, the role of nutrition on different cancers has been a major research focus for many years. The interaction between lifestyle, diet and genetics was highlighted by the contrasting incidence of cancers in different countries and the change in incidence seen in migrants and their children (changing rapidly to reflect cancer distribution in the new country).³⁸ Longitudinal cohort studies have not demonstrated the associations between nutritional factors and cancer incidence as consistently as for cardiovascular disease.^{45,46} This may be due to the complex interaction of factors involved in the initiation and progression of many cancers over an extended period. For example, it has been suggested that life-long fruit and vegetable intake, especially in early childhood, may be required to reduce cancer risk.¹⁸ Despite this, there is strong evidence of the role of nutrition in certain cancers.

Colorectal cancer is one of the most common cancers in most high income countries, particularly those with a Western diet. A comprehensive review by the World Cancer Research Fund concluded that processed meat and red meat are associated with increased risk of colorectal cancer.⁴⁷ The relative risk of colorectal cancer was 1.43 (95% CI 1.05-1.94) per serve of red meat/week in a meta-analysis of seven cohort studies. The relative risk of colorectal cancer was 1.21 (95% CI 1.04-1.42) per 50g processed meat/day in a meta-analysis of five cohort studies.

Body fatness (measured by BMI) is associated with increased risk of various cancers including colorectal, oesophageal, breast (post-menopausal), pancreas, endometrium and kidney.⁴⁷ For example, meta-analysis of 28 cohort studies found an increased risk of colorectal cancer of 15% per for each 5kg/m² and meta-analysis of 17 cohort studies found an increased risk of post-menopausal breast cancer of 8% per 5kg/m².⁴⁷ Obesity may increase cancer risk through several mechanisms including insulin resistance, increased levels of insulin-like growth factor and leptin, all of which can promote the growth of cancer cells. The hormonal changes associated with obesity include increase levels of sex steroid hormones, which increase the risk of several cancers, particularly breast cancer. Obesity also induces low-grade chronic inflammation resulting in

elevated levels of many cytokines that may also increase cancer risk.^{38, 47} As noted for diabetes, weight loss can reverse or reduce many of these metabolic changes.³⁸

Dietary factors which are likely to reduce the risk of certain cancers include increased dietary fibre, whole grains, dairy products and fruits and vegetables.^{18, 38, 47} The 2007 World Cancer Research Fund report found that the evidence for the protective effect of dietary fibre was stronger than their 1998 report. Meta-analysis of 8 cohort studies found that the RR of colorectal cancer is 0.90 (95% CI 0.84-0.97) with each additional 10g fibre/day.⁴⁷ However, a separate meta-analysis of 13 cohort studies found that the reduction in relative risk of colorectal cancer from increased dietary fibre was attenuated after adjustment for other risk factors, including intake of red meat, milk, alcohol, folate, total energy and non-dietary risk factors.⁴⁸ This is consistent with the observation that healthy lifestyle factors are correlated and that it may be more appropriate to study overall dietary patterns.

The World Cancer Research Fund report found that there is insufficient evidence of the association between any dietary pattern and cancer risk. This is due to the difficulty classifying dietary patterns, confounding by non-dietary factors, the focus of standard epidemiological studies on individual foods and reporting bias.⁴⁷ However, this report did note an association between the ‘western’ dietary pattern, characterized by high intake of meat, milk and other dairy products, refined grains, fatty and sugary foods and sugar-containing drinks, and increased risk of cardiovascular disease, Type 2 diabetes, obesity and some cancers. This section has highlighted the link between nutrition and the major causes of mortality in Australia and other similar high income countries.

1.1.5 Short-term benefits of improved nutrition

1.1.5.1 Oral Health and Nutrition

As the entry point of food to the body, the oral cavity is an obvious location to consider in the link between nutrition and health. There is a synergistic two-way relationship between nutrition and oral health.⁴⁹ Adequate nutrient intake is necessary both prenatally and after birth for normal growth of the oral cavity.^{49, 50} Mild to moderate malnutrition and/or folate deficiency has been shown to increase dental caries in both deciduous and permanent teeth.⁵⁰ The loss of teeth is both a cause and a consequence of reduced diet quality. For example, severe tooth loss (≤ 10 teeth remaining) was associated with lower intake of important food groups including total fruit, meats and

beans and oils and higher intake of saturated fat, added sugar and alcohol among 635 older adults in the USA after controlling for socio-economic status, education, age and sex.⁵¹

Dental caries are highly prevalent throughout the world. In the USA, 42% of 6-18 year old children and 90% of adults had caries in a recent survey.⁴⁹ Among Australian children, 48.7% of 5-6 year olds had dental caries in deciduous teeth and 45.1% of 12 year olds had decay in permanent teeth.⁵² In developed countries, as overall dental hygiene and care have improved, dental caries are disproportionately found in those from low socio-economic groups and disadvantaged ethnic minorities.⁵⁰ In Australia, this is illustrated by the higher rates of dental caries in Indigenous Australians, in both deciduous (2.25x higher) and permanent teeth (1.68x higher).⁵³ Even greater disparity is seen in the USA, where one survey found 5x increased rate of untreated caries in low income children and 6x increased rate of untreated caries in Native American children aged 2-4 years.⁵⁴ Extensive early childhood caries in the anterior maxillary teeth are strongly linked to feeding with sweetened beverages, high intake of sugary foods and being poor.⁴⁹ This is a striking example of the relationship between oral health, nutrition and social disadvantage.

1.1.5.2 Nutrition and the Immune System

Severe infections and high rates of mortality are frequently seen in severely malnourished populations.^{55, 56} What is the relevance of this link to relatively well nourished populations in high income countries? There is increasing evidence of dietary patterns characterized by excessive energy intake and micronutrient deficiencies in high income countries. Subclinical micronutrient deficiencies are likely to occur in countries such as the USA where intake < 50% of RDA is seen in up to 20% of the population.⁵⁷ These micronutrient deficiencies, particularly zinc, iron, selenium, vitamins A, C, E and β -carotene have been associated with clinically significant immune deficiencies and infections in children.⁵⁷ The mechanisms by which micronutrient deficiencies and infections are mutually reinforcing includes reduction in the physical barriers to infectious agents and reduced functioning of the immune system.⁵⁸ Vitamins A, B6, B12, C, D and E and zinc, iron, copper, selenium and folate have important roles supporting the protective activity of immune cells and vitamins A, B12, D and E and zinc enhance antibody production.⁵⁹

1.1.5.3 Healthy Lifestyles and Mortality Outcomes

Healthier lifestyles and behaviours are strongly correlated in adults^{60, 61} and children^{62, 63}. People who have high fruit and vegetable intake are also more likely to not smoke, be physically active and not drink alcohol at hazardous levels. Large prospective cohort studies have established that the more of these four healthy behaviours people have, the better the health outcomes and the lower the mortality.^{60, 64} Using data from 16,958 adults in NHANES III, Ford et al showed that having all 4 healthy lifestyle factors was associated with reduced mortality from all causes compared to those with none of these factors (Adjusted hazard ratio [AHR] 0.37, 95% CI 0.38-0.49), mortality from cancers (AHR=0.34; 95% CI=0.20-0.56) and mortality from cardiovascular disease (AHR=0.35; 95% CI=0.24-0.50).⁶⁴ The EPIC-Norfolk cohort study of 20,244 adults aged 45-79 in the UK showed that having none of these same four healthy behaviours compared to those with four was associated with increased mortality rates from all causes (relative risk (RR 4.04, 95% CI 2.95-5.54), cardiovascular disease (RR 5.02, 95% CI 2.93-8.61) and cancer (RR 3.74, 95% CI 2.34-5.98).⁶⁰ This association between healthy behaviours and lower mortality remained after adjustment for socio-economic status, which is also strongly correlated with healthier lifestyles in high income countries.^{60, 65} Although presented in opposite ways, these two studies report similar estimates of the relationship between healthy lifestyle behaviours and mortality. This is seen in the use of the observed mortality risks at different ages to calculate the equivalent chronological age advancement from change in mortality risk due to healthy behaviours. The impact of 4 healthy behaviours compared to none was estimated to be equivalent to being 14 years younger in the UK study⁶⁰ and 11.1 years younger in the US study⁶⁴.

These healthy lifestyle factors are also associated with better self-reported health. Tsai et al found among 430, 912 adults in the USA that those with all four healthy behaviours were 33% more likely to report optimal health than those with none.⁶⁶ In an intervention study of 9322 Danish adults, Pisinger et al found initially that those with all four healthy behaviours reported significantly better physical and mental health.⁶⁷ In this study, 6784 people were then randomly assigned to a healthy lifestyle intervention involving a comprehensive health assessment and healthy lifestyle consultation at baseline and after five years, with those at high risk for cardiovascular disease also receiving invitations to smoking cessation and/or diet and exercise groups at 0, 1 and 3 years and compared to 3324 controls who completed health assessments at baseline and

after five years. Those in the intervention group who reported an increase in physical activity were significantly more likely to report improved physical health (OR 2.3, 95% CI 1.7-3.2) and those who reported a much healthier diet were significantly more likely to report improved mental health (OR 1.68, 95% CI 1.1-2.5).⁶⁷

The contribution of healthy diet to these improved health outcomes is important although not perhaps as large as the impact of not smoking. In the EPIC-Norfolk study, Khaw et al found that having a low F&V intake (based on vitamin C level) was associated with an increased risk of death from all causes (RR 1.44, 95% CI 1.31-1.59) compared to high F&V intake, while current smokers had a higher risk of death from all causes (RR 1.77, 95% CI 1.55-2.01) compared to non-smokers.⁶⁰ Among the 430,912 adults who completed the Behavioural Risk Factor Surveillance System Survey in the USA, 70.9% were not currently smoking with 55.5 % reporting one or more healthy behaviours in addition to not smoking, while only 22.9% reported eating F&V five or more times/day of which almost all (22.2%) reported 1 or more other healthy behaviour. However, there were similar prevalence ratios for optimal self-reported health (~1.2) in all those who reported 2 or more of the four specified healthy behaviours compared to those with none of the behaviours.

Interventions that impact on individual behavioural risk factors, including improved nutrition, can have a positive impact on self-reported health and health outcomes.⁶⁸ However, there has been growing interest in the potential for multiple health behaviour change to address these clustered health behaviours simultaneously or sequentially to enhance effectiveness and cost-effectiveness.^{66, 69} Prochaska et al propose that successfully changing one health behaviour may increase self-efficacy and use the window of opportunity to build healthier behaviours.⁶⁹ There is some evidence that smoking cessation is associated with increased uptake of other healthy behaviours, particularly increased physical activity, in observational studies.^{69, 70} In a UK community-based intervention to promote F&V intake and awareness in adults from disadvantaged areas, Ashfield-Watt et al found that current smokers had lower baseline F&V intake than non-smokers and F&V intake declined in smokers but was unchanged in non-smokers after the intervention.⁷¹ Thus, the increasing success of recent multiple behaviour change interventions⁶⁹ and greater knowledge of the key factors that promote successful behaviour change⁷² suggest that this may be important to consider to promote the success of nutrition programs.

1.1.5.4 Emotional State, Cognitive Functioning and Nutrition

The inter-relationship between healthy lifestyle and improved health status is also reflected in emotional health. In a cross-sectional study of 34,603 employed adults reporting any three of four health lifestyle factors: not currently smoking, adequate physical activity, 5 or more serves of F&V/day and low alcohol intake was associated with significantly lower self-reported depression, emotional health affecting daily life and risk of stress.⁷³ A cross-sectional analysis of data from 1324 14 year old children in the Western Australian Pregnancy Cohort Study compared the association between two dietary patterns: a Western dietary pattern (high in takeaway foods, red meat and sweets) and a healthy dietary pattern (high in vegetables, fruit, whole grains and legumes) and children's behaviour (as a marker of mental health). A significant association was found between worse behavioural scores (higher levels of depressed, withdrawn, aggressive, delinquent behaviours) and Western diet after adjustment for total energy intake, BMI, physical activity, screen use, family structure, income and functioning, gender and maternal education. Better behavioural scores were associated with higher intake of leafy green vegetables and fruit.⁷⁴ This is an emerging area of research, with only a limited number of studies, but the positive association between healthy nutrition and emotional health is consistent with the link between nutrition and mental health described earlier.

1.1.5.4.1 *Cognitive function in children*

A positive association between cognitive function and nutrition has been described in children. Sorhaindo & Feinstein reviewed this evidence and concluded that adequate glucose is required to optimise cognitive function and that metabolic changes due to inadequate food intake in children is associated with reduced cognitive function and poorer school performance in the short-term.⁷⁵ This was particularly evident in children with poor nutritional status. A more recent systematic review concluded that high quality evidence of these links is limited.⁷⁶

There is an increasing evidence of the benefit of long chain polyunsaturated fatty acids in improving neurodevelopmental outcomes and cognitive performance, particularly in children with developmental and behavioural problems such as attention-deficit hyperactivity disorder and dyslexia.^{75, 76} Adequate intake of these long chain polyunsaturated fatty acids in infancy has been found to have longer-term impacts. A RCT of 79 term infants compared the impact of formula with or without

docosahexaenoic acid and/or arachidonic acid. There was also a non-randomised breast-fed comparison group. Infants who received docosahexaenoic acid and arachidonic acid supplemented formula had similar visual acuity and IQ scores to breast-fed infants, while control infants had significantly lower visual acuity and verbal IQ scores than breast-fed infants.⁷⁷

Other micronutrients have been shown to improve neuropsychological function. Zinc and iron deficiencies are associated with reduced neuropsychological function in children⁷⁸ and the critical importance of iodine during gestation and infancy on brain development has been highlighted.⁷⁹ Deficiencies of the B group vitamins, particularly vitamin B12 and folate, have also been linked to decreased cognitive performance in adults. One US study showed that vitamin B12 deficiency in early childhood was associated with reduced cognitive test performance in 10-18yo children.⁷⁹

1.1.5.4.2 Cognitive Function in Adults

The cognitive benefits of healthy patterns of living are not restricted to children. In older adults, healthier eating patterns are associated with adequate cognitive capacity and higher cognitive test scores. Requejo et al found that Mini-Mental State Examination scores ≥ 28 were associated with significantly higher intake of total food, fish, alcohol, vitamins B1 and C and folate and lower intake of saturated fat and sugar in 168 Spanish community-dwelling adults aged 65-90yo.⁸⁰ Higher F&V intake was associated with both higher cognitive test scores and increased plasma carotenoids and vitamin E in 193 older adults aged 45-102 years.⁸¹ These results were adjusted for age, gender, education and standard vascular disease risk factors.

Recent prospective longitudinal studies have shown that the Mediterranean diet is associated with reduced cognitive decline in older adults. The Chicago Health and Ageing Project is an ongoing longitudinal study of 3790 adults aged 65 years and over in the USA. After mean follow-up of 7.6 years, adherence to the Mediterranean diet was significantly associated with decreased rate of cognitive decline (using composite measures every three years) after adjustment for age, sex, race, education, energy intake and participation in cognitive activities.⁸² This study also compared the effect of adherence to the USA dietary guidelines (assessed using the Health Eating Index-2005) and found no association with cognitive decline. Another longitudinal cohort study of 1410 adults 65 years or older in France found that adherence to a Mediterranean diet

was associated with significantly reduced rate of cognitive decline (based on minimal state examination but not on three other measures of cognitive function).⁸³

The impact of medical comorbidities, such as diabetes mellitus, hypertension and hyperlipidaemia, and lifestyle factors, such as smoking or high alcohol intake, are also associated with cognitive decline.⁸⁴ It is difficult to separate the impact of nutrition on the brain from its contribution to these other vascular disease risk factors and from the interaction with other healthy lifestyle factors. However, there is increasing evidence of the role of essential nutrients, particularly ω -3 fatty acids, in the development and function of the central nervous system.⁸⁵ The potentially reversible dementia caused by vitamin B12 and folate deficiencies underscores the importance of nutrition to cognitive function.⁸⁴

1.1.6 Maternal and Fetal Nutrition

The importance of good nutrition is exemplified during pregnancy, with optimal growth of the fetus dependent on maternal, fetal and placental systems working together to transfer maternal nutrients to support fetal growth. If chromosomal and genetic disorders are excluded, fetal size is mainly determined by the supply of these nutrients and oxygen from the mother.⁸⁶ In addition to supporting feto-placental growth, there are also significant changes in the mother, such as an increase in red cell mass and increased fat deposition, to support the pregnancy and prepare for lactation. This indicates the need for increased intake of both macronutrients and many micronutrients.⁸⁷

The increase in macronutrient requirements is not that large, for example increased protein requirements are estimated at 6-10g/day.⁸⁶ However, the balance of macronutrients in the maternal diet, particularly protein intake in early pregnancy, may be important in determining birth weight.⁸⁶ The finding that high protein supplements increased the risk of small for gestational age births⁸⁸ has implications for the design of nutritional support programs in pregnancy. Fetal uptake of fatty acids depends on the maternal blood lipids and ultimately dietary intake. Fatty acids are important due to the much higher level of body fat in the human fetus, compared to other mammals, and recent experimental evidence that increased maternal intake of essential fatty acids is associated with increased neonatal growth and head circumference.⁸⁶

The fetus is dependent on an adequate supply of micronutrients from the mother, with calcium, copper, iodine, iron, magnesium, selenium and zinc all essential. Deficiencies of these micronutrients are associated with an increase in pregnancy complications and abnormal fetal development. The role of folate in preventing neural tube defects is the most well recognised effect of micronutrient deficiency in pregnancy and it is estimated that folate fortification and supplementation could prevent 70% of neural tube defects.^{86, 89, 90} Deficiencies of selenium, copper and iodine have all been associated with increased risk of early miscarriage and iodine deficiency in the mother is a cause of mental retardation in the baby. The main cause of these mineral deficiencies is inadequate diet quality. Iron and iodine are the commonest mineral deficiencies globally, and are prevalent in women in high income countries. In both the UK and USA, average iron and magnesium intake were below recommended levels, with average dietary iron intake found to be ~70% of RDA and average magnesium intake estimated to be ~80% of RDA.⁸⁶ However, there are differences between countries. In Australia, increased rates of iodine deficiency have also been described over the last 10-15 years.^{91, 92}

There are many factors that contribute to the aetiology and pathogenesis of intra-uterine growth retardation (IUGR) with maternal smoking an important risk factor. Further study is needed to elucidate the mechanisms and potential treatments.^{86,93} However, IUGR clearly increases neonatal mortality and morbidity.⁸⁶ The common pathway in most cases is a lack of adequate transfer of essential nutrients, particularly glucose, amino acids and fatty acids, to the fetus via the placenta resulting in IUGR.⁹³ There is fetal adaptation to this situation with decreased insulin levels and increased insulin sensitivity. Maternal metabolic balance in early pregnancy, particularly insulin sensitivity and glycaemic control, has been shown to have a critical impact on the growth and metabolic development of the fetus.⁸⁶ This may be linked to an increased risk of obesity and diabetes mellitus in adulthood, as will be discussed further below.

1.1.6.1 Nutrition in Lactation and Infancy

Exclusive breastfeeding is widely supported as the optimal nutrition for babies up to the age of 6 months.^{94, 95} This results in increased energy requirements for the mother of an average of 2.6MJ/day, which is obtained from increased intake and fat stores.⁸⁷ There is a corresponding increase in nutrients from the additional food, which supplies most of the necessary nutrient requirements for the baby in well-nourished women.

Recommended intake of protein and major vitamins and minerals during lactation are

17-95% higher than non-pregnant, non-lactating levels.⁸⁷ The wide variation in increased requirements reflects the need for particular nutrients and their rate of utilisation by the fetus. The exceptions are calcium and iron. It appears that calcium is obtained from maternal stores and is independent of intake. Iron requirements decrease by 50% as long as the woman remains amenorrhoeic.⁸⁷

Dietary fats are the main source of energy for the infant supplying over half the energy requirements. The quality of dietary lipids in young children has been shown to have an impact on growth and development. Breast milk is an important source of essential fatty acids, particularly long chain polyunsaturated fatty acids. The reduction of ω -3 fatty acids in people's diets has implications for infant health outcomes and current recommendations are to eat fish twice a week and/or take 200mg docosahexaenoic acid supplements daily to increase ω -3 fatty acids to optimal levels.⁸⁶

1.1.6.2 Prenatal and Infant Nutrition and Long-Term Disease Risk

The link between maternal and infant nutrition and health outcomes extends beyond the obvious impacts on birth weight and complications of infancy. Increased understanding of epigenetics has highlighted the potential impact on long-term chronic disease risk. Clinical and epidemiological studies together with animal experiments suggest that maternal factors can alter the risk of metabolic disease later in life.^{96, 97} For example, maternal obesity and gestational diabetes mellitus increases the risk of type 2 diabetes in the child - due both to genetic predisposition and high maternal blood sugar levels.⁹⁸ The development of hypertension in adults is increased if the mother has had long-term poor nutrition, particularly in females.⁹⁹ These long-term, even multigenerational, effects on an individual's health have been shown (in animal models) to be passed on by both maternal and paternal factors.¹⁰⁰

Developmental plasticity is now used to describe this responsiveness of the fetus and infant to environmental cues, such as maternal hyperglycaemia. Understanding of the underlying mechanisms is evolving, but there is increasing evidence for the role of epigenetic changes, such as DNA methylation and histone modification,¹⁰⁰ and adaptation of the placental area.⁹⁹ The implications of developmental plasticity add further to the importance of public health interventions to support the nutrition of women, both pre-conceptually and during pregnancy, and infants. For children, long-

term follow-up studies which show limited benefit after the age of two years in reducing chronic disease risk emphasise the role of early intervention in childhood nutrition.^{96, 101}

1.1.7 Fruit and Vegetable intake and Health outcomes

There are low levels of fruit and vegetables intake in most parts of the world.¹⁰² Hall et al reported on fruit and vegetable intake in adults from 52 (mostly low and middle income) countries in the 2002-3 Global Health Survey.¹⁰³ Overall, they found 77.6% of men and 78.4% of women consumed less than the 5 serves of fruit and vegetables/day recommended by the World Health Organization. This intake varied significantly between countries and low fruit and vegetable intake was associated with increasing age and lower income. Data from high income countries show similar patterns of inadequate fruit and vegetable intake. In Australia, data from the National Health Survey in 2004-5 showed that 49% of people aged 15 or over ate less than two serves of fruit/day, and 91% ate less than five serves vegetables/day.³ In the USA, data from the Behavioural Risk Factor Surveillance System showed that 80% of males and 72% of females consumed less than five serves of fruit and vegetables/day in 2005.¹⁰⁴ An association between low socio-economic status and lower F&V intake is also seen in both the USA¹⁰⁵ and Australia.⁶⁵ A trend of declining fruit and vegetable intake is part of the nutrition transition with increased consumption of energy dense foods and animal or hydrogenated vegetable fats, while overall physical activity levels are declining and as a consequence overweight/obesity rates are rising sharply.¹⁰²

The low intake of fruit and vegetables has been identified as a significant factor which increases the risk of common non-communicable diseases. Large cohort studies in Europe and the USA have shown that the risk of chronic disease, particularly cardiovascular disease, is reduced by consuming recommended levels of fruit and vegetables.^{45, 106, 107} In the Nurses' Health Study and Health Professionals' Follow-up Study, Hung et al found a non-significant decrease in chronic disease incidence with a relative risk of 0.95 (95% CI 0.89-1.01) for those in the highest quintile of F&V intake compared to those in the lowest quintile and a significant decrease in the incidence of cardiovascular disease (myocardial infarction and stroke) with a relative risk of 0.88 (95% CI 0.81- 0.95) for those consuming five or more serves of F&V/day.⁴⁵ In the EPIC study, consuming eight serves of F&V/day was associated with a 22% decrease in risk of fatal ischaemic heart disease compared to three serves/day: relative risk 0.79 (95% CI

0.65-0.95).¹⁰⁶ Both studies adjusted for other cardiovascular disease risk factors including smoking, sex, age, BMI, level of physical activity, alcohol intake, dietary fat and fibre, total energy intake, education, employment, marital status, history of diabetes, hypertension or hyperlipidaemia and family history of ischaemic heart disease. A 2007 meta-analysis of cohort studies examining the incidence of ischaemic heart disease and F&V intake found that consuming 3-5 serves/day was associated with a relative risk of 0.93 (95% CI 0.86-1.00) and consuming >five serves/day was associated with a relative risk of 0.83 (95% CI 0.77- 0.89) compared to consuming < 3 serves/day.¹⁰⁸ These studies suggest that for each additional serve of F&V/day there is a 4% reduction in risk of ischaemic heart disease. A similar reduction was seen in incidence of ischaemic stroke with a relative risk of 0.69 (95% CI 0.52-0.92) for those in the highest quintile of F&V intake compared to the lowest quintile. This was equivalent to a 6% reduction in the incidence of stroke for each additional serve of F&V/day.¹⁰⁹ The reduction in cardiovascular disease associated with increased F&V intake is modest, but likely to be real given the consistent evidence from the large cohort studies and the meta-analysis.¹¹⁰

These large cohort studies have shown limited impact on cancer incidence from higher F&V intake. In the Nurses' Health Study and Health Professionals' Follow-up Study, there was no reduction in relative risk for incidence of cancer associated with five or more serves F&V/day, relative risk 1.00 (95% CI 0.95-1.05).⁴⁵ The EPIC study found a small inverse association between F&V intake and incidence of cancer, for a 200g increase in F&V, the relative risk of cancer was 0.97 (95% CI 0.96-0.99), while for a 100g increase in vegetables the relative risk of cancer was 0.99 (95% CI 0.97-0.99).⁴⁶ This is consistent with the downgrading of the assessment of the links between F&V intake and cancer in the second World Cancer Research Fund report.⁴⁷ This report rated F&V as probably protective for cancer of the oropharynx, oesophagus, lung and stomach and lycopene (mainly from tomatoes) as probably protective against prostate cancer.

Various mechanisms by which fruit and vegetable intake may reduce chronic diseases, particularly cardiovascular disease, have been proposed. The reduction in blood pressure due to increased fruit and vegetable intake¹¹¹ has been proposed as one possible factor.¹⁰⁸ Crowe et al discuss the increase in potassium, magnesium and other antioxidant nutrients having a role in reducing blood pressure and potentially atherosclerosis.¹⁰⁶ Eastwood proposed the interaction of multiple plant antioxidant

molecules to produce an integrated reductive environment within the body.^{112, 113}

Studies which have assessed the impact of individual or combinations of anti-oxidants in tablet form have produced inconsistent results, with evidence of increased risk of cancer in high risk groups such as smokers.^{47, 114} This suggests that the emphasis should remain increasing intake of fruits and vegetables as part of a healthy dietary pattern.

There is an extensive and ongoing public health campaign to promote fruit and vegetable intakes as part of the strategy to reverse the increasing rates of chronic diseases. It was initiated in high income countries in the 1990s as evidence of the association of low fruit and vegetable intake and increased risk of chronic disease began to accumulate. In Australia, the Go for 2 & 5 campaign has been widely used to promote the recommendation of 2 serves of fruit and 5 serves of vegetables/day. In the USA, the longstanding ‘5 a Day’ campaign has been replaced by Fruit and Vegies-More Matters, to reflect the latest American dietary recommendations.¹¹⁵ The ‘5 a Day’ concept has also been promoted in several European countries to reflect the advice to consume at least 400g of F&V/day. The World Health Organization has advocated increased fruit and vegetable intake, as part of the Global Strategy on Diet, Physical Activity and Health, using campaigns such as ‘5 a Day’ since 2003.¹¹⁶ These high profile health promotion and social marketing campaigns have also been supported by a range of school and community programs, such as the school-based Crunch and Sip program which promotes fruit and vegetable snacks in several Australian states.¹¹⁷ However, an economic analysis of nutrition initiatives aimed at healthy adults in 2010 concluded that many of them are not cost-effective and have the potential to reduce only a small percentage of the burden of disease due to low fruit and vegetable intake.¹¹⁸ The authors of this study suggested that other approaches that may change the distribution of low F&V intake in the whole population, such as policies to increase availability or access to affordable F&V or taxing unhealthy alternatives, may be more effective and cost-effective.¹¹⁸ This will be discussed further below.

1.2 Methods of Nutritional Assessment

This section outlines standard techniques of both dietary assessment and biomarkers and their role in nutritional assessment. It includes a discussion of their uses and limitations. It will provide the background to the rationale for combining 24-hour diet recalls with biomarkers involving children in this Aboriginal community-based study.

1.2.1 Dietary Assessment techniques

The traditional methods used in nutrition studies to assess people's dietary intake have been food records, 24-hour recalls, food frequency questionnaires and diet histories. Short dietary questions have been developed more recently as a simple, easier method to complement these other methods. The use of a specific technique depends on the study population, the resources available, the purpose of the study and the data required.¹¹⁹

1.2.1.1 Food Records

Food records are undertaken by the person (or carer) recording all food and fluids consumed over a specified period. Quantities may be weighed or estimated and are recorded in a standardized format as soon as possible after consumption. Weighed food records are the most accurate method, traditionally conducted over three days, and have been considered the gold standard for assessment of dietary intake. Other dietary assessment techniques are often validated against weighed food records. However, like all forms of dietary intake assessment, they have the potential for problems with validity, particularly modification of dietary intake due to the recording process.¹¹⁹⁻¹²¹

1.2.1.2 Twenty-four hour recalls

This method involves a trained interviewer asking a person (or carer) to recall everything that was consumed in the preceding 24-hour period. It may be done in person or via telephone. Food models are often used to assist with estimating quantities consumed. Completing recalls at person's home has been shown to improve recall.¹¹⁹ Ideally recalls should be conducted on all days of the week as intake is known to vary in a non-random way during a week.¹¹⁹

As within subject variability is large from day to day, a single 24-hour recall cannot reflect usual intake for each individual. However, a single 24-hour recall from each individual in a group provides an estimate of average intake for the group. The size of the group required (n) can be estimated from the equation:

$$n = s_b^2 / e^2 \text{ where } s_b = \text{between subject variance, } e = \text{desired standard error.}^{119}$$

The size of the group required for valid estimates of average intake depends on the variability within and between subjects but will generally require 50 or more people. In undertaking 24-hour recalls with children, it is generally advised that children ≥ 8 years can reliably complete a recall, while for children 4-8 years the recall should also involve the primary carer but still involved the child as consensus recall improves accuracy.¹¹⁹ The problem of under-reporting has been partially addressed by excluding recalls where energy intake/basal metabolic rate < 0.90 , as this level of intake has been shown not to be consistent with maintaining body weight.¹²²

1.2.1.3 Food Frequency Questionnaires

These questionnaires collect qualitative information about the frequency of consumption of specified foods over a given period, commonly the previous month or year. They may be self-administered or completed with an interviewer. They vary in length from short questionnaires containing only select food groups or detailed lists with up to 150 items to describe dietary diversity. Semi-quantitative information can be obtained by multiplying serves from simultaneous 24 hour recalls or average serves from nutrition surveys.¹¹⁹⁻¹²¹

1.2.1.4 Diet history

This method involves a trained interviewer recording a 24-hour recall together with a focused food frequency questionnaire and information about usual overall eating pattern - both meals and snacks with detailed overall eating pattern and usual portion sizes. This method provides the most detailed dietary information, but also requires the more time and input from interviewer and subject.¹¹⁹⁻¹²¹

1.2.1.5 Short dietary questions

This technique involves specifically designed questions to obtain estimates of intake of a limited number of foods/food groups. Participants are asked to estimate the average frequency and quantity of these foods to allow a quantitative measure of intake. They

have been validated in Australia to facilitate collection of dietary information as part of national surveys. The main advantage of this method is that it can be collected more quickly and easily. It is intended to supplement more detailed dietary information.^{123, 124}

1.2.2 The challenge of reducing error in dietary assessment

All dietary recall methods have the potential for measurement error - both random and systematic - which means that no method is able to completely describe the 'true' diet. Random error will tend to reduce the reproducibility of results, which is the ability of the method to produce similar results when used in the same setting. Systematic error affects the validity of the results or how closely the results represent the actual dietary intake. The consequences of these errors include inaccurate estimates of inadequate or excessive nutrient intake in the study population and attenuated correlations between nutrient intake and outcomes, which then obscures the relationship between diet and disease.^{119, 121}

The sources of error are common to most of the methods of dietary assessment although the relative importance varies with the particular technique. One of most important errors is respondent bias with under-reporting and (to a much lesser extent) over-reporting of intake. This is related to social desirability and perceptions about 'bad foods'. It has been found more commonly in overweight/obese and those dieting.¹¹⁹ Memory lapses are also important, particularly in recalls and food histories. Assessment of portion sizes is a particular challenge that affects quantitative methods such as 24-hour recalls and estimated food records. Similarly, inaccurate frequency of consumption, particularly overestimating certain foods is a problem for FFQs. Day to day variation in intake is a challenge for 24-hour recalls, although the impact varies depending on the specific nutrient. Other sources of error include low response rates, interviewer biases, food coding errors, omission of supplement use and inaccuracies in mixed food dishes.^{119, 120, 125, 126}

These errors are minimized and controlled in several ways. Random error can be reduced by increasing the sample size, emphasizing the role of sample size calculations in planning studies.¹²¹ Quality control strategies are important to deal with the challenges identified above.¹¹⁹ These include standardized interview techniques or questionnaires with training for interviewers, the use of pretesting or piloting of questionnaires and reinforcing compliance with interview techniques. Memory aids,

including food models, real samples or photographs, are used to improve quantity estimates. A standard multiple pass process is used in 24-hour recalls using iteration and probing to obtain the most complete data possible.^{119, 121} Minimising the time between consumption and recording reduces memory bias; it is suggested that food records are completed as food is eaten.¹¹⁹ Under-reporting of energy intake is commonly addressed by exclusion of those with implausible energy intakes based on basal metabolic rates, as proposed by Goldberg,¹²¹ although this has been criticized unless energy expenditure information is also measured.¹²⁰

1.2.3 Dietary assessment studies involving children

Recent Australian child nutrition surveys have used single or duplicate 24-hour recalls and food frequency questionnaires (FFQs) to facilitate comparisons with the 1995 national nutrition survey.¹²⁷⁻¹²⁹ Twenty-four hour recalls have been used in recent Australian nutrition intervention trials in Indigenous²⁹ and mainstream settings.¹³⁰ FFQs have been used and validated in young children,¹³¹ however some people, particularly children, find reporting usual intake difficult.¹¹⁹ Twenty-four hour recall was shown to have higher validity than a FFQ in 11-12yo Norwegian children.¹³² More generally, European researchers support the use of 24 hour recalls in children although they advocate the involvement of parents for children below 10 years of age.¹²⁶ Short dietary questions, such as those recently validated in 10-12yo Aboriginal and non-Aboriginal children in New South Wales,¹³³ have not been widely used in younger children.

Twenty-four hour recalls would appear to be the most appropriate to assess self-reported dietary intake of a cohort of children. Importantly such data will allow comparison with other recent Australian surveys involving children. Short dietary questions relevant to fruit and vegetable intake can be asked simultaneously without increasing the burden on participants greatly; this would provide useful comparative data on self-reported dietary intake, particularly for the older children.

1.2.4 Dietary assessment in Aboriginal and Torres Strait Islander people

The use of individual dietary assessment techniques was rigorously assessed by Lee et al¹³⁴ in a study in two remote Aboriginal communities in the Northern Territory in 1986. This study involved the comparison of 24-hour recalls, food frequency questionnaires, diet histories and weighed dietary records. This study also reported on the 'store-

turnover' method to assess community level dietary intake, using store sales data from the only retail food outlet in these isolated communities. The individual dietary assessment techniques were poorly accepted due to cultural and language barriers. The 'store-turnover' method was the most acceptable and was judged to have a lower risk of bias than individual dietary assessment. The 'store-turnover' method was used, together with nutritional biomarkers, to assess the impact of subsequent nutrition intervention studies.^{135, 136} More recently, Brimblecombe and O'Dea highlighted the limitations of the 'store-turnover' method due to the expansion of alternative food sources in remote Aboriginal communities.²⁸

In non-remote settings, the 'store-turnover' method is not feasible due to the availability of multiple food outlets. In these non-remote locations, the limited number of nutritional research studies involving Aboriginal people have used individual dietary assessment. Twenty-four hour recalls were used in studies involving adults in North Queensland.^{29, 137} A short FFQ together with dietary biomarkers were used to assess nutritional intake in 897 Indigenous Australian adults in the Darwin Region Urban Indigenous Diabetes study.¹³⁸ In a study involving Aboriginal and non-indigenous children in rural communities in New South Wales, Gwynn et al¹³⁹ validated short dietary questions against three 24-hour recalls. These authors acknowledged the concern about bias in the self-reported dietary intake, particularly for the Aboriginal children, and local Aboriginal researchers were considered important to minimize the cultural barriers to accurate self-reported dietary intake data. Thus, individual dietary assessment techniques have been considered valid and feasible in studies involving Aboriginal and Torres Strait Islander adults and children in both rural and urban locations. This reflects the substantial erosion of traditional culture and language among Aboriginal and Torres Strait Islander people due to far greater engagement with non-Indigenous Australians in more densely populated areas in Australia.

1.2.5 Biomarkers

1.2.5.1 Biomarkers as Indicators of Nutritional Status

A biomarker is defined as: "a characteristic that is objectively measured and evaluated as an indicator of normal biologic processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention."¹⁴⁰ Biomarkers are widely used in health research as proxy markers of health outcomes. As the definition indicates, they may

have a role in physiological or pathological processes, which explains their link to health outcomes. Advances in understanding of biologically active molecules in food have stimulated the investigation and use of biomarkers. It has been necessary to establish both the link between nutritional biomarkers and health outcomes and also their relationship to dietary intake.

In nutritional epidemiology studies, the role of biomarkers to improve the validity of self-reported dietary intake has been most important. The particular benefit of biomarkers is that they are regarded as more accurate and objective measures than self-reported dietary intake.^{120,141} As discussed previously, this is important due to the biases associated with self-report. There are, however, potential challenges with the use of biomarkers that may limit their accuracy and reproducibility. A high level of between and within subject variability, particularly in plasma, and confounding due to other biological factors, such as smoking, may obscure the association with true dietary intake.¹⁴² Recommendations to enhance this reliability of biomarkers have emphasised the importance of specimen collection, handling and storage and the use of standardized laboratory techniques with external and internal calibration.¹⁴³

There are several important criteria that are necessary if biomarkers are to be useful as indicators of nutritional intake. These include the ability to distinguish between different levels of intake and responsiveness to the interventions being trialled. They also need to be easily obtained and reproducible with standardised measurement techniques.¹⁴¹ Bingham has emphasised the distinction between recovery biomarkers and concentration biomarkers.¹²⁰ Recovery biomarkers, such as 24 hour urinary nitrogen and potassium, generally have very high correlations with intake of a nutrient and can be used to measure absolute intake. Concentration biomarkers, such as serum vitamin C and carotenoids, have only moderate correlation with intake and thus cannot accurately assess absolute intake but are useful to rank intake of nutrients.¹⁴²

The health benefits associated with increased F&V intake have stimulated interest in potential biomarkers of F&V intake. This research has focused on substances found in fruit and vegetables which demonstrate the criteria discussed above. This includes carotenoids, vitamin C, folate and flavonoids. The focus is on both their responsiveness to different levels of intake and also increased understanding of their role in biochemical processes that contribute to better health outcomes.

1.2.5.2 Carotenoids

Carotenoids are the pigmented compounds which provide fruits and vegetables with their distinctive colours. There are many naturally occurring carotenoids but six of these are the predominant carotenoids found in commonly consumed fruits and vegetables and in humans: β -carotene, α -carotene, β -cryptoxanthin, lycopene, lutein and zeaxanthin. The physiological role and potential health benefits of carotenoids are areas of active research. There has also been considerable interest in establishing the role of these carotenoids as markers of fruit and vegetable intake.

1.2.5.2.1 Carotenoids - Sources and Bioavailability

Fruit and vegetables are the predominant source of carotenoids in the diet.¹⁴⁴ The six common carotenoids are found in different concentrations in specific fruits and vegetables.¹⁴⁵⁻¹⁴⁷ β -carotene is found in many yellow, orange and green fruits and vegetables, particularly carrots, pumpkin, sweet potato, spinach/other leafy green vegetables, rockmelon, lettuce and tomatoes. β -carotene is the most widely distributed carotenoid. α -carotene is found predominantly in carrots and pumpkin. β -cryptoxanthin is found in many red/orange F&Vs, particularly pumpkin, papaya, mandarin, red capsicum, oranges, corn and watermelon. Lycopene is found in red F&Vs including tomatoes and watermelon. The major source of lycopene in the diet is tomatoes and tomato products. Lutein and zeaxanthin are found in many green F&Vs, particularly spinach and other leafy green vegetables, peas, pumpkin, brussels sprouts and broccoli.

The bioavailability of dietary carotenoids depends on their release from the plant matrix.^{145, 148} This was shown in a study where supplementary β -carotene was more bioavailable than dietary β -carotene as it did not need to be released from the plant matrix.¹⁴⁹ Carotenoids are highly fat soluble, except lutein and zeaxanthin which are more water soluble.¹⁵⁰ Thus, absorption is generally enhanced by chopping/processing and consuming together with fats.¹⁴⁵ However, individual carotenoids still vary in their bioavailability.¹⁴⁹

1.2.5.2.2 Carotenoids - Normal ranges and determinants in children

The range of carotenoids in healthy children has been reported in studies undertaken in Europe, North America and Australasia. Ford et al¹⁵¹ reported on carotenoid levels in 4231 children aged 6-16 years using data from the third National Health and Nutrition Examination Survey (NHANES III) in the USA. They found that β -carotene, α -

carotene, β -cryptoxanthin, lutein and zeaxanthin decreased with age, particularly among 12-16 years olds, while lycopene remained unchanged. Boys had slightly higher levels of carotenoids than girls but this was only statistically significant for lycopene. BMI was inversely associated with all carotenoid levels except for lycopene. Other important covariates in this sample were C-reactive protein, total and HDL cholesterol, cotinine concentration and ethnicity. Cotinine, as a marker of tobacco smoke exposure, was inversely associated with β -carotene, α -carotene, and β -cryptoxanthin. In this sample of American children, African-American children had higher levels of β -cryptoxanthin, lutein and zeaxanthin and lycopene but lower α -carotene than white children while Hispanic children had higher α -carotene, β -cryptoxanthin, lutein and zeaxanthin but lower lycopene than white children.

Malvy et al¹⁵² found β -carotene decreased with age among 587 French children aged 3-16 years, although there was no association with gender. There were similar trends in a sample of 129 German children aged 1-18 years with α -carotene and β -carotene decreasing with age while lycopene increased with age and gender showed no association with carotenoids.¹⁵³ Karr et al found a mean β -carotene of 0.30 $\mu\text{mol/L}$ in 467 Australian children aged 1-5 years- with no association with age or gender.¹⁵⁴

1.2.5.2.3 Carotenoids and Fruit and Vegetable intake

There have been several large observational studies which have established the correlation between dietary intake of F&V and serum levels of carotenoids. These studies have also provided information about other factors which influence serum carotenoids. Data from NHANES III in the USA provided large samples of carotenoids from both adults and children. Gruber et al¹⁵⁵ found a moderate correlation ($r=0.17$) between dietary lutein/zeaxanthin intake and serum levels in 7059 adults >40 years. Ford et al¹⁵¹ found significant positive association between fruit and vegetable intake and the concentration of all major carotenoids except lycopene among 1415 adolescents.

The European Prospective Investigation into Cancer and Nutrition (EPIC) study extended this analysis by reporting on the correlation between serum carotenoids and specific fruit and vegetables among 3089 adults in 9 European countries.¹⁵⁶ The strongest correlation was between β -cryptoxanthin and total fruits ($r=0.52$), lycopene was strongly correlated with tomato and tomato products ($r=0.38$) and α -carotene with root vegetables ($r=0.39$) and total carrots ($r=0.38$). It was noted that β -carotene had only

moderate correlation with vegetables ($r=0.21$) and fruit (0.11) despite being the most widely distributed carotenoid. These correlations were based on FFQs. Dietary intake data were also collected using 24 hour diet recall which found slightly lower correlations than those reported using FFQ.

Dauchet et al¹⁵⁷ investigated a more limited range of biomarkers among 3521 adults aged 35-60 years. They found a moderate association between fruit and vegetable intake and vitamin C ($r=0.38$) and β -carotene ($r=0.20$) using multiple 24 hour diet recalls. They found no association between fruit and vegetable intake and vitamin E. Females had higher levels of vitamin C (18%) and β -carotene (33%) than males. This study also demonstrated significant linear dose-response relationships between fruit and vegetable intake and β -carotene and vitamin C.

1.2.5.3 Vitamin C

Vitamin C is also predominantly found in fruit and vegetables. High levels of vitamin C are found in many fruits and vegetables particularly peaches, red capsicum, oranges and orange juice, grapefruit juice, apricot nectar, papaya, strawberries, broccoli, brussel sprouts, green capsicum, and kohlrabi.¹⁴⁶ Vitamin C is water soluble and its absorption is not affected by the presence of fat.

Thus, changes in vitamin C levels can complement observed changes in carotenoids. The findings of Dauchet et al of a moderate correlation ($r=0.38$) between vitamin C and F&V intake¹⁵⁷ (see Section 1.2.4.2.3) has previously been shown in other smaller studies. Block et al found that vitamin C had a higher correlation with F&V intake ($r=0.64$) than β -cryptoxanthin ($r=0.50$) and β -carotene ($r=0.38$) in 116 non-smoking males aged 35-72 years.¹⁵⁸ Drenowski et al found slightly lower correlations between vitamin C ($r=0.29$) than β -carotene ($r=0.36$) with total F&V intake in 837 French adults.¹⁵⁹ However, 42% of males and 23% of females in this sample were smokers. Smoking reduces vitamin C levels,¹⁵⁹ possibly due to increased turnover of vitamin C.¹⁶⁰ Vitamin C has been shown to be more strongly correlated with fruit intake than vegetable intake.^{157, 159}

The main limitations to the use of vitamin C as a biomarker are its lability and the widespread availability and use of vitamin C supplements. Vitamin C assays have been increasingly standardized and careful handling of specimens is equally important for

light-sensitive carotenoids. It is important to account for the intake of supplementary vitamin C whenever vitamin C levels are used as biomarkers.

1.2.5.4 Folate

Folate has a role as a complementary biomarker of F&V intake. It is present in many green vegetables including spinach, kale, asparagus, lettuce as well as citrus fruits and legumes.¹⁴⁶ Both serum folate and red blood cell folate have been used as markers of folate status. Red blood cell folate is thought to represent longer term intake than serum folate.¹⁶¹ In a sample of 5533 Norwegian adults aged 45-47 and 71-74 years, Brevik et al found significant positive trends in serum folate associated with increasing quartiles of fruit, vegetable and juice intake.¹⁶² Overall, there were moderate correlations between folate and F&V intake including orange juice ($r=0.22$), fruit intake ($r=0.16$) and vegetable intake ($r=0.18$). This population is exposed to very little folate fortification. Coyne et al found a significant positive association between red blood cell folate and daily serves of F&V over the range $\leq 1 - \geq 4$ serves in 1598 Australian adults aged over 25 years.¹⁶¹ In a study of 88 pregnant women, Mikkelsen et al found fruit, vegetable and juice intake had a higher correlation with red cell folate ($r=0.33$) than β -carotene ($r=0.21$) while the correlations between F&V intake and red cell folate ($r=0.31$) and β -carotene ($r=0.32$) were very similar based on FFQ.¹⁶³

However, due to the recognition of the critical role of folate in the prevention of neural tube defects, many foods are fortified with folate. In Australia, this includes breakfast cereals and (since September 2009) all bread-making flour. Supplements are also widely used, particularly by pregnant women. Thus, intake of folate from these sources needs to be considered when folate is used as a biomarker of F&V intake.¹⁶²

1.2.5.5 Impact of fruit and vegetable interventions on biomarkers

The long-term health benefits of increased F&V have been discussed. It remains impractical to undertake long-term prospective studies to demonstrate that specific F&V interventions result in these outcomes. As in other areas of medical research, this has led to the use of interim or proxy measures. In nutritional epidemiology, this has involved the use of self-reported dietary intake and biomarkers.

A recent systematic review¹⁴¹ identified ninety-six studies of dietary interventions with biomarkers as primary outcomes. Of these, fifty-two studies were of mixed fruit and vegetable interventions with sixteen involving nutrition counselling and thirty-six

studies involving food provision. The majority of the studies measured four or more biomarkers, most commonly carotenoids and/or vitamin C, in healthy adult participants. Among the thirty-six food provision studies, only one study did not find a significant increase in any biomarker measured. β -carotene, vitamin C and α -carotene were the most responsive to the interventions increasing significantly in 79%, 78% and 76% of studies in which they were measured respectively. Of the other carotenoids, lutein increased in 69%, β -cryptoxanthin in 60%, lycopene increased in 40% (but also decreased in 20%) and zeaxanthin in 27% of studies in which they were measured. In this review, flavonoids, particularly quercetin, also showed potential as biomarkers in a limited number of studies.

Carotenoids and vitamin C are able to discriminate between low and recommended intake of fruit and vegetables. In a 4 week study of 47 adults, Broekmans et al¹⁶⁴ found those randomized to consume 500g F&V had significantly higher levels of lutein (46%), β -carotene (45%), β -cryptoxanthin (128%), lycopene (22%), α -carotene (121%) and vitamin C (64%) compared to those who consumed only 100g F&V. In a cross-over feeding trial with 40 adults, Brevik et al¹⁶⁵ found significant higher levels of β -carotene (44%) and α -carotene (42%) and non-significant trends for higher lutein (22%), zeaxanthin (19%) and lycopene (17%) in those consuming 5 serves of F&V compared to those consuming 2 serves F&V/day. Van het Hoff et al¹⁴⁹ demonstrated similar impacts in a controlled feeding trial with 45 adults. Those consuming 490g vegetables had significantly higher levels of β -carotene by 49%, α -carotene by 64%, lutein by 190%, zeaxanthin by 232%, β -cryptoxanthin by 26% and vitamin C by 27% compared to those consuming 130g of vegetables.

The impact on biomarkers in these controlled feeding trials has also been replicated in intervention studies involving nutrition counselling. Zino et al¹⁶⁶ conducted a RCT in New Zealand with 87 adults who typically consumed 3 or less serves of F&V/day. Subjects in the intervention were instructed to increase consumption to 8 serves of F&V/day for 8 weeks. Self-reported F&V intake increased from 2.4 serves/day to 7.1 serves/day among those in the intervention while controls were unchanged. This resulted in increases in β -carotene by 50%, α -carotene by 71% and vitamin C by 78% while vitamin A and vitamin E were unchanged. In an intensive nutrition counselling intervention with 122 women, Djuric et al¹⁶⁷ showed that those receiving the intervention increased their F&V intake by 6.9 serves/day and maintained this for 12

months. This resulted in significant increases in β -carotene, α -carotene, β -cryptoxanthin, lutein and vitamin C while lycopene, zeaxanthin, vitamin A and vitamin E did not change significantly.¹⁴¹ A less intensive nutrition counselling RCT in the UK with 690 adults resulted in an increase of 1.4 serves F&V/day.¹¹¹ This also resulted in significantly higher levels of β -carotene (7%), α -carotene (7%), lutein (4%), β -cryptoxanthin (25%) and vitamin C (7%) among those who received the intervention compared to controls.

These studies have demonstrated that serum carotenoids and vitamin C consistently increase when F&V intake increases from low levels to recommended levels. Even the more limited increases in F&V which were achieved in nutritional counselling or health promotion interventions of longer duration generally increased serum carotenoids significantly.^{111, 141} The dose-response relationship between F&V intake and serum carotenoids and vitamin C was investigated by McCall et al, who randomized 147 participants to consume 1, 3 or 6 serves F&V/day.¹⁶⁸ In this study, there were significant linear trends for lutein and β -cryptoxanthin and a non-significant linear trend for vitamin C with increasing F&V intake. Zeaxanthin, β -carotene and α -carotene changed minimally and lycopene showed a non-significant decreasing trend.

The impact on folate of fruit and vegetable interventions has also been assessed. In the four week feeding trial of 47 adults described above, Broekmanns et al found that those consuming 500g F&V/day had a 15% higher level of plasma folate compared to those consuming 100g F&V/day.¹⁶⁴ This small though statistically significant change was due largely to a decrease in folate among the group consuming only 100g F&V/day. Ortega et al compared the effect of hypocaloric diets with either increased intake of vegetables to 3 times/day or increased consumption of folate-fortified cereal products over 6 weeks in 67 overweight women aged 20-35 years in a RCT.¹⁶⁹ Although the vegetable group increased their intake of vegetables by 2 serves/day and fruit by 2.8 serves/day after six weeks, there was a non-significant 23% increase in plasma folate compared to a significant 79% increase in the cereal group. Thus, the evidence for the role of folate as a marker of the response to fruit and vegetable interventions is limited.

Overall, it would appear that both carotenoids and vitamin C are useful as biomarkers of F&V intake,¹⁴¹ perhaps best used in combination with self-reported F&V intake.^{142, 156,}

¹⁵⁷ Folate may have a role as a complementary biomarker, provided supplementary and fortified sources are identified.

1.3 Promoting Healthy Nutrition

1.3.1 Determinants of dietary behaviour

Nutritional intake has become an ever more important issue globally for many of the reasons outlined above. The importance of nutrition as a cause of the non-communicable diseases that dominate the global burden of disease, the rapid emergence of obesity as a major health issue and the rapid ‘nutrition transition’ underway in many low and middle income countries underscores the need to understand the factors that shape people’s dietary behaviour.¹⁰²

The most obvious point to start to understand dietary behaviour is individual factors - taste preferences, nutrition knowledge, attitudes and motivation. This has been the focus of traditional health education and clinical interactions. It is clear though that these individual factors are shaped by interactions with those around us from infancy. Each person decides what food will be ingested. However, as Leach describes, one person in the family/household often has a major influence on what is eaten by others:

- the cook, food purchaser, ...any member of a group who makes food choices on behalf of that group is sometimes referred to as the ‘key kitchen person’... What social factors influence their choice of food to prepare?...the broad answer is they select according to the unwritten rules or norms of the culture to which they belong. (Leach in Mann & Truswell, 2007, p.516)³⁸

This recognition of the crucial interaction between the individual and the environment in shaping and maintaining eating habits (and other health behaviours) has expanded the focus of health promotion to the broader determinants of health. Brug et al draw on social cognitive theory to elucidate a framework in which personal factors operate within an environmental framework.¹⁷⁰ The authors categorise the environment as the physical environment (availability of choices), economic environment (costs of different foods or meal choices), political environment (rules in institutions or families which

govern eating) and socio-cultural environment (social and cultural norms, social influences on specific behaviours, SES). These environmental factors may operate at both the level of individual interactions and a community/macro level. Thus, health behaviours are seen to be shaped by motivation, abilities and opportunities.¹⁷⁰

The available evidence, drawn mostly from cross-sectional studies, suggests that among environmental factors, social and cultural influences are more important than the physical environment. Thus, food habits that have developed from long-standing cultural traditions, family patterns including modelling behaviour and emotional support, and socio-economic status have all been shown to be influential in shaping food choices.¹⁷⁰ Data from the Australian Longitudinal Study of Women's Health supported the idea that food habits have an important social component, with similar diet patterns found in both younger and older participants.¹⁷¹ In that study, healthier diets were associated with other healthy lifestyle behaviours, higher socio-economic status and residing in an urban area. In an investigation of the psychosocial predictors of F&V intake in adults, Shaikh et al found that self-efficacy and social support together with knowledge were the most important predictors.¹⁷²

However, recognizing the importance of social and cultural influences does not discount others aspects of the environment. Thus availability and accessibility of food choices is important in people of all ages. A study of young Dutch adults found the majority are motivated to eat healthily, be active and avoid excessive weight gain.¹⁷³ However, the availability of energy dense foods, together with social pressures to eat these foods and ever-increasing opportunities to avoid occupational and leisure physical activity has created an 'obesogenic environment'.¹⁷⁰ Modern approaches to support healthy dietary behaviour needs strategies that impact on this environment to really assist people to implement healthy lifestyles.

1.3.1.1 Taste, Palatability and Energy Density

The importance of the palatability of fats, salt and sugars to changes to the diet in industrialised countries is well recognised.¹⁷⁴ These dietary changes have been enhanced by the wide availability of energy-dense foods, whose real cost has decreased over time.^{175, 176} The energy density of foods is an important determinant of energy intake in the short-term.¹⁷⁷ This has important implications for dietary choices, particularly among those with low incomes (see 1.3.2 below). However, in the longer term energy

density of foods appears to play a less important role, due to changes in the palatability of food with increased intake of that food and post-ingestive sensory factors which modify palatability.¹⁷⁷ Experimental evidence suggests that taste preferences are learned, with childhood an important period for shaping these preferences.¹⁷⁸ This emphasises again the importance of the social context of eating in shaping most aspects of dietary behaviour.

1.3.2 Socio-economic status and Diet

The positive relationship between socio-economic status and better health outcomes within high income countries was firmly established by the landmark studies of the British Civil Service reported by Marmot et al.¹⁷⁹ This social gradient in health has since been replicated in many countries.¹⁸⁰ The contrast between the health outcomes of Aboriginal and Torres Strait Islander people and non-Indigenous Australians is the most obvious example of this disparity in Australia. The extent to which this social gradient is reflected in nutrition and dietary behaviour and the underlying reasons is important given the strength of the association between nutrition and health outcomes.

A correlation between low socio-economic status and less healthy diets has been consistently found among both adults and children in many high income countries in Europe, North America and Australasia.^{65, 181-190} This is in the context that not meeting dietary guidelines recommendations is common in the overall population, particularly recommended daily intake of fruit and vegetables.^{31, 188, 190} The 1995 Australian National Nutrition Survey included data from 7695 adults aged 18-64 years and 654 children aged 13-17 years. In that survey, there was a significant inverse association between likelihood of fruit consumption on the previous day and SES quintiles among adults (based on household income) and adults in the lowest SES quintile were significantly more likely to have not consumed vegetables the previous day compared to the highest quintile (OR 1.6 95% CI 1.2-2.2).⁶⁵ In the 2005 Canadian Community Healthy Survey of 15,512 adults aged 18-64 years, 77% of people reported consuming F&V less than five times/day. Stratifying the results by education, among those with less than high school education only 13.8% consumed F&V five or more times/day compared to 25.5% among those with a post-graduate degree.¹⁹⁰ A 2006 Australian study of 1003 adults in Brisbane reported that people with the least education and

income were significantly less likely to purchase foods that were high in fibre, low in fat, sugar and salt.¹⁸⁴

Some studies have attempted to characterize dietary patterns as this reflects more realistically how people eat, rather than highlighting specific foods. One study in the UK of a nationally representative sample of 2197 adults aged 16-64 years characterized their diets as: healthy, sweet/mixed, traditional and beer/convenience foods.¹⁸⁷ In this study people in social class I, II were significantly more likely to consume a healthy diet and those in social class IV, V were significantly more likely to report consuming a beer/convenience foods diet or a traditional diet. Data from the Whitehall II study of 8004 middle-aged British civil servants characterized diets into six patterns: very healthy diet, moderately healthy diet, French diet, sweet unhealthy diet, unhealthy diet, very unhealthy diet. Both males and females in the lowest employment grade were significantly more likely to have an unhealthy diet (Males OR 1.26, Females OR 2.98, $p < 0.05$) or a very unhealthy diet (Males OR 3.34, Females OR 6.19, $p < 0.05$) and significantly less likely to have a French diet (Males OR 0.13, Females OR 0.25, $p < 0.05$) than those in the highest grade. These associations were attenuated after adjusting for spouse's SES and, to a lesser extent, by smoking and physical activity levels. This study also measured the association between dietary pattern and cardiovascular risk factors. Overall, dietary pattern accounted for 25-50% of the variation in HDL cholesterol and triglycerides.¹⁸⁵

SES is commonly measured and defined by social class, educational achievement and/or household income. Social class is usually defined by occupational categories. The measures of SES vary between studies in different countries. Examining these individual components of SES provides some insight into how SES impacts dietary intake. In a study of 8817 Norwegian adolescents which examined the association between parental SES and diet intake, differences in parental education, particularly the mother's education, had the most impact. Those whose mothers had ≤ 9 years of education were significantly more likely to drink soft drinks or eat candy daily and significantly less likely to eat vegetables daily, than those whose mothers had a tertiary education. Parental social class had smaller but still significant effects, while income was found to have minimal impact on dietary intake.¹⁸⁹ In studies of Canadian adults, low educational achievement appears to be a more significant factor in low F&V intake, which attenuates the impact of income.^{190, 191} In a study of 1002 pregnant Japanese

women, significantly higher dietary intake of vegetables, fish and shellfish, dietary fibre and ω -3 PUFAs was associated with increased level of education, while there were no dietary associations with household income.¹⁹² However, studies of children and adults in the USA and adults in Australia have shown associations between income and healthier dietary intake.^{65, 182, 188}

Thus, level of education appears to have more impact than household income on dietary intake, at least in some countries. The mediating process by which these factors impact on dietary intake were investigated by Turrell & Kavanagh in a study of 1003 Australian adults.¹⁸⁴ They found that higher educational level was associated with better dietary knowledge and the significant association between healthier food purchasing behaviour and educational level was attenuated to a large extent by dietary knowledge. They also reported a significant inverse association between household income and food cost concern. The significant association between household income and healthier food purchasing was attenuated moderately by food cost concern. These findings reinforce the importance of education and addressing real or perceived higher food costs for reducing inequalities in dietary behaviour.¹⁸⁴

There is an ongoing debate about the relative cost of healthy food. Kettings et al estimated that a welfare-dependent family with two adults and two children in Australia would need to spend 44% of weekly income (or 38% if generic brands substituted) to purchase food consistent with Australian dietary guidelines.¹⁹³ Drewnowski & Darmon drew attention to the fact that people on low incomes aim to maximize the energy density per unit of cost due to financial constraints.¹⁷⁵ They emphasised that healthy diets with increased nutrient density (and reduced energy density) are more expensive.^{194, 195} These findings have been replicated in analysis of food costs in a remote Aboriginal community in Australia.¹⁹⁶ Other studies in Europe and the USA have shown higher quality diets are more expensive.^{197, 198} However, Bernstein et al showed that a healthier diet can be achieved with limited additional cost by spending more on nuts, beans and whole grains.¹⁹⁹ A critique of these low cost healthier diets is that they require people on limited budgets to adopt unfamiliar eating habits and are too different from mainstream diets to be widely acceptable.^{175, 200}

A related theme in research has been the relationship between higher prices or less access to healthier food options in lower SES areas.¹⁸⁶ The use of geographical

information systems has assisted recent analyses of spatial distribution of food retailers. A recent systematic review identified 40 studies of geographical access to fast food restaurants.²⁰¹ This review found that 16/21 studies (76%) showed that fast food restaurants are more common in low income areas compared to middle or high income areas and that 10/12 studies (83%) showed that fast food restaurants are more common in areas with higher concentration of ethnic minorities compared to areas with a majority of Caucasians. For example in one study in New Orleans, geographical analysis showed that predominantly black and low income areas had 2.4 fast-food outlets/square mile compared to 1.5 in predominantly white areas.²⁰² An analysis in St Louis, Missouri showed that in relatively disadvantaged areas of the city, there was less access to healthier foods in supermarkets and fast-food restaurants.²⁰³ The majority of these studies were in the USA. Australian studies have shown that access to F&V at supermarkets and greengrocers is not consistently related to SES in the local area.²⁰⁴ Further, access to, price or availability of F&V had a small effect on the association between SES and F&V consumption.^{204, 205}

The studies from the UK, particularly the Whitehall studies, use occupational category or occupational grade to examine the relationship between SES and diet. As discussed above, there is a definite gradient with higher social classes having higher likelihood of healthier diets. In this cohort of white collar workers, there would have been more limited variation in education. The data did not show that financial concerns had a significant impact. The factors that had the most impact on attenuating the relationship between SES and diet were spouse's SES, marital status for males, and to a lesser extent job control and clustering of unhealthy behaviours.¹⁸⁵ The authors suggest that the broad social and cultural context within the household, shaped by individual food preferences, may be important in explaining the association between SES and diet.

The social context has been emphasised consistently in understanding food habits as discussed earlier.^{38, 170} It is clear that less healthy eating behaviour is associated with individuals, families and communities of low SES. Thus, it is likely that there will be less support for and modelling of healthy eating in low SES settings. This will contribute to lower intakes of healthy food and impact on the development of dietary behaviour.¹⁸³

1.3.3 Promoting healthy nutrition in Aboriginal and Torres Strait Islander communities

In a landmark study, O'Dea demonstrated the potential for traditional Aboriginal diet and lifestyle to improve the health status of Aboriginal adults and reverse their Type II diabetes.²⁰⁶ Further work by O'Dea et al²⁰⁷ in Arnhem Land, documented that Aboriginal adults with limited exposure to Western dietary patterns were slim and with healthy levels of nutritional biomarkers including blood glucose, cholesterol, plasma fatty acid. However, there are diminishing opportunities to pursue traditional Aboriginal diet and lifestyles, even in remote communities.

This led to the development of nutritional and lifestyle interventions with a focus on improving the nutritional quality of food available at the single community store together with locally relevant health promotion strategies in other remote Aboriginal communities. Lee et al¹³⁵ demonstrated significant improvements in dietary biomarkers, including total cholesterol, vitamin C, vitamin B6 and folate, and reductions in blood pressure among adults after a health and nutrition project over 12 months in Minjilang in Arnhem Land. There were similar improvements in dietary biomarkers, including carotenoids, homocysteine and total cholesterol among adults over four year follow-up of the Looma Healthy Lifestyle program in the Kimberley.¹³⁶ In both of these communities, there have been motivated local people who have recognised the need to address diet and lifestyle changes to reduce the high prevalence of chronic disease, particularly diabetes, affecting adults in these communities.

Despite these successful Aboriginal community nutrition programs, diet and lifestyle-related chronic diseases remain highly prevalent in Aboriginal communities.

Brimblecombe explored the historical, social, economic and political influences that have shaped the lifestyle changes in another Aboriginal community in Arnhem Land.²⁰⁸ Brimblecombe emphasised the importance of engaging the community to successfully modify social norms regarding diet and lifestyle. This study also highlighted the importance of high food costs and low incomes in shaping the food choices of families in this remote community.¹⁹⁶ As discussed in section 1.3.2, the food choices of low income Aboriginal families are consistent with those reported in other low socio-economic groups in high income countries. Lee et al²⁰⁹ highlighted the potential for food subsidy programs to complement other strategies to address the high cost per unit energy of healthy foods. There is a precedent for using subsidies to reduce the cost of

healthy food in remote Aboriginal communities, as freight subsidies have been used in remote community stores managed by the Arnhem Land Progress Association.

However, there has been no formal analysis of the impact of this initiative.

It is unclear how the evidence from these remote Aboriginal communities can be applied to Aboriginal communities in rural towns in other parts of Australia where much greater acculturation has occurred over generations and there is access to a much wider range of food outlets. It was clear though that poor nutrition was a significant factor contributing to the poor health status of Aboriginal children in an isolated school near Grafton, New South Wales. A school nutrition program incorporating a range of strategies including school lunches, fruit breaks, healthy cooking sessions and a garden was established.²¹⁰ This was championed by a local Aboriginal staff member with support from the local Aboriginal Medical Service and other school staff (Fiona Smith, personal communication). Over a short period, there were substantial improvements in health status with decreased prevalence of chronic suppurative otitis media and skin infections.^{210, 211} This demonstrated the importance of local community engagement in program design and implementation in this non-remote setting. The cost of healthy foods and the availability of food outlets selling less healthy food choices are also relevant in designing nutrition promotion programs for Aboriginal and Torres Strait Islander people in non-remote locations.

1.3.4 Population-based strategies to promote healthy nutrition

Health education has traditionally complemented clinical health services and has focused on individual knowledge and behaviour change. A review of existing systematic reviews of behaviour change to promote healthy lifestyles found that self-monitoring, risk communication and social support were the most effective overall.²¹² These findings came predominantly from studies of smoking cessation and physical exercise. In the few studies of healthy nutrition promotion, the most effective strategies included specific goal setting, self-efficacy together with risk communication and self-monitoring.

However, increased understanding of the interaction between socio-economic status and health outcomes and more broadly of the social determinants of health has fundamentally changed the approach to public health.²¹³ This new approach recognises the importance of the social and environmental influences on behaviour. The social-

ecological theory was proposed to explain how external factors influence an individual.²¹⁴ This theory emphasises the impact that interactions between social and physical factors have in shaping individual behaviour.^{208,215} Social factors include laws/policies, social norms and formal or informal enforcement of these by groups in the community while physical factors include community facilities, housing and the availability of healthy options.

The implication of these insights is that promotion of healthy nutrition includes much more than providing information to individuals and supporting individual behaviour change. Capacci et al, in a review of policies to promote healthy eating in Europe, broadly categorized these interventions into those supporting more informed choices and those that change the market environment.²¹⁶ This review found that the most commonly implemented interventions were public information campaigns and nutrition education at schools (informed choice). There were a smaller number of interventions to change the market environment, particularly school meals and government action to encourage private-sector action. A limited number of fiscal measures have been implemented in Europe including taxes on less healthy foods and subsidies to disadvantaged people. The evidence of the effectiveness of these policies/interventions was rated as suggestive for most of these categories with much of the evaluation focused on changes in attitude or intentions rather than behaviour.²¹⁶

1.3.4.1 Fiscal measures to promote healthy nutrition

The evidence for fiscal measures to improve healthy nutrition has come predominantly from economic modelling studies. It has been estimated that a 10% decrease in the price of F&V would increase intake by 2-8% and that a 10% increase in the price of fat would reduce intake by a similar amount.^{217, 218} Not surprisingly, taxes and subsidies have been shown to have the largest impact on consumption among those of low SES.^{219, 220} As a consequence, these approaches have the potential for greater health effects, but also a larger financial burden, in those of low SES. However, this impact can be unpredictable due to differences in price elasticity for specific foods/nutrients among individuals and groups. For example, Smed et al found that the young adults were most responsive to changes in the price of saturated fat while middle-aged adults (30-59 years) were most responsive to changes in the price of sugar.²¹⁹ The potential displacement of intake due to price changes can be minimized by combining taxes and subsidies simultaneously.^{217,}

The impact on health outcomes as a result of changes in food intake due to fiscal strategies has also been modelled. Noanham et al estimated that the combination of taxation of less healthy foods and subsidising F&V would increase F&V intake and decrease CVS disease and cancer mortality, while taxation alone was projected to increase CVS and cancer mortality.²²¹ The negative health impact of taxation alone was due to different cross-price elasticities. The fall in F&V intake due to having less money to spend had a greater impact than the reduction in fat intake due to increased taxation of high fat foods. A 2010 US study used longitudinal data from 5115 young adults aged 18-30 years to examine the relationship between price and dietary intake of soda and take-away pizza.²²² A 10% increase in price of soda and pizza was found to significantly decrease energy intake from these foods by 7% and 11% respectively. A price increase of US\$1.00 for soda and pizza was associated with significant reductions in total energy intake, weight and insulin resistance.

Economic evaluations extend the analysis of health interventions by comparing costs as well as benefits. Taxes on less healthy food choices have been found to offer potential cost savings due to low cost of implementation and reduced health care expenditure from reductions in chronic diseases. The Assessing Cost-Effectiveness-Prevention study modelled the impact of a 10% tax on less healthy foods in Australia.²²³ This study found that such a tax would result in a reduction of 170,000 disability-adjusted life years and would be cost-saving to the Government over the life of the 2003 Australian population (health care costs averted far exceed the implementation costs). Similar analysis of fiscal strategies to combine 10% taxes on less healthy foods and 10% subsidies for F&V in a number of middle and low income countries (China, India, Brazil, Mexico, South Africa and Russia) shows cost-savings in all countries from reduced health care costs which exceed the implementation costs over both 20 and 50 years.²²⁴ It would appear sensible to adopt such cost-saving measures; however, there are also political and social considerations inherent in additional taxation that must be addressed.²²³

1.3.4.2 Food subsidy programs

Research studies of food subsidy programs have primarily been conducted in the USA, where food subsidy programs have been a feature of social security for disadvantaged and low income families since the inception of the Food Stamp Program in the early 1960's.²²⁵ The Food Stamp Program is a national program run by the United States Department of Agriculture and explicitly supports American agriculture and food

production. The program provides food vouchers (instead of cash benefits) to low income families. It is an important program promoting food security for the most vulnerable families,²²⁶ but has been criticized for a limited focus on healthy nutrition.²²⁷ The program has been adapted in recent years to promote healthier eating and was renamed the Supplemental Nutrition Assistance Program in 2008 to reduce stigma.²²⁵

The Special Supplemental Nutrition Program for Women, Infants and Children (WIC), which commenced in 1972 to provide subsidised healthy food, nutrition education and referrals to appropriate health and social services for pregnant and postpartum women and young children under five years of age, has been the focus of many of these research studies. There have been two national evaluations and numerous studies at a state or local level.²²⁸ Studies have shown nutritional and health benefits among WIC participants, including increased intake of targeted nutrients, improved pregnancy outcomes including a reduction in low birthweight and improvements in children's nutritional status and early intellectual development.²²⁸ Economic evaluations of WIC concluded that the improvements in birth outcomes alone save between \$1.77 and \$3.13 in healthcare expenditure for each dollar of program funds.^{229, 230}

There has been an ongoing debate about the benefits of the WIC program due to concerns about selection bias in existing studies²³¹ and the limited number of high quality studies.²³² The widespread support for food subsidies led to the rapid expansion of this program nationally in the USA and made it difficult to randomise WIC participation, with only one RCT of the WIC program undertaken.²³³ The only systematic review of food subsidy programs in high income countries focused on pregnancy outcomes.²³² The authors concluded that the WIC program increased intake of targeted nutrients, but there was limited evidence of improvements in pregnancy outcomes, such as low birthweight, and the quality of the economic analyses was limited. This systematic review was commissioned prior to the replacement of the longstanding Food Welfare Scheme in the UK in 2006 by Healthy Start, which also provides healthy food subsidies to pregnant women and young children. Other high income countries have launched similar programs, including Poland²¹⁶ and South Korea.²³⁴

Thus, limited evidence supports the potential for fiscal strategies to improve the nutrition and health status of populations and specific evaluation studies are needed to confirm the impact of individual policies of taxation and/or subsidies.

1.4 Summary and Rationale for the Thesis

Nutrition has an important mediating role in promoting good health and potentially in lowering or increasing the risk of many diseases. The high prevalence of chronic diseases and of nutrition-related risk factors, including hypertension, hyperlipidaemia, obesity and low fruit and vegetable intake, highlights the potential impact of nutrition. Beginning in utero and infancy, nutrition contributes to short and longer term health outcomes. The establishment of healthy dietary habits and other lifestyle behaviours are vital, given the evidence of the substantial impact on mortality of adequate fruit and vegetable intake, not smoking, being physically active and avoiding harmful alcohol intake.

Interventions to promote healthy nutrition encompass both individual and environmental strategies, where environment refers to everything external to the individual. Behavioural change research has emphasised the importance of social and cultural influences in shaping dietary behaviour. There is limited evidence that strategies which change the environment have positive impacts on dietary intake. Conceptually, environmental strategies could complement individual health promotion and education by impacting on some of the underlying determinants of nutrition, such as availability and accessibility of healthier food choices.

Less healthy dietary patterns are common in the population generally. However, socio-economic status has been shown to have a significant association with less healthy behaviours including dietary intake. This may be mediated through both lower income and less formal education. There have been significant health promotion and education campaigns to promote healthy nutrition at an individual and population level. Despite these programs the prevalence of many chronic non-communicable diseases has increased substantially. Limited evidence suggests that fiscal strategies may be more effective to promote healthier behaviour in the population. Subsidies are seen as important to minimize potential negative effects of additional taxation of food on those

with least income. Much of the evidence about food subsidy programs comes from studies of the WIC program in the USA.

In Australia, Aboriginal and Torres Strait Islander people are the most clearly identified disadvantaged group in the population and there is ample evidence of poorer health outcomes among Aboriginal and Torres Strait Islander people. In non-remote settings, where there has been extensive integration over generations, it is unclear the extent to which this is due to low socio-economic status, which is more common amongst Aboriginal and Torres Strait Islander people. Staff at an Aboriginal community-controlled health service in northern NSW responded to the challenge of poor nutrition in the local Aboriginal community by instigating a fruit and vegetable subsidy program to complement nutrition education and health promotion initiatives. This thesis incorporates an impact evaluation of this fruit and vegetable subsidy program on the health and nutrition of participating Aboriginal children.

The challenge of accurately and validly measuring dietary intake using any of the common self-reported methods is well described. Recent Australian nutritional surveys involving children have used 24-hour recalls, which balance the feasibility and validity in this group. Biomarkers have been used to complement self-reported dietary intake data, as they have different sources of measurement error and are considered to be more objective. The most commonly used biomarkers in fruit and vegetable interventions have been carotenoids and vitamin C. For these reasons, assessment of nutritional status in this study incorporated 24-hour recalls with carotenoids, vitamin C and folate.

1.4.1 Rationale

Food subsidy programs have not been trialled on a large scale in Australia. There is however, considerable interest in the upstream determinants of health, particularly the interaction between lower socio-economic status and lower rates of health-promoting behaviours. This thesis aims to document the evidence for the impact of food subsidy programs on the health and nutrition of disadvantaged families in high income countries. A systematic review of food subsidy programs was appropriate due to the publication of only one previous systematic review, completed in 2006, which focussed exclusively on pregnant women. The review investigates whether there is evidence beyond the well-known WIC program and the implication of this evidence in other

countries with different social systems and the potential of food subsidy programs to reduce the prevalence of chronic non-communicable diseases.

As noted above, this thesis incorporates an evaluation of the fruit and vegetable subsidy program at Bulgarr Ngaru Medical Aboriginal Corporation (BNMAC) in Grafton, New South Wales. This program had evolved from a successful fruit and nutrition program at an isolated Aboriginal community school visited by BNMAC staff. This school program had dramatically improved the children's health over a period of months, particularly reducing the rates of chronic suppurative otitis media and skin infections.^{210,}
²¹¹ Thus, the BNMAC fruit and vegetable program represented an opportunity to investigate the nutritional impact of a healthy food subsidy program and whether this impact was associated with improved short-term health outcomes in disadvantaged Aboriginal children in a rural Australian community.

The specific aims of this thesis are:

1. To review the impact of food subsidy programs on the nutritional intake and health status of disadvantaged adults and children in high income countries.
2. To investigate the extent of the impact of the Bulgarr Ngaru fruit and vegetable subsidy program on nutritional biomarkers in blood samples and fruit and vegetable intake by dietary recall in participating children.
3. To investigate the extent of any health benefits at 12 months in participating children through reduction in
 - a. the incidence of pyoderma or otitis media
 - b. the prescription of antibiotics
 - c. abnormal body mass index (BMI) for age
4. To document the development of the Bulgarr Ngaru fruit and vegetable program and the community perceptions of and suggestions for this food subsidy program.

The intention when writing the chapters in this thesis was to publish each as standalone peer-reviewed publications. Thus, there is some overlap in the introduction and discussion in Chapters 2, 4, 5 and 6 with the ideas presented in Chapters 1, 3 and 8.

2 Food subsidy programs and the health and nutritional status of disadvantaged families in high income countries: a systematic review

2.1 Introduction

Good nutrition is an important factor in maintaining and promoting health, particularly given the global rise of non-communicable diseases such as vascular diseases and cancer in most countries. The Global Burden of Disease studies estimated that nutrition-related risk factors such as overweight/obesity, high cholesterol, inadequate fruit and vegetable intake and high blood pressure cause 25% of disease and disability each year.¹ In addition, nutrition has a vital role in pregnancy and early childhood. During pregnancy, good nutrition is especially important in supporting normal fetal development and protecting the mother from the pregnancy-related risks, such as gestational diabetes, excessive weight-gain, pregnancy-induced hypertension and iron-deficiency anaemia.⁸⁶ Nutrition complements other factors in early childhood which promote development and foster healthy behaviours that hopefully travel into adulthood.

International research suggests that there are multiple barriers to improving people's nutrition including the cost and taste of healthy food, poor dietary habits, and a limited understanding of nutritional concepts.^{65, 194, 203} Low socioeconomic status is associated with lower uptake of health promoting behaviours,⁶⁰ including healthy eating.^{181, 182} In this context, health promotion and education alone may have little impact in disadvantaged families. Further, structural/ecological interventions, such as food pricing strategies, may have a greater impact on health behaviours than individual interventions alone.²¹⁴

Food subsidy programs are one element of food pricing strategies and have been operating for many years in the United States and the United Kingdom. The Special

Supplementary Nutrition Program for Women, Infants and Children (WIC) in the United States commenced in 1972 to provide healthy foods, referrals to health and social services and nutrition education to pregnant women and families with young children.²³⁵ This program was developed to target demonstrated nutritional deficiencies in the diets of disadvantaged pregnant women and children.²³⁶ It has been evaluated more than any other US food subsidy program, with many studies demonstrating improvements in pregnancy outcomes and children's nutritional status and early intellectual development.²²⁸ However, the rapid uptake of the program nationally made it difficult to conduct robust randomised trials resulting in concerns about selection bias in existing evaluation studies.^{231, 237, 238} The longstanding Welfare Food Scheme program in the United Kingdom was expanded and renamed Healthy Start in 2006 with a renewed focus on improving the nutrition of low income women and their children.²³⁹ Both WIC and Healthy Start have changed recently to provide more fruit and vegetables (F&V) to address current nutritional challenges in target populations. Food subsidy programs remain topical in other countries; South Korea has trialled a program modelled on the WIC program²³⁴ and the Food Miles program in Canada provides transport subsidies to reduce the cost of healthy foods for disadvantaged families.²⁴⁰ A collation of existing evidence may contribute to existing and future initiatives in this area.

The only systematic review of food subsidy programmes to date has focussed exclusively on pregnancy-related outcomes.²³² In this 2006 review, D'Souza et al concluded that food subsidy programs can increase key targeted nutrients, but that there was limited evidence of their impact on birth weight or other pregnancy outcomes. It was suggested that the aims of food subsidy programs should be broadened to recognise the need for longer-term support of families throughout child-rearing. The authors also identified the need for robust evaluation of new or expanded programs, such as the Healthy Start Program.

The overall aim of the current review was to determine the impact of food subsidy programs on the nutritional intake and health status of disadvantaged adults and children in high income countries. A secondary aim was to identify any adverse effects of these programs. In order to expand the work of D'Souza et al²³² participants of all ages were included, while recognising the importance of pregnancy and early childhood. In the context of the global campaign to increase fruit and vegetable

consumption,¹¹⁶ the current review considered whether the nutritional impacts of food subsidy programs are sufficient to contribute to reducing non-communicable disease prevalence. Finally, this review focused on high income countries as it is considered that the underlying nutritional status and the community resources available locally are distinctly different in low and middle income countries.

2.2 Methods

This review was undertaken based on the methods outlined in the Cochrane Handbook²⁴¹ and the Cochrane health promotion and public health guidelines.²⁴²

2.2.1 Criteria for studies included in the review

2.2.1.1 Types of studies

Randomised controlled trials (RCTs), controlled before- and after studies (CBAs), and interrupted time series analyses of routine data (ITS) were eligible for inclusion. ITSs were defined as analyses where data had been collected at three or more time points both before and after an intervention was implemented.

2.2.1.2 Types of participants

Eligible participants were socio-economically disadvantaged adults, children or families in high income countries. High income countries were as defined by the World Bank.²⁴³

Socio-economic disadvantage was defined as

- families/participants from areas described as disadvantaged by authors (e.g. low income area, ghetto, social housing projects); or
- families/participants of low socio-economic status (SES) (e.g. working class, low income, unemployed); and/or
- disadvantaged minorities e.g. Indigenous peoples.

2.2.1.3 Types of interventions

Eligible interventions were those that provided subsidized food alone or in combination with other health interventions. The food subsidy programs may have used any direct or indirect strategy to reduce the price of food including policy initiatives, transport and

infrastructure subsidies, cross-subsidies. Eligible food subsidy programs had to have provided a 10% or greater reduction in the price of targeted foods because this level of reduction has been shown to impact on food expenditure.^{221, 244}

In the RCTs and CBAs, at least one group had to have received a food subsidy programme and another group to serve as a control (no intervention, delayed intervention, or attention control).

Emergency food relief services (e.g. Food banks) were excluded as they provide intermittent or one-off assistance. School meals programs were also excluded as these programs were reviewed in a recent (2007) Cochrane review.²⁴⁵

2.2.2 Outcomes

To be eligible for the review, a study must have reported valid measures of at least one of the following as a primary outcome:

- Nutritional intake/food purchases (measured by validated dietary assessment techniques, food purchasing, or biomarkers)
- Anthropometric measures-e.g. body weight, body mass index, waist circumference
- Any measure of physical health- e.g. mortality, morbidity, hospital admissions or emergency department attendances
- Pregnancy related measures- e.g. rate of pre-term delivery, or low birth weight (LBW)
- Child growth and development measures e.g. BMI percentile for age
- Health service utilization- e.g. vaccination rates, participation in preventive health activities
- Any adverse outcomes reported for participants were recorded (e.g. stigmatisation, dependency, decreased total food expenditure, increase in high fat/high sugar foods (including take-away food) and obesity or excessive weight loss).

2.2.3 Search strategy

The following electronic databases were searched for relevant articles published between 1980 to November 2010:

Medline, Central (Cochrane), DARE, Embase, Cambridge Scientific Abstracts - Social Services Abstracts & Sociological Abstracts, Web of Science- Science Citation Index, Social Science Citation index, CINAHL, Informit- Health, Food Science and Technology Abstracts, and EconLit.

A Medline search strategy was developed that incorporated terms for: 1.Food (e.g. health food, fruit, vegetables, food preferences, food habits), 2.Nutrition programs (e.g... food subsid*, national health program, price discount*, nutrition policy, fruit or vegetable subsidy) and 3.Nutrition and health outcomes (e.g... outcome assessment, nutritional physiological phenomena, biological markers, health behaviour, nutritional status, carotenoids). Filters for high income countries and study design, adapted from another systematic review of community level interventions to improve food security,²⁴⁶ were applied. The Medline search strategy is shown in **Appendix A** and was adapted for other databases as required. The full search strategy is available from the authors upon request. Bibliographies of screened studies and relevant reviews and manuscripts were also searched for eligible studies and a search was conducted of the following relevant websites: The Food and Nutrition Service (<http://www.fns.usda.gov/fns/>) and the Economic Research Service (<http://www.ers.usda.gov/>) of the United States Department of Agriculture.

2.2.4 Data synthesis and analysis

All manuscripts from searches were downloaded into an Endnote library. The titles were scanned by two authors independently (JB, AB). The abstracts of potentially eligible studies were then assessed by one author (AB). Full-text manuscripts for potentially eligible studies were obtained and reviewed by two authors using the eligibility criteria (JB, AB). These two authors achieved consensus on the eligibility of all studies after discussion of any discrepancies. Records of reasons for rejection were kept. The results were extracted into a Word document and a summary of outcomes tabulated in an Excel spread sheet. Missing data were sort from study authors where possible.

Due to the heterogeneity of study designs and outcomes and the limited number of studies reporting individual outcomes, narrative synthesis was used to summarise the majority of outcomes. However, sufficient data were available to undertake meta-analysis for one outcome: mean birth weight (in WIC studies). Cochrane Review Manager 5 was used to produce a forest plot, with weighted mean differences and 95% confidence intervals for this continuous variable. As recommended in the Cochrane Handbook, the summary statistic was suppressed due to the heterogeneity of study designs incorporated.²⁴¹

2.2.5 Assessment of risk of bias in included studies

Included studies were assessed for risk of bias on relevant domains based on the Cochrane guidelines for RCTs²⁴¹ and both the Effective Practice of Care (EPOC) guidelines²⁴⁷ and the Newcastle-Ottawa Scale²⁴⁸ to assess the quality of CBA and ITS study designs. In accordance with Cochrane guidelines,²⁴¹ studies were not given an overall risk of bias rating; instead the domains rated as low risk of bias are summarised in **Table 2.1**.

2.3 Results

Systematic literature searching identified 5,328 articles from which 684 were retrieved for abstract review (see **Figure 2.1**). There were 16 articles (14 separate studies) which met the inclusion criteria and were included in the systematic review.^{231, 233, 244, 249-261}

The 14 studies included four RCTs^{233, 244, 249, 254}, seven CBAs^{250-252, 255, 258-260} and three ITSs^{231, 256, 261}. Eleven of the studies were from the United States^{231, 250, 233, 252-261} with nine of these focussed on the WIC program.^{231, 233, 250, 252, 253, 255-260} Two studies were from the United Kingdom^{249, 251} and one from New Zealand²⁴⁴. The dates of publication ranged from 1983-2010. The characteristics of included studies are shown in **Table 2.1**.

Participants in eight of the 14 studies were pregnant women (six WIC^{231, 233, 256, 258-260} and two other studies^{249, 261}). There were also three WIC studies involving postnatal women.^{250, 252, 255} Of the other non-WIC studies there was one study of healthy adults²⁴⁴ and another of overweight African-American women.²⁵⁴ There was also one study of 2-

14 year old children.²⁵¹ The vast majority of participants were low income, from disadvantaged local areas or from Indigenous or ethnic minority groups.

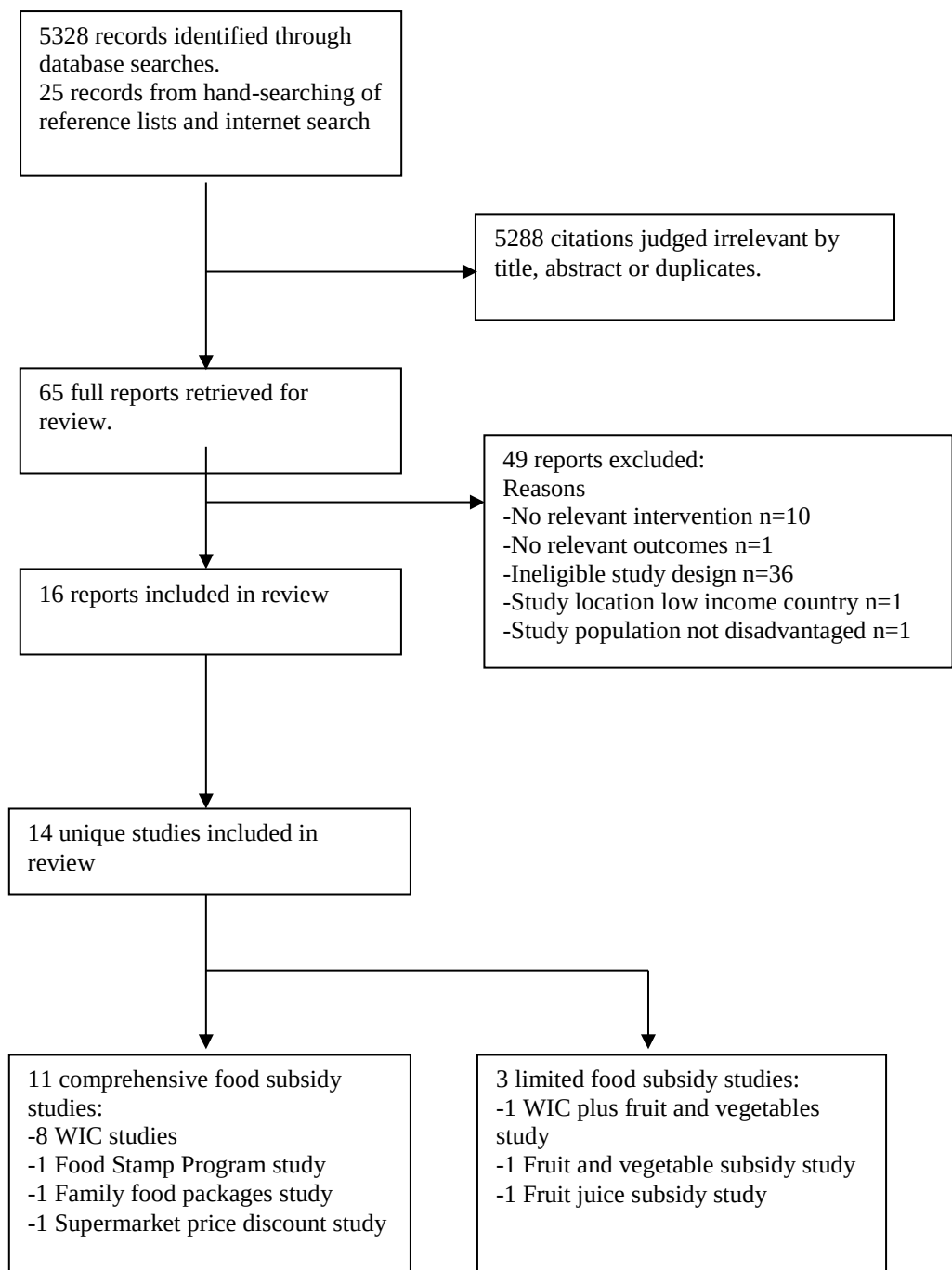


Figure 2.1 Flow-chart of search results

2.3.1 Scope of included studies

Of the nine WIC studies, there were two ITS studies of routine birth registry data including 28 million births²³¹ and 11 million births²⁵⁶. There was one RCT²³³ and two larger CBA studies^{258, 259} that reported the impact on pregnant women. These larger CBA studies were part of a National WIC evaluation in the 1980s. There were also four smaller CBA studies,^{250, 252, 255, 260} involving 101-702 participants, which evaluated different aspects of the WIC program. Of the five non-WIC studies, there were three RCTs: one of supermarket price discounts for 1104 regular adult shoppers in New Zealand,²⁴⁴ one of subsidised fruit juice for 190 pregnant women in the UK²⁴⁹ and another of a F&V subsidy for 40 overweight women in the USA.²⁵⁴ There was an ITS using Californian birth registry data to evaluate the Food Stamp Program in the USA²⁶¹ (renamed the Supplemental Nutrition Assistance Program in 2008) and a 1930s CBA study of supplemental feeding of 1089 children either with family food packages or at school in the UK.²⁵¹

2.3.2 Risk of bias in included studies

The majority (n=8) of the studies appeared to be at moderate to high risk of bias. The studies that satisfied all or most methodological criteria (0-2 relevant criteria not satisfied) and appeared to be at lower risk of bias included three WIC studies- the two ITS^{231, 256} and a CBA study of postnatal women,²⁵⁵ and three non-WIC studies- the RCT from NZ,²⁴⁴ the ITS of the Food Stamp Program²⁶¹ and the CBA study of supplemental feeding of children from the UK²⁵¹ (**Table 2.1**). Sensitivity analysis using only studies judged to be at low risk of bias was not possible due to the limited number of studies. However, the results from these studies are highlighted in the results and/or discussion. Selection bias was a particular concern in the National WIC evaluation CBA studies; controls were less disadvantaged than WIC participants in these studies and 25% of controls were also found to be on the WIC program at follow-up.²⁵⁷

2.3.3 Interventions and Outcomes

The interventions included the standard WIC program^{231, 233, 256, 258-260} or enhancements to the WIC program with either an additional six months of postnatal supplements^{250, 255} or \$US10 F&V per week²⁵². The standard WIC program includes monthly food vouchers, nutrition education and healthcare referrals at WIC clinics. The food vouchers are for designated quantities of foods including iron-fortified cereal,

vitamin C-rich fruit and/or vegetable juice, eggs, milk, cheese, peanut butter, dried beans or peas, canned tuna and carrots (prior to 2009). In 2009, US\$10 fruit and vegetables, whole-wheat bread and alternative canned fish were added to packages. Women may receive WIC foods while pregnant and for 12 months if breast-feeding or six months if not breast feeding and children receive foods up to age four years. Non-breast fed infants receive infant formula and all infants are eligible for baby foods from four months.²⁶² Of the non-WIC studies, interventions included: a 12.5% supermarket price discount on healthier options with or without nutrition education;²⁴⁴ subsidised monthly food vouchers up to US\$142/month (1974 figures) dependent on income (Food Stamp Program in USA);²⁶¹ free home-delivered fruit juice weekly;²⁴⁹ specified family food packages weekly or daily school feeding;²⁵¹ and US\$10 F&V weekly with nutrition education at a local community centre.²⁵⁴ The duration of the interventions ranged from 12 weeks for one of the WIC studies²⁶⁰ to 12 months for the family food packages²⁵¹ (**Table 2.1**).

The presentation of the impact of food subsidy programs on primary and secondary outcomes distinguishes between comprehensive food subsidy interventions which subsidise a wide range of food items or an overall package of food (**Table 2.2**) and those in which only one or a limited range of foods are subsidised (**Table 2.2**). The comprehensive food subsidy studies include all except one of the WIC studies,^{231, 233, 250, 255, 256, 258-260} the supermarket price discount RCT,²⁴⁴ the family food packages study in the UK²⁵¹ and the Food Stamp Program ITS.²⁶¹ The limited food subsidy studies include the home-delivered fruit juice²⁴⁹ and the subsidised fruit and vegetables at the community centre²⁵⁴ and fruit and vegetables as an enhancement of the standard WIC program.²⁵²

The outcomes assessed were dietary intake including fruit and vegetable intake using validated measures, biomarkers, anthropometric and growth parameters and perinatal outcomes including mean birth weight and % low birth weight. The results are presented in categories based on these outcomes: fruit and vegetable intake, other dietary intake and biomarkers, perinatal outcomes and other health outcomes.

2.3.3.1 Diet and nutrition related outcomes

Nine of the studies (six WIC^{233, 252, 253, 255, 258-260} and three other studies^{244, 249, 254}) reported participants' nutritional status or dietary intake. Six of these studies reported dietary intake information using either 24 hour recalls^{252, 259, 260} or food frequency questionnaires.^{249, 254, 255} Two of the studies reported food purchases,^{244, 258} with the more recent study using electronic shopping data.²⁴⁴ Four studies reported on biomarkers of nutritional status,^{233, 249, 255, 260} with three studies reporting on both biomarkers and dietary intake.^{249, 255, 260}

2.3.3.2 Health outcomes

Health outcomes were reported by ten of the studies (seven WIC^{231, 233, 250, 255, 256, 259, 260} and three other studies^{251, 254, 261}), with all the WIC studies reporting pregnancy-related outcomes. Four of these studies reported health outcomes together with dietary intake measures.^{254, 255, 259, 260} Only the three ITS studies reported pregnancy-related health outcomes without any nutritional status measures.^{231, 256, 261}

Table 2.1 Characteristics of included studies (in chronological order)

First author, year, Setting/Location	Participants, Recruitment	Interventions, No. of subjects	Methods	Outcomes	Duration of intervention	Risk of bias ratings (Indicates criteria met)*
Bailey 1983 ⁴² WIC clinic and hospital prenatal clinic, Florida, USA	101 pregnant women aged 15-41 years WIC and control participants recruited from different prenatal clinics at 30 weeks gestation	1. Standard WIC program- Monthly vouchers for specified quantities of milk, canned fish, carrots, cereal, cheese, eggs. 6 monthly nutrition education and health care referrals n=43 2. Routine antenatal care through hospital clinic n=58	Controlled before and after study Follow-up period 12 weeks	Serum iron, vitamin B6, folic acid, Red cell folate Dietary iron, vitamin B6, and folic acid Birth weight % Low birth weight	12 weeks	Methods appraisal: 4,5,7*
Metcoff 1985 ³⁵ Hospital prenatal clinic, Oklahoma City, Oklahoma, USA	824 pregnant women stratified by predicted birth weight; all WIC eligible All participants recruited from same hospital prenatal clinic	1. Standard WIC program with research assessments and routine prenatal care n=238 2. Routine prenatal care with research assessments n=172 3. Routine prenatal care n=353	Randomised controlled trial Follow-up period 24 weeks	Birth weight Plasma B-carotene Maternal weight Plasma amino acids	~21 weeks	Methods appraisal: 5,6*
Caan 1987 ³¹ 48 local WIC agencies, California, USA	703 post-partum women- all WIC participants prenatally All WIC participants prenatally, divided into control & intervention groups retrospectively based on WIC benefits post-partum	1. Standard WIC program maintained for 6 months post-partum for non-lactating women n=333 2. Standard WIC entitlement for 0-2 months post-partum n=309	Controlled before and after study Follow-up period- duration of prenatal care in second pregnancy	Birth weight Low birth weight Macrosomia Maternal Hb Maternal BMI	6 months	Methods appraisal: 2,4,5,7*
Rush 1988a ³⁸ National sample of counties, USA	11,154,673 pregnant women from 1392 US counties in 19 states WIC participants increased over time from 0 to 39% from government reports	1. Standard WIC program	Interrupted time series Follow-up period 1972-1981	Birth weight Duration of gestation Fetal mortality (>28 weeks) Infant mortality rate Inadequate prenatal care	Duration of prenatal WIC participation	Methods appraisal: 2,3,4,5,6,7,8,9*
Rush 1988b&c ^{39, 41} 174 WIC clinics and 55 prenatal clinics, national sample, USA	6563 pregnant women, all WIC eligible by income WIC participants recruited at WIC clinics, controls recruited at public prenatal clinics in counties with low WIC coverage	1. Standard WIC program and research assessments n=5205 2. Routine antenatal care and research assessments n=1358	Controlled before and after study Follow-up period 6-9 months	Nutrient intake Mean nutrient intake % RDA Anthropometry Duration of gestation Birth weight Fetal mortality	Duration of prenatal WIC participation	Methods appraisal: 1,7*
Rush 1988c&d ^{39, 40} 174 WIC clinics and 55 prenatal clinics, national sample, USA	5004 pregnant women, mean age 22.4 years WIC participants recruited at WIC clinics, controls recruited at public prenatal clinics in counties with low WIC coverage	1. Standard WIC program n=4219 2. Routine antenatal care n=785 A subset of women were asked to complete a food diary at follow-up: WIC n=1031, Control n=551	Controlled before and after study Follow-up period 6-9 months	Family food expenditure Family grocery expenditure Family meals out expenditure	Duration of prenatal WIC participation	Methods appraisal: 3,7*

First author, year, Setting/Location	Participants, Recruitment	Interventions, No. of subjects	Methods	Outcomes	Duration of intervention	Risk of bias ratings (Indicates criteria met)*
Gunnell 2000 ³² 8 rural and urban locations in Scotland and England, UK	1089 children aged 2-14 years, mean age 8 years Disadvantaged families selected and divided into intervention and control groups arbitrarily School in adjacent areas were also selected as intervention and controls non-randomly	1. Daily school feeding soup/ milk, halibut oil capsules, oranges or milk and marmite n=298 2. Family food packages weekly-milk, cheese, wheat germ, marmite, oranges, cod liver oil, eggs n=269 3. No food subsidy- control families n=261 4. No food subsidy- control schools n=258	Controlled before and after study Follow-up period 13 months for children's growth and 60 years for mortality	Height Leg length Mortality	12 months	Methods appraisal: 1,3,4,6,7*
Pehrsson 2001 ³⁷ Urban WIC clinics, Maryland, USA	110 post-partum non-lactating females >18 years old, all WIC participants prenatally Participants recruited at WIC clinics in different counties	1. Standard WIC program for 6 months post-partum n=57 2. Standard WIC program for 0-2 months post-partum n=53	Controlled before and after study Follow-up period 6 months	Haemoglobin Transferrin receptor Anaemia % Ferritin	6 months	Methods appraisal: 1,3,4,6,7*
Burr 2007 ³⁰ District hospital prenatal clinic, Wales, UK (disadvantaged area)	190 pregnant females aged >=17 yo All participants recruited from one hospital prenatal clinic at booking visit	1. Vouchers for free 2L fruit juice weekly (home delivery) n=63 2. Advice/written information from midwives to promote fruit intake during pregnancy n=63 3. Routine antenatal care n=64	Randomised controlled trial Follow-up period 30 weeks	Frequency of specific fruit consumption Serum β -carotene	Throughout prenatal care period (~30 weeks)	Methods appraisal: 1,2*
Herman 2006 & 2008 ^{33,34} 3 WIC clinics, Los Angeles, California, USA	602 post-partum women >18yo- all WIC participants Intervention and control participants recruited at three separate WIC clinics with similar socio-demographics	1. \$10 voucher weekly for F&V at local supermarket plus standard WIC program n=200 2. \$10 voucher weekly for F&V at local farmers market plus standard WIC program n=200 3. Standard WIC program n=202	Controlled before and after study Follow-up period 1 year	F&V intake	6 months	Methods appraisal: 1,2,4,7*
Currie 2008 ⁴³ California, USA	All pregnant Californian women 1961-1974 n=4864673 Food stamp participation rates by county used to calculate impacts	1. Standard Food Stamp Program- monthly food vouchers for any foods up to \$200/person/month dependent on income and household size	Interrupted time series Follow-up period 1961-1974	Median birthweight Low birthweight rate Probability of birthweight <specified cut-off	Duration of prenatal FSP participation	Methods appraisal: 2,3,4,5,6,7,8,9*
Hoynes 2009 ¹³ National sample of counties, USA	28,000,000 pregnant women in the 2059 US counties with a WIC program by 1979 (85% of US births in the 1970s) WIC participation estimated from government reports	1. Standard WIC program	Interrupted time series Follow-up period 1971-75 & 1978-82	Birth weight % Low birth weight	Duration of prenatal WIC enrolment	Methods appraisal: 2,3,4,5,6,7,8,9*

First author, year, Setting/Location	Participants, Recruitment	Interventions, No. of subjects	Methods	Outcomes	Duration of intervention	Risk of bias ratings (Indicates criteria met)*
Kennedy 2009 ³⁵ Community centre, East Baton Rouge, Louisiana, USA	40 African-American women aged >18yrs, non-pregnant Participants recruited by local community advertising and personal communication	1. F&V \$10/week with recipes from mobile store at community centre, monthly nutrition education, cooking demonstrations and anthropometric assessment n=20 2. Monthly anthropometric assessment and written nutrition education n=20	Randomised controlled trial Follow-up period 6 months	Fruit and vegetable consumption Weight BMI Bp Quality of life General and emotional health	6 months	Methods appraisal: 5*
Ni Mhurchu 2010 ³⁴ 8 supermarkets in Wellington, Wanganui and New Plymouth, NZ	1104 adult >18 years, main household shopper, 86% female Participants recruited by mail invitation, supermarket advertisements and community group promotion (for Maori and Pacific communities)	1. Tailored nutrition education—computer-generated messages and shopping lists plus generic recipes monthly by mail n=274 2. Price discount of 12.5% on healthy foods applied automatically at check-out n=275 3. Price discount plus tailored nutrition education n=277 4. Control n=278	Randomised controlled trial Follow-up period 15 months	Total food purchased Healthy food purchased Less healthy food purchased F&V purchased Macronutrients purchased	6 months	Methods appraisal: 1,2,3,4,5,6*

***Methods appraisal- CBA** 1. Baseline measurements similar 2. Separate study and control sites similar 3. Blinded or objective assessment of primary outcome 4. Control contamination unlikely 5. Reliable primary outcome measures 6. Follow-up ≥80% 7. Appropriate design or analysis to ensure comparability **RCT** 1. Random sequence generation adequate 2. Allocation concealment adequate 3. Blinding of participants and/or investigators 4. Blinded outcome assessment 5. Follow-up ≥80% 6. Complete outcome reporting **ITS** 1. Intervention independent of other changes 2. Appropriate data analysis used, 3. Rationale for number of points pre- and post-intervention given, 4. Nature of intervention effect specified, 5. Intervention unlikely to affect data collection, 6. Blinded outcome assessment, 7. Data from ≥80% participants, 8. Reliable primary outcome measures, 9. Appropriate design or analysis to ensure comparability

2.3.4 Impact of food subsidy programs

2.3.4.1 Fruit and Vegetable (F&V) intake

Three RCTs^{244, 249, 254} and one CBA study²⁵² reported on F&V intake/purchases. There were consistent and significant increases in the measures of F&V intake in these studies (**Table 2.2** and **Table 2.3**). Only the supermarket price discount RCT was a comprehensive food subsidy. In this study, Ni Mhurchu et al showed an increase of 0.48kg/week (95% CI 0.21-0.75) of healthier F&V purchased, which was an 11% increase from baseline after 6 months of a 12.5% supermarket price discount intervention. At 12 month follow-up (6 months after intervention) increased purchases of healthier F&V (0.28kg/week 95% CI 0-0.56) persisted, but was attenuated.²⁴⁴ This was a large RCT (n=1104) that met most quality criteria and with a low risk of bias, however, there was no change in the primary outcome, saturated fat purchases, in this study (**Table 2.2**).

The remaining three studies assessed limited subsidies of either F&V or fruit juice. None were assessed to have a low risk of bias. In the community centre F&V RCT (n=40), Kennedy et al reported that overweight women who received US\$10/week of F&V for six months increased mean consumption of fruit by 1.0 serves/day (95% CI 0.1-1.9, p=0.02) and vegetables by 0.9 serves/day (95% CI 0.3-1.5, p=0.002) compared to controls, whose intake was unchanged.²⁵⁴ Burr et al assessed the impact of free home-delivered fruit juice and/or nutrition education throughout prenatal care on the overall fruit intake of pregnant females in a RCT (n=190) in the UK.²⁴⁹ Among those who received subsidised juice, there was a net increase of 34.8% in the proportion consuming more fruit juice, while the intake of fruit juice declined among the control (-7.9%) and nutrition education groups (-24.3%). Herman et al assessed the impact of an additional US\$10/week fruit and vegetable subsidy for six months for WIC participants in California at either a supermarket or farmer's market in a CBA study.^{252, 253} Participants receiving subsidised F&V consumed 4.1 serves/4186kJ/day (Supermarket) or 3.9 serves/4186kJ/day (Farmer's market) while controls consumed 3.0 serves/4186kJ/day (F=9.75, p<0.001). This increase persisted in both groups 6 months after the intervention (**Table 2.3**).

2.3.4.2 Other Dietary Outcomes and Biomarkers

Four comprehensive food subsidy programs reported on other dietary outcomes: the supermarket price discount RCT²⁴⁴ and three WIC CBA studies^{255, 259, 260} (**Table 2.2**). In the supermarket price discount RCT, the only study with a low risk of bias, Ni Mhurchu et al found that a 12.5% price discount significantly increased purchases of total (0.90 kg/week 95% CI 0.29-1.52) and healthier food (0.79kg/week 95% CI 0.43-1.16) after 6 months.²⁴⁴ The most comprehensive estimates of dietary intake were from the National WIC evaluation which assessed 6563 pregnant women.²⁵⁹ This study reported that the intake of most macronutrients and micronutrients were 10-20% ($p < 0.05$) higher among WIC participants compared to controls, including four of the five nutrients targeted by the WIC program: protein, calcium, iron and vitamin C. The smaller CBA studies showed variable results: Bailey et al found intake of folate was higher, iron and B6 the same, and protein lower among prenatal WIC participants;²⁶⁰ Pehrsson et al found no difference in iron intake between postnatal WIC participants and controls.²⁵⁵

Four studies reported the impact on nutrition-related biomarkers; three were comprehensive food subsidies (all WIC studies) (**Table 2.2**) and one limited subsidy (the fruit juice RCT) (**Table 2.3**). None of these studies were assessed to have a low risk of bias. In the WIC program RCT, Metcalf et al found non-significant increases in β -Carotene (10% $p = \text{NS}$) and iron-binding capacity (27%, $p = \text{NS}$) among pregnant WIC participants after adjustment for duration of gestation, baseline level and interval between measurements.²³³ The two smaller WIC CBA studies showed variable effects on biomarkers. Pehrsson et al, who found no difference in iron intake, also found that ferritin and transferrin receptors were not significantly different in postnatal WIC participants and non-participants.²⁵⁵ Bailey et al, who reported higher folate intake and no difference in iron and vitamin B6 intake, showed that serum vitamin B6 and transferrin saturation were significantly higher in WIC participants, however, serum iron showed no difference and both red cell folate and serum folate were lower in WIC participants ($p < 0.05$ only for serum folate).²⁶⁰ In the fruit juice RCT, Burr et al found fruit juice vouchers increased β -carotene in pregnant recipients (mean (SD) 35.6 (77.2) ng/ml) compared to a decrease in controls (-20.2 (43.3) ng/ml $p < 0.0001$)²⁴⁹ (**Table 2.3**). This was consistent with the increase in the proportion consuming fruit juice observed in the same study.

2.3.4.3 Perinatal outcomes

Six WIC studies reported on mean birth weight and low birth weight <2500g (LBW) proportion- 1 RCT²³³, 2 ITS^{231, 256} and 3 CBA studies^{250, 259, 260} (**Table 2.2**). The Food Stamp Program ITS study²⁶¹ also reported on LBW (**Table 2.2**). All of these were comprehensive food subsidy programs. The three ITS studies were the only ones among these studies assessed to have a low risk of bias. Overall, there would appear to be a small increase in mean birth weights as reflected in the forest plot of this outcome for WIC studies (**Figure 2.2**) and a non-significant trend to decreased rate of low birth weight among WIC participants. However, the heterogeneity of study designs and missing data precluded meta-analysis of these outcomes.

The two WIC ITS studies reported on birth weight trends during the 1970s when the WIC program was progressively implemented in the USA. Hoynes et al found a significant 2.7g increase in mean birth weights in the total sample attributable to WIC (Mean birth weight 3316g), which they estimated as a 29g increase in infants of WIC participants, based on WIC participation rates.²³¹ Rush et al estimated that WIC participation increased mean birth weight by 23g (mean birth weight 3335g p<0.05).²⁵⁶ The WIC RCT found a non-significant 91gram increase in mean birth weight of infants whose mothers received WIC during pregnancy (WIC 3254g vs. Control 3163g p=NS) after adjusting for maternal weight.²³³ The National WIC evaluation CBA study found a non-significant 7 gram increase in mean birth weight (WIC 3292g vs. control 3285g p=NS).^{257, 259} In the two smaller CBA studies, Bailey et al showed mean birth weight was 47g lower in WIC infants (although statistically non-significant) (WIC 3229g vs. control 3276g p=NS)²⁶⁰ and Caan et al found mean birth weight of WIC infants 131g higher (WIC 3468g vs. control 3337g p=0.003)²⁵⁰. Two studies reported on the impact of prenatal WIC participation among smokers. In the WIC RCT, the mean birth weight of infants of WIC participants who smoked (>10 cigarettes/day) was significantly higher than those of controls who smoked (WIC 3235g vs. control 3059g, p=0.017).²³³ Bailey et al found that whereas there was significantly lower mean birth weight among smokers compared to non-smokers in the control group, the WIC smokers had (non-significantly) higher mean birth weight than WIC non-smokers.²⁶⁰

The three ITS studies showed no significant impact on LBW proportions. Hoynes et al reported no change in the proportion of low birth weight due to WIC (% LBW=7.2%).²³¹ Rush et al reported a non-significant decrease in LBW proportion of

0.43% among WIC participants (Total sample % LBW=6.84%).²⁵⁶ In the Food Stamp study, Currie et al found no significant changes overall in low birth weight in California after the introduction of the Food Stamp Program in the 1960s.²⁶¹ In the National WIC evaluation CBA study, a non-significant decrease of 1.13% in the proportion of LBW was reported (WIC 5.62% vs. control 6.75% p= NS).²⁵⁹ There were non-significant changes in % LBW in the two smaller WIC CBA studies and the RCT, Bailey et al (WIC 5% vs. control 10%, p=NS)²⁶⁰, Caan et al (WIC 3.2% vs. control 5.1%, p=0.08)²⁵⁰ and Metcalf et al (WIC 8.7% vs. control 6.9%, p=NS)²³³. Only the two National WIC evaluation studies by Rush et al^{256, 259} and the Caan et al study²⁵⁰ adjusted LBW proportion for gestational age.

2.3.4.4 Other Health Outcomes

Four comprehensive food subsidy programs- all WIC studies- reported maternal anthropometry and/or haematological parameters.^{233, 250, 255, 259} Only the CBA study by Pehrsson et al²⁵⁵ was assessed to have a low risk of bias. Three CBA WIC studies reported maternal haemoglobin (Hb) levels (**Table 2.2**): Rush et al in the national WIC evaluation found a non-significant 0.06g/dL increase in Hb among prenatal WIC participants.²⁵⁹ Pehrsson et al and Caan et al found postnatal WIC participation significantly increased Hb by 0.61g/dL (5%)²⁵⁵ and 0.29 g/dL (2.4%)²⁵⁰ compared to controls respectively. Three studies also reported on maternal anthropometry (**Table 2.2**). In the WIC RCT, Metcalf et al found prenatal WIC participants had greater weight gain during pregnancy (p=0.19).²³³ Rush et al found that WIC participants started with significantly lower weights in early pregnancy, but had identical weight in late pregnancy to controls.²⁵⁹ Caan et al found maternal de Quetelet's index decreased significantly during pregnancy.²⁵⁰ Only the 1930s family food packages study in the UK reported on health outcomes in children. In this study, Gunnell et al found that food subsidies increased children's height and leg length significantly, however, there was no significant impact on mortality after 60 years follow-up (**Table 2.2**).²⁵¹

Table 2.2 Nutritional and health outcomes associated with comprehensive food subsidy programs

First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes
Bailey 1983⁴² Standard WIC program Pregnant women	Dietary intake Mean (SD) Iron, mg Vitamin B6, mg Protein, g Folic acid, µg Energy, kcal Biomarkers Mean (SD) Serum iron, ug/dL PlasmaVit. B6, ng/ml Transferrin sat. % Serum folate, ng/ml RBC folate, ng/ml Haematocrit, % Biomarkers Mean (SD) Leukocyte protein synthesis** pMol 3H-leucine/h Alanine** Cystine** **Adjusted for week of gestation for initial measurement, initial value, elapsed interval between measurements	Perinatal outcomes Mean (SD) Birth weight, g Low birth weight, % (<2500g) Ponderal index, g/cm ³ (Infant weight x100/length ³) Birth weight Smokers, g Non-smokers, g p<0.05 for smoking status of control groups only Perinatal outcomes Mean Birth weight, g* All births† Smokers >10 cig/day Low birth weight, % Maternal outcomes Maternal wt gain, kg Biceps skin fold, mm *Adjusted for gestational age, sex of baby, prenatal care, smoking, interval since last pregnancy, race, history of previous LBW baby †After adjusting for maternal weight at entry to study, the effect of WIC on all births was not statistically significant
Metcoff 1985³⁶ Standard WIC program Pregnant participants Results from 410 mother-baby pairs with complete data available	Biomarkers Mean (SD) Leukocyte protein synthesis** pMol 3H-leucine/h Alanine** Cystine** **Adjusted for week of gestation for initial measurement, initial value, elapsed interval between measurements	Perinatal outcomes Mean Birth weight, g* All births† Smokers >10 cig/day Low birth weight, % Maternal outcomes Maternal wt gain, kg Biceps skin fold, mm *Adjusted for gestational age, sex of baby, prenatal care, smoking, interval since last pregnancy, race, history of previous LBW baby †After adjusting for maternal weight at entry to study, the effect of WIC on all births was not statistically significant

First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes
Caan 1987³¹ WIC program maintained for 6 months post-partum for non-lactating women instead of normal 0-2 months Pregnant women in subsequent pregnancy		Perinatal outcomes Mean (SE) Birthweight, g* 3468 (30.0) 3337 (31.1) p 0.003 Ponderal index, * g x 100/cm3 2.72 (0.03) 2.73 (0.02) NS Low birth weight, % 3.2 5.1 0.08 Macrosomia, OR (95% CI) (I vs. C) 1.30 (0.70-2.42) NS Maternal outcomes Mean (SE) Hb, g/dL** 12.43 (0.08) 12.14 (0.08) p 0.02 Low Hb, OR (95%CI) (I vs. C) 0.65 (0.45-1.07) 0.07 Mat. de Quetelets index lb/in ² x100† 3.43 (0.36) 3.59 (0.36) 0.003 *Adjusted for parity, pregravid weight/height, infant sex, birth weight of last infant, race and smoking status **Adjusted for race, parity , BMI, duration of gestation at time of measurement and anaemia status during 1 st pregnancy † Adjusted for race, age, interbirth interval, birth weight of first infant, weight status in first pregnancy, smoking status
Rush 1988a³⁸ Standard WIC program Pregnant women		Perinatal outcomes Mean Birth weight, g 3335 3358 <0.01 Low birth weight (<2500g), % 6.84 6.41 NS Fetal mortality, >28 wk gest/1000 6.21 4.09 NS Infant mortality/1000 0-27days, total 10.59 8.30 NS 28-364 days 3.77 4.46 NS Duration of gestation, weeks 39.06 39.26 <0.05

First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes																																																																																										
Rush 1988b,c ^{39, 41} Standard WIC program Pregnant women	Dietary intake* <table><tr><th>Mean</th><th>I</th><th>C</th><th>p</th></tr><tr><td>Protein, g</td><td>80.76</td><td>75.54</td><td><0.01</td></tr><tr><td>Calcium, mg</td><td>1003.7</td><td>871.0</td><td><0.001</td></tr><tr><td>Iron, mg</td><td>17.22</td><td>14.06</td><td><0.001</td></tr><tr><td>Vitamin A, mg</td><td>2.06</td><td>1.83</td><td>NS</td></tr><tr><td>Vitamin C, mg</td><td>134.11</td><td>111.68</td><td><0.001</td></tr></table> Other macro- and micronutrients had statistically significant increases in WIC participants including energy, carbohydrate, fat, magnesium, phosphorus, vitamins B1, B2, B3, B6, B12 Nutrient intake as % of RDA* <table><tr><th>Mean</th><th>I (%)</th><th>C (%)</th></tr><tr><td>Energy (2400kcal)</td><td>84</td><td>79</td></tr><tr><td>Protein (74g)</td><td>109</td><td>102</td></tr><tr><td>Calcium (1200mg)</td><td>84</td><td>73</td></tr><tr><td>Magnesium (450mg)</td><td>60</td><td>54</td></tr><tr><td>Vitamin B6 (2.6mg)</td><td>73</td><td>60</td></tr></table> Phosphorus, Vitamins A, B1, B2, B3, B12 and C were all 95%-180% of RDA at baseline and follow-up in both WIC and control groups. RDA for pregnant women aged 19-22 years old *Adjusted for duration of gestation, initial intake, 35 other maternal characteristics including smoking status, age, race, family income and size, woman and partner's educational and employment status, social security benefits and program participation 181 of the 711 controls had enrolled in WIC before follow-up. The diet intake data for this group were analysed separately and were similar to the WIC intervention group No difference in nutrient intake for groups at baseline	Mean	I	C	p	Protein, g	80.76	75.54	<0.01	Calcium, mg	1003.7	871.0	<0.001	Iron, mg	17.22	14.06	<0.001	Vitamin A, mg	2.06	1.83	NS	Vitamin C, mg	134.11	111.68	<0.001	Mean	I (%)	C (%)	Energy (2400kcal)	84	79	Protein (74g)	109	102	Calcium (1200mg)	84	73	Magnesium (450mg)	60	54	Vitamin B6 (2.6mg)	73	60	Perinatal outcomes* <table><tr><th>Mean</th><th>I</th><th>C</th><th>p</th></tr><tr><td>Birth weight, g</td><td>3292</td><td>3285</td><td>NS</td></tr><tr><td>Low birth weight (<2501g), %</td><td>5.62</td><td>6.75</td><td>NS</td></tr><tr><td>Duration gestation, days</td><td>279.0</td><td>279.3</td><td>NS</td></tr><tr><td>Preterm births, %</td><td></td><td></td><td></td></tr><tr><td>< 33 weeks</td><td>0.30</td><td>0.90</td><td><0.05</td></tr><tr><td>< 37 weeks</td><td>9.45</td><td>12.07</td><td>NS</td></tr><tr><td>Head circumference, cm</td><td>34.13</td><td>33.95</td><td><0.05</td></tr><tr><td>Fetal mortality/1000</td><td>5.09</td><td>9.54</td><td>NS</td></tr></table> *Adjusted for duration of gestation and 35 other maternal characteristics including smoking status, age, race, family income and size, woman and partner's educational and employment status, social security benefits/program participation Maternal outcomes* <table><tr><th>Mean</th><th>I</th><th>C</th><th>p</th></tr><tr><td>Initial weight, kg</td><td>65.17</td><td>65.89</td><td><0.05</td></tr><tr><td>Follow-up weight, kg (36 weeks gestation)</td><td>72.17</td><td>72.17</td><td>NS</td></tr></table> WIC group women initially lighter than control women had caught up with control women by 36 weeks gestation No clinical (or statistically) significant difference in haemoglobin at baseline or follow-up. Data not shown *Adjusted for duration of gestation, conception weight and 35 other maternal characteristics as above	Mean	I	C	p	Birth weight, g	3292	3285	NS	Low birth weight (<2501g), %	5.62	6.75	NS	Duration gestation, days	279.0	279.3	NS	Preterm births, %				< 33 weeks	0.30	0.90	<0.05	< 37 weeks	9.45	12.07	NS	Head circumference, cm	34.13	33.95	<0.05	Fetal mortality/1000	5.09	9.54	NS	Mean	I	C	p	Initial weight, kg	65.17	65.89	<0.05	Follow-up weight, kg (36 weeks gestation)	72.17	72.17	NS
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First Author, Year Intervention, Participants	Nutritional outcomes				Health outcomes
Rush 1988c, d^{39, 40} Standard WIC program Pregnant women	Food purchases^{*,†} Mean (SD) Total expenditures, \$ Recall Diary Groceries, \$ Recall Diary Meals away from home, \$ Recall Diary * Adjusted for family size, income, ethnicity, presence of father in household, maternal education, amount of food stamps and free school meals, number of guests and baseline expenditure † Baseline food expenditures differed with WIC families spending significantly less on total food, groceries and meals away from home				
		I	C	p	
		48.28	52.07 (33.34)	<0.001	
		61.20	62.85 (39.44)	NS	
		38.30	39.95 (22.97)	<0.05	
		50.50	49.15 (35.68)	NS	
		3.84	4.94 (6.44)	<0.001	
		10.93	13.69 (16.20)	<0.001	

First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes																																								
Gunnell 2000 ³² Intervention included either daily school feeding (SF) or family food packages weekly (FP) and two controls with no food subsidy- families and school students Children aged 2-14 years		Growth outcomes* <table><tr><td>Mean, (SD)</td><td>I</td><td>C</td><td>p</td></tr><tr><td>Height increase, cm</td><td>6.10(1.50)</td><td>5.56(1.45)</td><td><0.0001</td></tr><tr><td>Leg length increase, cm</td><td>4.98 (2.07)</td><td>4.87(2.25)</td><td>0.0006</td></tr><tr><td>Trunk increase, cm</td><td>1.12 (2.17)</td><td>0.69 (2.23)</td><td>0.17</td></tr></table> Stature increases by method of feeding, [†] <table><tr><td>Mean (95%CI)</td><td>SF</td><td>FP</td></tr><tr><td>Change in height (I-C), mm</td><td>6.7 (2.7-10.6)</td><td>2.0 (-0.7-4.8)</td></tr><tr><td>Change in leg length (I-C),mm</td><td>7.2 (1.9-12.4)</td><td>2.3 (-1.5-6.2)</td></tr></table> Mortality <table><tr><td></td><td>Hazard ratio I vs. C (95%CI)</td><td>p</td></tr><tr><td>All causes</td><td>1.15 (0.7-1.7)</td><td>0.46</td></tr><tr><td>CHD</td><td>1.62(0.76-3.47)</td><td>0.21</td></tr><tr><td>Cancer</td><td>0.69 (0.35-1.38)</td><td>0.30</td></tr><tr><td>Non-smoking related cancer</td><td>0.59 (0.18-1.99)</td><td>0.59</td></tr></table> * Adjusted for initial anthropometry and location. [†] Adjusted for initial anthropometry, location, age, sex, duration of follow-up, household food expenditure, diet intake, family size, social class	Mean, (SD)	I	C	p	Height increase, cm	6.10(1.50)	5.56(1.45)	<0.0001	Leg length increase, cm	4.98 (2.07)	4.87(2.25)	0.0006	Trunk increase, cm	1.12 (2.17)	0.69 (2.23)	0.17	Mean (95%CI)	SF	FP	Change in height (I-C), mm	6.7 (2.7-10.6)	2.0 (-0.7-4.8)	Change in leg length (I-C),mm	7.2 (1.9-12.4)	2.3 (-1.5-6.2)		Hazard ratio I vs. C (95%CI)	p	All causes	1.15 (0.7-1.7)	0.46	CHD	1.62(0.76-3.47)	0.21	Cancer	0.69 (0.35-1.38)	0.30	Non-smoking related cancer	0.59 (0.18-1.99)	0.59
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First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes
Pehrsson 2001 ³⁷ Standard WIC program continued for 6 months post-partum Postpartum women	Dietary intake Iron No data presented. No significant differences between groups. All intakes <74% RDA (15mg/day) Vitamin C No data presented. No significant differences between groups. All intakes >150% RDA (60mg/day) Biomarkers* Mean (SD) I C p Ferritin, ug/L 36 (20.1) 35 (20.3) NS Transferrin receptor, mg/L 6.1 (2.1) 6.5 (2.1) NS *Results at 6 month follow-up	Maternal outcomes Mean (SD) I C p Haemoglobin, mmol/L* 8.01 (0.82) 7.63 (0.82) <0.05 g/dL 12.8 (1.31) 12.2 (1.31) Anaemia, % * 17 51 <0.05 (Hb<7.45mmol/L or 12g/dL) *Results at 6 month follow-up
Currie 2008 ⁴³ Standard Food Stamp program Pregnant women	*Results at 6 month follow-up	Perinatal outcomes Change in low birth weight % (SD) All parity First birth Teen mum White -0.014 (1.05) 0.062 (1.00) 0.27 (0.92)* Black 0.47 (1.64) 0.26 (1.43) 0.175 (1.58) *p<0.05 Fertility outcomes* % increase in births All parity First birth Teen mum White 3.0 13.0 6.9 Black 12 9.0 24.6 *Statistically significant for blacks in all categories and white first births and teen births

First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes
Hoynes 2009¹³ Standard WIC program Pregnant participants		Perinatal outcomes Mean Birth weight, g 3316 Change in birth weight, g 2.7 Low birth weight, % 7.2 Change in low birth weight 0 %, 95% CI (-0.0784- 0.0784) Fertility rates No statistically significant difference after WIC introduction
Ni Mhurchu 2010²⁴ 12.5% discount on healthier foods at point-of-sale (PD) or tailored nutrition education (NE) or both compared to no intervention Main household shoppers >18 years	Food purchases* Change in foods/nutrients at 6 months (PD- no PD) Mean (95%CI) PD p Foods, kg/week All foods 0.90 (0.29-1.52) 0.004 All healthier 0.79 (0.43-1.16) <0.001 All less healthy 0.07 (-0.15-0.29) 0.56 Healthier F&V 0.48 (0.21-0.75) <0.001 Healthier meat 0.06 (0.02-0.11) <0.001 Healthier dairy 0.21 (0.10-0.31) <0.001 No change was noted in intake of saturated fat (primary outcome), energy density or any other macronutrients There were no effects of tailored nutrition education on food purchases at 6 months. Change in foods/nutrients at 12 months (PD- no PD)** Mean (95%CI) PD p Foods, kg/week All foods 0.37 (-0.26-1.00) 0.25 All healthier 0.38 (0.01-0.76) 0.045 All less-healthy 0.05 (-0.18-0.27) 0.67 Healthier F&V 0.28 (0.00-0.56) 0.05 Healthier meat 0.03 (-0.01-0.08) 0.15 Healthier dairy 0.06 (-0.04-0.18) 0.21 *Adjusted for baseline values, ethnicity, income, age, sex **The 12 month follow-up was 6 months after intervention ended	

Table 2.3 Nutritional and health outcomes in limited food subsidy programs

First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes																																				
Burr 2007 ³⁰ Free home-delivered orange juice using vouchers(V), nutritional advice promoting fruit and fruit juice (A) or standard care during prenatal care period (C) Pregnant women	Dietary intake Net % consuming more fruit <table><tr><td>Mean</td><td>V</td><td>A</td><td>C</td></tr><tr><td>Apples</td><td>2.2</td><td>-13.2</td><td>-2.7</td></tr><tr><td>Oranges</td><td>-2.2</td><td>-21.1</td><td>-11.8</td></tr><tr><td>Bananas</td><td>-17.4</td><td>-7.9</td><td>-29.7</td></tr><tr><td>Fruit juice</td><td>34.8*</td><td>-7.9</td><td>-24.3</td></tr></table> *Voucher group net % significantly greater than advice or control (p<0.05) Biomarkers Mean (SD) β-carotene change, ng/ml <table><tr><td>V</td><td>A</td><td>C</td><td>p</td></tr><tr><td>n=39</td><td>n=37</td><td>n=42</td><td></td></tr><tr><td>35.6(77.2)</td><td>-20.2(43.3)</td><td>-20.2(43.3)</td><td><0.0001</td></tr><tr><td></td><td>-2.7(65.5)</td><td></td><td>0.435</td></tr></table>	Mean	V	A	C	Apples	2.2	-13.2	-2.7	Oranges	-2.2	-21.1	-11.8	Bananas	-17.4	-7.9	-29.7	Fruit juice	34.8*	-7.9	-24.3	V	A	C	p	n=39	n=37	n=42		35.6(77.2)	-20.2(43.3)	-20.2(43.3)	<0.0001		-2.7(65.5)		0.435	
Mean	V	A	C																																			
Apples	2.2	-13.2	-2.7																																			
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	-2.7(65.5)		0.435																																			
Herman 2006 & 2008 ^{33, 34} Standard WIC program plus \$10 voucher weekly for F&V from local supermarket (SM) or farmer's market (FM) Post-partum women >18yo- all WIC participants	Dietary intake Mean F&V intake, serves/4186kJ/day End of intervention 4.1 3.9 3.0 F=9.75, p<0.001 6 mths post-intervention 4.0 4.0 3.1 F=6.66, p=0.001 Vegetable intake, serves/4186kJ/day End of intervention 2.3 2.1 1.5 F=11.0, p<0.001 6 mths post-intervention Data not shown F=-0.59, p=0.02 Fruit intake Data not shown, no significant differences between SM, FM and control																																					

First Author, Year Intervention, Participants	Nutritional outcomes	Health outcomes
Kennedy 2009³⁵ Free fruit and vegetables \$10/week with recipes from mobile store at community centre with monthly nutrition/cooking sessions and anthropometric assessment African-American women	Dietary intake Change in intake at six months Mean (SD) Energy, kcal/day Fibre, g/day Fruit, serves/day Veg, serves/day I -456 (1032) 1.7 (5.7) 1.0 (1.7) 0.9 (1.2) C -636 (1326) -4.3 (19.7) 0 (1.2) -0.2 (1.8) p 0.48 0.03 0.02 0.002	Anthropometric and cardiovascular outcomes Change at 6 months Mean (SD) Weight, kg BMI, kg/m ² Waist size, cm Syst BP, mmHg Dias BP, mmHg I -2.0 (3.2) -0.7 (1.2) -0.5 (5.3) -2.3 (13.0) 0.8 (8.1) C 1.1 (2.0) 0.4 (0.8) 1.9 (3.7) -1.4 (12.3) 0.1 (9.3) p <0.001 0.001 0.12 0.14 0.68 Self-rated health General health and quality of life were rated across multiple domains. Trends generally favoured intervention group, but only self-esteem (p=0.03) and emotional role (p=0.04) improved significantly

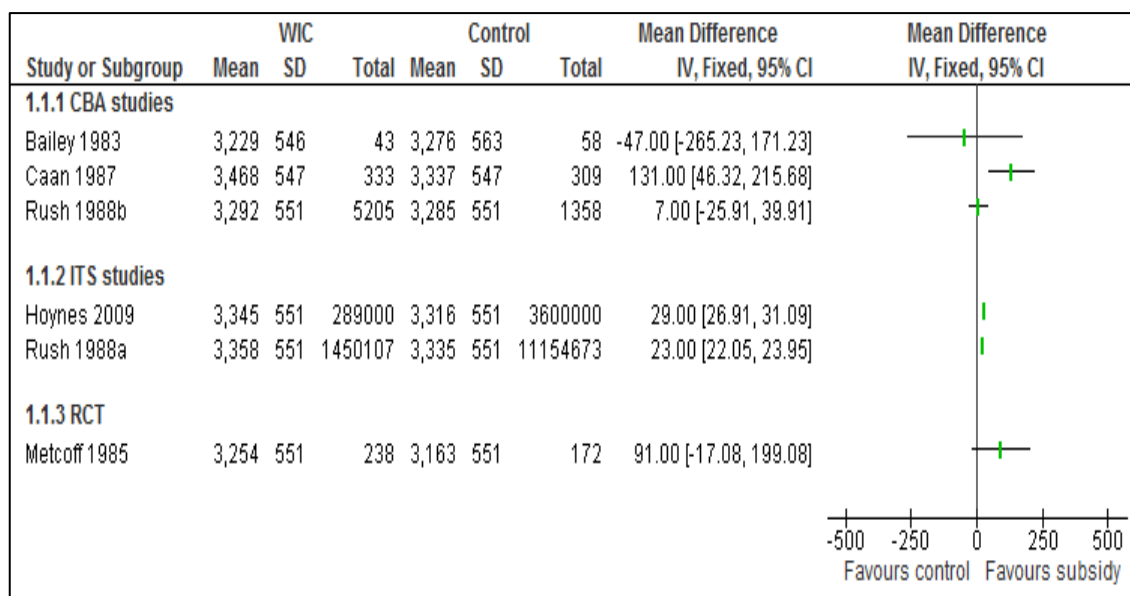


Figure 2.2 Forest plot of the impact of food subsidy programmes on birth weight outcomes (WIC studies)*

*SD is missing for Rush 1998b, Hoynes 2009, Rush 1988a and Metcoff 1985 and average SD from available studies is used as an estimate

2.3.4.5 Adverse effects

The only possible adverse effects reported were significantly higher fertility rates among teenage mothers in the Food Stamp Program study²⁶¹ and significantly lower total food and groceries expenditure (based on recall but not diary method) among WIC participants compared to controls in the National WIC evaluation CBA study²⁵⁸ (Table 2.2).

2.4 Discussion

This review found a limited number of rigorous studies have been undertaken to investigate the impact of food subsidy programs on participants' nutritional intake and health outcomes. However, there have been an increasing number of high quality studies reported in the last five years. The targeted F&V subsidies with nutrition education were able to increase F&V intake by 1-2 serves/day in women. The National WIC evaluation CBA study showed increases of 10-20% in measured nutrients in pregnant women. Studies of other comprehensive and limited food subsidies showed similar improvements in nutrient intake, biomarkers or food purchases. Thus, there are

measurable improvements in nutrition, even though they cannot be precisely quantified in this review. Evidence of the link between improvements in nutritional status and in health outcomes is predominantly from perinatal outcomes of the WIC program. There is consistent evidence of a small but significant increase in mean birth weight from the two WIC ITS studies, although there is no evidence of significant changes in the proportion of low birth weight. There is suggestive evidence that the WIC program may have a more substantial impact on the mean birth weight of infants whose mothers are regular smokers.

This review was conducted according to the protocols recommended by the Cochrane Collaboration.²⁴¹ A comprehensive search strategy and screening process makes it is likely that relevant published studies were identified. Moreover, this review focussed on studies with robust research designs, increasing the likelihood that any positive effects could be attributed to the interventions.²⁶³

However, this review was limited by the heterogeneity of both study design and outcomes. This prevented meta-analysis and limited the precision of estimates of effect. There were also limitations in individual studies. Most studies reported multiple nutritional outcomes without specifying a primary outcome, which increases the likelihood of significant associations occurring by chance.²⁶⁴ Much of the dietary intake data was based on self-report, which has well recognised limitations due to imprecision and potential recall biases.¹¹⁹ Biomarkers, such as carotenoids and vitamin C, and electronic shopping data are more precise and objective measures of dietary behaviour with different potential biases.^{141,265} Thus, greater use of these measures has the potential to complement self-reported intake data. There were limited data reported on the health and nutritional outcomes for children and no data for men. WIC studies have reported nutritional improvements in children,^{266, 267} but more rigorous study designs would strengthen these conclusions. An exclusive focus on women and young children in food subsidy programs does not reflect completely the social dynamics that shape dietary behaviour.²⁶⁸ Research involving whole families would increase the understanding of the wider impacts of food subsidy programs. Although only limited adverse effects were reported in these studies, this is more likely to indicate the absence of evidence rather than evidence of no adverse effects. There should be improved efforts to identify all impacts of food subsidy programs.

The findings of a positive impact on birth weight in this review contrast with those of D'Souza et al,²³² who concluded that the WIC program did not have a significant impact on birth weight or the likelihood of low birth weight, except possibly for smokers. The conclusions in this review of WIC's impact on birth weight were based particularly on the two ITS studies^{231, 256} (assessed as low risk of bias) that were not included in the D'Souza et al²³² review. However, the modest impact on perinatal outcomes supports their suggestion that food subsidy programs should focus on improving nutritional status with the aim of improving longer term health outcomes.

In this review, only Gunnell et al²⁵¹ reported long-term health outcomes, finding no mortality benefit from a 12 month childhood food subsidy program. This 12 month program was the longest intervention included in the review. However, a 10-20% increase in key nutrients or 1-2 serves of F&V/day have the potential, if sustained, to decrease rates of non-communicable diseases, including ischaemic heart disease, cancer and diabetes, and ultimately mortality. Prospective longitudinal studies have confirmed the association between healthier nutrition and better health outcomes.^{43,45, 106} For example, it is estimated that for each additional serve of F&V consumed, there is a 4% decrease in the risk of coronary heart disease.^{106, 107}

The evidence of sustainable impacts on dietary behaviour as a result of food subsidy programs in both adults and children is limited. Only two included studies reported on follow-up post-intervention- both after subsidies of six months duration- and found persistence of significantly increased F&V intake²⁵² and healthier food purchases²⁴⁴ at 12 months respectively (though 50 % less than while receiving the food subsidy in the latter study²⁴⁴). The WIC program provides food subsidies for longer (up to age five for children), however, Rush et al²⁶⁹ found that the dietary intake improvements in children were only seen in current WIC participants. The optimal duration and design of food subsidy programs is unlikely to have a simple answer given the complex influences on dietary behaviour¹⁷⁰ but remains important given the link between lower socio-economic status and less healthy nutrition.^{203,204}

Longitudinal controlled studies of sufficient duration which quantify the extent of any reductions in chronic diseases from specified improvements in nutrition would build the strongest possible evidence base for food subsidy programs. However, most evaluation research of food subsidies is likely to focus on measures of nutritional intake as markers

of improvement. Future nutrition intervention evaluations should use robust validated nutritional intake measures reported in a standardised format (e.g. repeated 24 hour recalls) to enable comparisons with other studies including meta-analyses.²⁷⁰ As discussed, the use of objective measures, including biomarkers and electronic shopping data, should be considered as alternatives to self-reported intake data where feasible. Assessment of the overall diet, using principle component analysis or comparison with dietary indices, is another alternative that provides realistic data to complement other dietary intake assessments^{271, 272} and addresses the inherent limitation of significance testing when evaluating multiple outcomes, discussed above.

Further economic analyses based on high quality outcome studies would provide complementary data to help determine whether new or amended food subsidy program represent an effective investment within a country. Such analysis would facilitate comparison of potential cost-savings in the health system with the tangible upfront public funding required. In the USA, positive cost-benefit analyses are part of the explanation for the investment in food subsidies.^{229, 230} However, D'Souza et al²³² concluded that the WIC economic analyses were of poor quality. An evaluation of the Healthy Start program in the UK^{273, 274} was limited by the long-standing commitment to welfare food entitlements which prevented allocation using randomisation. This will reduce the strength of economic analyses based on such data.

Non-cash programs, particularly the food subsidy programs, are central to the social security system for low income people in the USA. For countries with their own specific social security systems, the outcomes of food subsidy programs may be quite different. The impact may depend on whether they reduce existing benefits or income or represent an additional investment to improve the health status of the population or decrease inequality. Modelling studies suggest that healthy food subsidies in combination with taxation of less healthy foods could have a larger impact on the nutrition of those on low incomes.²¹⁶ However, the provision of a food subsidy could allow increased spending of other income on less healthy foods, cigarettes or alcohol. The negative health impacts could outweigh the positive nutritional impacts of the food subsidy, as was suggested in one unhealthy food taxation modelling study.²²¹ The decision about which foods to subsidise (or tax) is important. Although limited food subsidy programs were found to increase the intake of targeted foods in this review, it is important to focus on the impact on overall dietary intake in the design and

implementation of a food subsidy program. The design of any food subsidy program should also include consideration of how to mutually reinforce other public health initiatives, including social marketing, school nutrition programs and healthy lifestyle programs. In the USA, WIC promotes preventive health activities effectively and links well with health services,²⁷⁵ although operating as an independent service funded by the US Department of Agriculture.

2.4.1 Conclusions

This review identified limited high quality evidence of the impacts of food subsidy programs on the health and nutrition of adults and children in high income countries. This evidence, predominantly from studies of the WIC program in the USA, suggests that female participants have 10-20% increases in targeted nutrients and foods due to these food subsidy programs. Associated improvements in perinatal outcomes were limited and most evident in women who smoked during pregnancy. Thus, food subsidy programs for pregnant women and children should aim to improve nutritional status in the longer term. The improved intake of targeted foods such as fruit and vegetables could potentially reduce the rate of non-communicable diseases in adults, if the changes in diet are sustained. There have been virtually no adverse effects of food subsidy programs reported. Further prospective data are needed to confirm that food subsidies produce sustainable improvements in dietary intake and document any adverse effects. Evaluation of new initiatives should include controlled trials where possible and economic analyses to provide evidence of effectiveness in a local context.

3 Methods

3.1 Participants

This study was undertaken at the Bulgarr Ngaru Medical Aboriginal Corporation (BNMAC) in Grafton, NSW, Galambila Aboriginal Medical Service (AMS) in Coffs Harbour, NSW and Giingan Darrunday Marlaanggu Health Clinic (auspiced by Durri Aboriginal Medical Service) in Bowraville, NSW.

3.1.1 Location- Regional Australia

Grafton, with a population of 19,000, is about 620 km north of Sydney and 320 km south of Brisbane (**Figure 3.1**). It is the major town in the Clarence Valley and services the surrounding community. It lies on both sides of the Clarence River and provides services for the surrounding rural communities. The other large towns in the Clarence Valley are Maclean with a population of 13,000 and Yamba with a population of 12,000. Maclean is 43km down river from Grafton and the major service centre for the lower Clarence Valley. Yamba is a seaside-resort town at the mouth of the Clarence River, 58 km north-east of Grafton. The locations of other study sites are shown on **Figure 3.2**.

Coffs Harbour is the largest town on the north coast of NSW with a population of approximately 80,000. It is 540km north of Sydney. As a coastal town, it is a popular tourist destination and provides full range of services to the local region. Bowraville is a small rural community in northern New South Wales approximately 70 km south west and inland from Coffs Harbour. Bowraville has a population of 1350.



Figure 3.1 Map of New South Wales (Main study location indicated by arrow)

3.1.2 Local Aboriginal Communities

The Aboriginal and Torres Strait Islander population of the Clarence Valley was 2306 with 924 children aged 0-14 years in the 2006 Census and in the Coffs Harbour region was 2310 with 907 children aged 0-14 years.²⁷⁶ The Aboriginal and Torres Strait Islander population in the Nambucca Valley was estimated as 1025 with 439 children 0-14 years in the 2006 Census.²⁷⁶ It was estimated that around 40% of Aboriginal and Torres Strait Islander families may be eligible for the program based on workforce participation rates.²⁷⁷



Figure 3.2 Map of Northern NSW with arrows indicating study communities

3.2 Study design

3.2.1 *Fruit and vegetable program*

The Bulgarr Ngaru Medical Aboriginal Corporation (BNMAC) fruit and vegetable program was developed after the success of a local school fruit program.²¹¹ The BNMAC fruit and vegetable program involves the provision of a weekly \$40 box of subsidised fruit and vegetables with an individual contribution of five dollars. Cooking classes and nutrition education are offered to participants with individual consultations by dietitians also available. The program is also intended to engage people in preventive health activities. Hence, annual health assessments including dental and hearing checks are undertaken for each child. Recruitment to the program is by invitation to disadvantaged families whose children are identified as nutritionally at risk by BNMAC staff. There is currently a waiting list of eligible families due to funding constraints. The program is managed by the BNMAC fruit and vegetable committee which includes staff from all sections of the health service, the majority of whom are Aboriginal.

3.2.1.1 Fruit and vegetable programs at Coffs Harbour and the Nambucca Valley

The Mid-North Coast Division of General Practice obtained additional funding from the Department of Health and Ageing (Healthy Active Australia program) for other Aboriginal Medical Services in the area to trial similar nutrition programs. Galambila Aboriginal Health Service in Coffs Harbour and Giingan Darrunday Marlaanggu Health Clinic in Bowraville decided to establish similar fruit and vegetable subsidy programs for families. As a result, Galambila and Bowraville also elected to participate in the fruit and vegetable program evaluation. There was agreement by both these health services and the research team that it was appropriate to combine the results of the participants at each site in an overall evaluation as the nutritional status and demographics of each of the local Aboriginal communities was similar.

The programs that were implemented at Coffs Harbour and Bowraville differed from the ongoing program in the Clarence Valley in several ways due to local circumstances. In the Clarence Valley, both greengrocers collected the \$5 contribution from families and packed mixed boxes of seasonal fruit and vegetables. In Coffs Harbour, the only greengrocer who would participate in the program required families to pay the \$5 contribution at the health service and then receive a voucher to choose their own fruit and vegetables up to the specified amount. In Bowraville, the only available greengrocer

was in a different town; hence the health service collected the \$5 contribution and home-delivered boxes of fruit and vegetables to participating families.

3.2.2 Evaluation design

This was a pre- and post-assessment of the impacts and outcomes of the fruit and vegetable program (**Figure 3.3**). The participants had evaluation assessments done prior to starting and after twelve months on the program. The intervention was offered to families, but the target group for assessment was children 0-14 years. All children from new families who joined the fruit and vegetable program during recruitment for the evaluation were required to participate in the evaluation. Consent was obtained from each individual parent/carer.

The fruit and vegetable program involves all participating children having an annual health assessment. The annual check includes a clinical health assessment including anthropometric measurements and a dental check-up and hearing screening. This took approximately 1.5 hours for each participant (which may be over one or more clinic attendances). The results of these assessments were discussed with parents/carers.

The impact evaluation involved two additional elements as part of the annual health assessment. Participants completed a 24 hour dietary recall with a dietitian or trained AHW. In addition, each participant had a blood test to assess nutritional status (haemoglobin, iron, ferritin, transferrin, red cell folate, tocopherol, retinol, cholecalciferol, carotenoids, total cholesterol and high density lipoprotein cholesterol) and an inflammatory marker (C-reactive protein).

A retrospective clinical audit of health records was undertaken to compare rates of sick and well visits to health services, antibiotic prescriptions, episodes of otitis media, pyoderma, upper and lower respiratory tract infections, and hospital attendances and admissions. This involved a comparison between the 12 months prior to the program and the initial 12 months on the program.

A process evaluation was undertaken to document the development and implementation of the program and the perceptions of participating families. This involved focus groups in each community in the Clarence Valley (where BNMAC provides services) and interviews and discussions with key stakeholders. The results are summarised descriptively as formal qualitative analysis was beyond the scope of this thesis.

3.2.3 Outcome measures

The primary outcomes were the changes in biomarkers including carotenoids, vitamin C and red cell folate. This panel of biomarkers was used rather than a single primary outcome as the aim was to detect a change in dietary pattern with increased consumption of a range of fruit and vegetables. Thus, changes may be expected in one or more biomarkers.

The secondary outcomes included dietary outcomes, including change in fruit and vegetable intake and change in macronutrient intake, and health outcomes, including changes in episodes of illness, antibiotic prescriptions and emergency department attendances, admissions, BMI, haemoglobin, iron status and vitamin D. These were all continuous or ordinal variables which were calculated by subtracting the before value from the after value for each outcome. These were assessed on the basis that there were changes in the primary outcomes which suggested increased intake of fruit and vegetables, hence it was logical to then assess the extent of any other changes in dietary intake or specified health outcomes.

The crude changes were calculated and these were then adjusted for sex, age and community. Both sex and community were included as factors (categorical variables), while age was a covariate (continuous variable) in the statistical model used. The units for each outcome are specified in the results (chapters 4-6). The ordinal health outcomes, such as episodes of illness, are presented as episodes per year.

The Mid-North Coast Fruit and Vegetable Program

Aim:

To improve the health status of disadvantaged Aboriginal families with young children by increasing the intake of healthy foods and engaging these families in preventive health activities .

Objectives:

- To increase the intake of fruit and vegetables by reducing the barrier due to cost
- To increase the knowledge of healthy eating and meal preparation
- To improve food budgeting skills
- To increase the proportion of families who regularly attend the health service for well visits or preventive health activities

Strategies:

- Weekly subsidised box of fruit and vegetables
- Regular sessions incorporating nutrition promotion, practical cooking education and budgeting skills
- Annual health assessments for children at health service, schools, home-visits
- Annual dental check-up and hearing screening as indicated
- Recalls for immunisations, reviews as indicated
- Community gardens where feasible

Evaluation Components

Outcome evaluation

Clinical audits
Anthropometric assessments

Impact evaluation

24-hour diet recalls, blood tests-biomarkers

Process evaluation

Audit of number of boxes collected by families
Focus groups/Interviews

Figure 3.3 The fruit and vegetable subsidy program and components of the evaluation

3.2.4 Eligibility criteria

Families with one or more children 0-14 years and/or pregnant women were eligible for the fruit and vegetable program if they were:

- Regular Bulgarr Ngaru, Bowraville or Galambila clients (2 or more visits in previous 24 months).
- Received Centrelink payments/Community Development Employment Program as the major source of family income.
- Prepared for themselves/their children to have a health assessment including dental and hearing checks, a diet assessment and a blood test.

AND

- Children had identified nutritional risk
 - Anthropometric- e.g. abnormal growth (under- or overweight, slow growth), low birth weight.
 - Biomedical- e.g. nutritional deficiency disease, iron deficiency anaemia, chronic or recurrent infections.
 - Dietary risk- e.g. highly restricted diets, inappropriate infant feeding.

OR

- Children or their families presented frequently to health service for sick visits.

3.2.5 Recruitment Strategy

Potential participants were identified by any BNMAC, Bowraville or Galambila staff with reference to the eligibility criteria. Outreach visits to local schools and pre-schools allowed staff at these schools to identify potential participants. People also self-referred to participate in the fruit and vegetable program. The BNMAC fruit and vegetable committee considered their eligibility based on the eligibility criteria. The opportunity to participate in the program was offered by one of the fruit and vegetable committee either in person or by phone. All new participants were required to participate in the evaluation during this recruitment period.

3.2.6 Sample size calculations

It was expected that there would be a 10-50% improvement in the levels of nutritional markers as a result of the participation in the healthy food subsidy program. This was based on the nutritional improvements observed in the WIC program in the United States²⁶⁶ and a healthy lifestyle program at Looma.¹³⁶ A sample size of 22 (using paired samples) was required to detect a 50% increase in β -carotene with a statistical significance level of 5% and power of 80%. Sample size calculations for other carotenoids and fruit and vegetable intake are shown in **Appendix B**. The intention was to recruit a cohort of 60 new families which should provide sufficient sample size with allowance for attrition during the program.

3.2.7 Timeline of evaluation

The recruitment and baseline assessments were undertaken between December 2008 and September 2009, with follow-up assessments completed between December 2009 and September 2010. The dates of data collection in each community are shown in **Figure 3.4**.

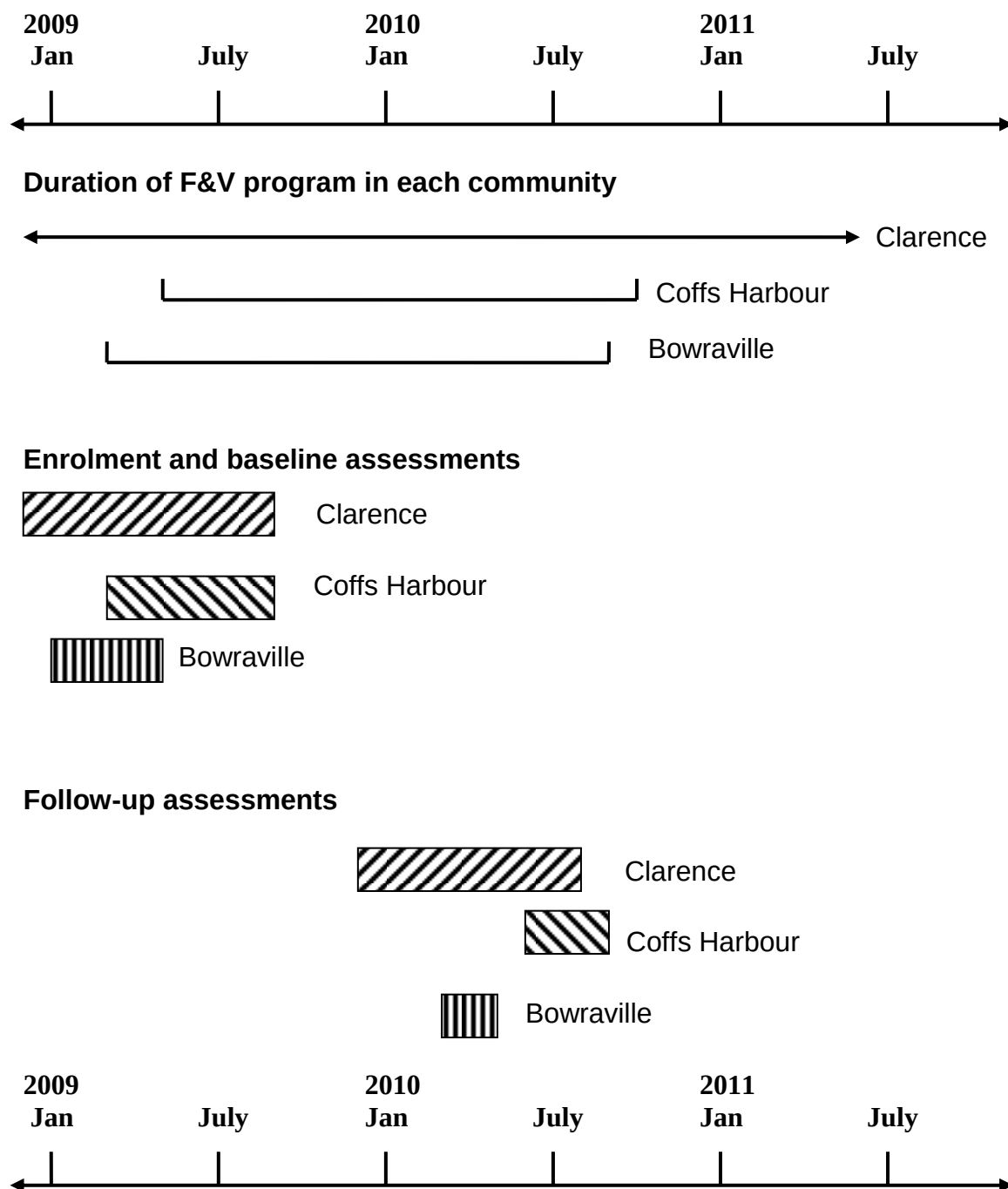


Figure 3.4 Timeline of the duration of the fruit and vegetable program in each community and timing of evaluation assessments.

3.3 Data Collection

3.3.1 Pathology samples

Non-fasting venous blood samples were collected by clinical staff into tubes wrapped in foil. Specimens were protected from light throughout processing to prevent carotenoid degradation. They were stored on ice prior to transport as soon as possible to Grafton Hospital Pathology or Symbion-Lavery Pathology, Coffs Harbour. There they were separated and plasma for the carotenoids and vitamin A and E were frozen at -20°C. The Grafton specimens were transported on dry ice to Hunter Area Pathology Service for storage at -80°C until transfer in batches to the University of Melbourne for storage at -80°C prior to analysis. The Symbion pathology specimens were stored at -20°C and transferred on dry ice in batches to the University of Melbourne for storage at -80°C prior to analysis.

3.3.2 Dietary recall

The 24 hour diet recalls were completed by participants face-to-face with the two qualified dietitians at BNMAC and one of the BNMAC dietitians or a trained Aboriginal health worker at Galambila and Bowraville. For participants aged < 10 years, these were completed together with a parent/carer. The data collection followed the multi-pass method described in the 1995 National Nutrition Survey.²⁷⁸ In addition, participants were asked about their usual consumption of fruit and vegetables using validated short dietary questions based on the Dietary Intake Assessment Tool developed in Queensland.¹²³ The diet recall form is in **Appendix C**.

3.3.3 Anthropometric measurements

These were done by one of the BNMAC clinical staff. Height, and weight were measured on all children aged 0 – 14 years. Two measurements were taken for each variable and the mean value used.¹²⁹

Height was measured without shoes or thick socks using a Seca Model 214 portable stadiometer or S&M wall-mounted stadiometer. The portable stadiometer was checked before each use against a steel tape measure to ensure correct assemblage. The participant stood with the heels together and the heels, buttocks and upper part of the back touching the upright of the stadiometer. The head was kept in the Frankfort plane while the participant held a deep breath during the measurement. Children less than 3

years who were unable to stand unaided were measured supine using a Seca baby measuring mat on a firm surface. Two people assisted the child to lie flat with the head in the Frankfort plane and heels together.

Weight and body fat were measured using a Tanita Body Fat Monitor Model UM030 wearing light clothing only, with empty pockets and shoes and socks removed. Body fat was only measured for children ≥ 7 years as per the Tanita recommendations. The scale was placed on a hard, even surface (not carpet). The participant stood on the centre of the scales without support and with the weight distributed evenly on both feet. Children < 2 years who are unable to stand unaided were weighed on a Soehnle Professional 7725 baby scale.

Body mass index was calculated as weight in kilograms divided by height in metres squared for children 2-14. Age- and sex-specific BMI cut-offs for normal weight, overweight and obese among children and adolescents were applied to the data.^{21, 279}

3.3.4 Clinical audit

Participant's health records at the Aboriginal Medical Service, other regular GP and their hospital record were reviewed by Dr Andrew Black. A discrete episode of each illness category was defined as a new diagnosis that was not related to any recent diagnoses or episodes of care. This was clarified with the relevant clinician/s if necessary. Skin infection was defined as a diagnosis by the attending clinician of impetigo or one or more infective skin ulcers or abscesses. Middle ear disease was defined as a diagnosis of one or more of: acute otitis media, tympanic membrane perforation with or without otorrhoea, and otitis media with effusion. These data were extracted on a clinical audit form (**Appendix D**).

3.4 Analysis

3.4.1 Blood specimens

Blood samples collected in the Clarence Valley were analysed at Grafton Base Hospital Pathology for red cell folate (RCF), iron, ferritin, transferrin, lipids, CRP and haemoglobin. Haemoglobin was analysed on a Sysmex XT-2000i haematology analyser (Roche Diagnostics, Australia) Lipids, iron, ferritin, transferrin and CRP were analysed on a Cobas Integra 800 chemistry analyser (Roche Diagnostics, Australia). Frozen plasma was transported from Grafton on dry ice to Hunter Area Pathology service, Newcastle, NSW where they were analysed for 25-hydroxyvitamin D. Vitamin D assay was performed using a Liaison platform (DiaSorin Inc., Minnesota, USA). This platform utilizes chemiluminescent immunoassay to determine the total concentration of 25-hydroxyvitamin D. The coefficients of variation (%) at concentrations of 18, 54 and 88 nmol/L are 5.5%, 4.0% and 2.9% respectively. Whole blood EDTA samples were transported to Pathology North - Lismore laboratory at 2-8°C for RCF analysis. Samples were pre-treated with a lysis reagent containing guanidine hydrochloride and ascorbic acid and then a lysis diluent to obtain a final 1:21 dilution. RCF was then analysed by chemiluminescent microparticle immunoassay on an Architect i2000 Immunoassay analyser (Abbott Diagnostics, Australia).

Blood samples collected in Coffs Harbour and the Nambucca Valley were analysed for red cell folate, iron, ferritin, transferrin, lipids, CRP and haemoglobin at Symbion Lavery Pathology, Coffs Harbour. Full blood counts were analysed on a Sysmex XT haematology analyser (Sysmex Corporation, Singapore). Lipids and CRP were measured on a Cobas Integra 400 chemistry analyser (Roche Diagnostics, Australia). RCF, ferritin and 25-OH vitamin D assays were performed on the ADVIA Centaur XP automated immunoassay platform (Siemens Diagnostics, Australia). Whole blood was pre-treated with a folate ascorbic acid diluent to haemolyse the specimen prior to RCF analysis. Iron and transferrin were measured on the ADVIA 2400 chemistry analyser (Siemens Diagnostics, Australia).

Frozen plasma samples from both locations were transported on dry ice to Royal Prince Alfred Hospital, Sydney, where they were analysed for vitamin C. 200µL of plasma was diluted with 400µL 10% TCA. Ten µL samples of this mixture was analysed for

vitamin C using HPLC (lab-packed LiChrosorb RP-18 (5 micron) column) with electrochemical detection.

Plasma samples were analysed for carotenoids, tocopherols and retinol at St Vincent's Hospital, University of Melbourne. The extraction and analysis of individual carotenoids (lycopene, lutein, zeaxanthin, alpha- and beta-carotene), retinol and tocopherols (alpha- and gamma-tocopherol) was based on the method as described by Su et al²⁸⁰ with minor changes. Briefly, 200µl of plasma was extracted twice with 1ml of hexane containing 0.01% BHT. For quantification an internal standard of echinenone 0.167 µg/ml was added to all samples prior to the extraction. The extract was dried under nitrogen at room temperature, then reconstituted in 100µl of mixture CHCl₃:MeOH:CH₃CN (30:35:35). Then 50 µl was injected into the HPLC (Shimadzu HPLC machine equipped with an SPD-M20A PDA detector and a NovoPak C¹⁸ column) with absorbance detection at 292 nm for the tocopherols, 325 nm for retinol and 450 nm for the carotenoids. The carotenoids, retinol and tocopherols were eluted from the column using a mobile phase of 0.0125% ammonium acetate in MeOH (A), 100% CHCl₃ (B) and CH₃CN with 0.1% triethylamine (C) in three linear gradient steps: from 0 to 5 minutes, A 50%, C decreased from 50% to 44% and B increased to 6%; from 5 to 16 minutes, A increased to 55%, C decreased from 44% to 30% and B increased from 6% to 15% and then washed with A:C 50/50 mixture for 3 minutes.

3.4.2 Statistical analysis

Collected data was entered into a Microsoft Access database. Dietary recall data was initially entered and analysed in FoodWorks Professional 2009 dietary software program (Xyris, Queensland, Australia) using the AusNut 2007 Australian food database. These data were then entered into a Microsoft Access database. This facilitated analysis of nutritional intake and calculations of fruit and vegetable intake. Statistical analysis was undertaken using SPSS Version 19 (IBM, New York, USA). The analysis was based on intention to treat using available cases with the reasons for missing data accounted for if possible.

Outcomes were assessed by comparing the change between pre- and post- levels, which increased the likelihood that these outcomes were normally distributed. Outcomes were checked for normality prior to undertaking parametric analyses. The crude change in biomarkers, dietary and health outcomes are presented as means and 95% confidence

intervals using paired t-tests. These outcomes were adjusted for age, sex and community using a General Linear Model. Sex and community were included as factors, while age was included as a covariate in the statistical model. The effect of additional covariates in the statistical model was assessed, including total cholesterol and baseline values for biomarkers and baseline values for dietary and health outcomes.

The red cell folate data were transformed to z scores prior to analysis as above. This was done as red cell folate were analysed at two pathology laboratories using different techniques that produced results which were not directly comparable. The z scores were calculated for combined pre- and post- results from each laboratory. Dietary outcomes were divided by total energy intake in MJ to facilitate analysis that reflected the nutrient density of the diet.

3.4.3 *Validity of the self-reported dietary data*

Potential under-reporting in the 24-hour dietary recalls was assessed by comparing the ratio of energy intake (EI)/basal metabolic rate (BMR).^{119, 121} A cut-off of 0.90 was used to determine potential under-reporting.¹¹⁹ Twelve (10%) of the initial dietary recalls and 21 (18%) of the follow-up dietary recalls were potentially implausibly low. However, dietary recalls were not excluded on the basis of EI/BMR ratio, as energy expenditure or physical activity levels were not assessed.¹⁹ One 24-hour recall was excluded due to known acute illness and extremely limited food intake.

3.5 Ethics

This study was supported by the Boards of BNMAC, Galambila AMS and Durri AMS which represent the local Aboriginal communities. The proposed research evaluation was developed in collaboration with BNMAC staff- many of whom are Aboriginal people from the local community. The fruit and vegetable program has significant community support. This extended to support for a program evaluation that would provide information about the health benefits of the program and how it could be improved.

Ethics approval was obtained from the University of Melbourne and the Aboriginal Health and Medical Research Council (NSW) human research ethics committees in

2008 to conduct the community-based evaluation of the fruit and vegetable program at the three Aboriginal health services. Ethics approval was also obtained from the University of South Australia human research ethics committee for this study after I transferred to the University of South Australia in 2010. Ethics approval was obtained from the North Coast Area Health Service research ethics committee to undertake the clinical audits of participant's hospital records in 2011.

4 Nutritional impacts of the fruit and vegetable program

4.1 Introduction

Higher intake of fruit and vegetables reduces the risk of chronic diseases including cardiovascular disease^{45, 106}, diabetes²⁸¹, stroke^{109, 282} and cancer⁴⁷. It is also linked to lower risk of obesity²⁸³ and hypertension.²⁸⁴ Despite this, low intake of fruit and vegetables is common in many countries.¹⁰³ In high income countries, low fruit and vegetable consumption is more prevalent in those of lower socio-economic status.^{65, 105, 190} Successful strategies to increase fruit and vegetable intake offer the potential to reduce the economic costs and prevalence of chronic diseases. Strategies which are effective in those of low socio-economic status have the potential to also reduce health inequalities.

Extensive social marketing and health promotion campaigns to promote fruit and vegetable consumption have not been sufficient to reduce the high prevalence of less healthy dietary patterns. Fiscal strategies, including both taxation of less healthy foods and price discounts or subsidies for healthier foods, have been proposed as an alternative strategy which could complement health promotion.¹¹⁸ Economic modelling consistently indicates that price subsidies for healthy foods are likely to produce significant improvements in healthy food consumption including fruit and vegetables,^{217, 218} particularly in those on low incomes.^{219, 220} In the USA and UK, where longstanding food subsidy programs are an important component of social security for low income families, there have been recent changes to some of these programs to better promote fruit and vegetables. Despite the large investment in food subsidy programs, particularly in the USA, there is limited high quality evidence of their effectiveness.²³² A 12.5% price discount, but not tailored nutrition education, increased healthy food purchases by 11% in one RCT in a supermarket setting.²⁴⁴ Another RCT,

currently underway, will enhance these findings by comparing skill building for healthy eating with or without price discounts.²⁸⁵

In Australia, Aboriginal and Torres Strait Islander people have poorer health outcomes and are more likely to have significantly lower socio-economic status than the general population.⁵ Fiscal strategies to promote healthy nutrition have not been widely implemented in Australia, either among Indigenous Australians or those on low incomes. In this context, this paper reports on a fruit and vegetable subsidy program instituted at three rural Aboriginal community-controlled health services. The program was initially instituted in 2005 at one service in response to poor nutrition among low income families attending the health service. The aims of the program were to improve nutritional intake and engage participants in preventive health activities.

In this chapter, the nutritional impact of the fruit and vegetable subsidy program on a cohort of children was examined by comparing nutritional biomarkers and self-reported intake of fruit and vegetables and macronutrients before and after participation in the program for 12 months.

4.2 Methods

4.2.1 Study design and data collection

This chapter presents the before and after comparison of the nutritional outcomes after participation in the fruit and vegetable program. Details of the fruit and vegetable program are described in section 3.2.1. As part of the annual health assessments, each child's nutritional status was assessed with a 24 hour diet recall and a blood test before and after 12 months on the program. These assessments were completed as close to one year apart as possible to minimise seasonal variation. The details of these assessments are described in section 3.3.

4.2.2 Data analysis

Blood samples were analysed for haemoglobin, iron studies, red cell folate, tocopherol, retinol, cholecalciferol, carotenoids, total cholesterol and high density lipoprotein cholesterol and C-reactive protein. The handling, storage and analysis of the blood samples have been described in detail in section 3.3 and 3.4.

The dietary recall data were analysed using FoodWorks Professional 2009 dietary software program (Xyris, Queensland, Australia) using the AusNut 2007 Australian food database. The nutrient intake data including fruit and vegetable intake and the biomarker data were then entered into a Microsoft Access database for cleaning.

Statistical analysis was completed comparing changes between the follow-up data and baseline data for each participant using paired t-tests and the General Linear Model function in SPSS Version 19 (IBM, New York, USA). The difference in the mean age at baseline by community was compared with univariate analysis of variance. The differences in the proportion of children living in a household with smokers and gender by community were compared with pairwise Chi-squared tests with $p < 0.025$ to allow for multiple comparisons. Details of the statistical analysis were presented in section 3.4. The differences in the implementation of the program at the three locations led to a change in the analysis plan with the mean differences and 95% confidence intervals compared for both the overall sample and the individual communities. This decision was made after the data collection and the findings for the individual communities were assessed prior to assessment of the pooled data.

4.2.3 Ethics

Ethics approval was obtained from the University of Melbourne and the Aboriginal Health and Medical Research Council (NSW) human research ethics committees. Community consent was obtained from the Boards of the three participating health services. Further details are outlined in section 3.5.

4.3 Results

4.3.1 Baseline demographic characteristics of participants

There were 55 Aboriginal families recruited to participate in the evaluation of the fruit and vegetable program at the three Aboriginal Health Services which included 174 children. The baseline assessment of these children aged 0-17 years was undertaken. There were 90 children assessed at BNMAC, 36 children at Galambila and 48 children at Bowraville. Baseline characteristics of the participants are shown in **Table 4.1**. In comparison with the overall sample, the mean age of the children was significantly older at Coffs Harbour and younger at Bowraville ($F(2,173) = 11.64, p < 0.001$). There was a greater proportion of females at Bowraville compared to the other two

communities, although this was not statistically significant [Clarence versus Bowraville, $\chi^2(1) = 2.33$, $p=0.127$; Coffs Harbour versus Bowraville, $\chi^2(1) = 1.31$, $p=0.252$]. A lower proportion of children lived in a household with smokers at Coffs Harbour compared to the other communities, although this was also not statistically significant [Coffs Harbour versus Clarence, $\chi^2(1) = 4.48$, $p=0.034$; Coffs Harbour versus Bowraville, $\chi^2(1) = 3.44$, $p= 0.064$].

Table 4.1 Baseline demographic characteristics of participating children

	All communities	Clarence	Coffs Harbour	Bowraville
Families, n	55	30	12	13
Children, n	174	90	36	48
Age (years) Mean (SD)	7.6 (4.2)	7.5 (3.8)	11.0 (3.3)	5.8 (4.3)
Sex, n (%)				
Male	82 (47%)	46 (51%)	18 (50%)	18 (37%)
Female	92 (53%)	44 (49%)	18 (50%)	30 (63%)
Children with smoker(s) in household, n (%)	107 (66%)	62 (69%)	18 (50%)	27 (71%)

4.3.2 Baseline levels of biomarkers

At the initial assessment, 145 children had blood samples taken. The baseline carotenoids and vitamin A, vitamin C and vitamin E levels are presented in **Table 4.2**. These baseline carotenoids were similar, except for lycopene, to a US population survey of children aged 6-16 years ($n=4231$).¹⁵¹ In the US study, mean β -carotene was 302.3 nmol/L, mean α -carotene was 69.8 nmol/L, mean β -cryptoxanthin was 190.7 nmol/L, mean lutein/zeaxanthin was 312.2 nmol/L, mean lycopene was 454.5 nmol/L. β -carotene was similar and vitamin A was higher in this study, than those reported in 467

Australian preschool-aged children in 1997, in whom mean β -carotene was 300 nmol/L and mean vitamin A was 1.29 μ mol/L.¹⁵⁴

Table 4.2 Baseline biomarkers of Aboriginal children 0-17 years

Biomarkers	Mean (SD)	Median	Interquartile range
	nmol/L	nmol/L	nmol/L
β -carotene	346.6 (173.0)	315.0	221.5 - 415.0
α -carotene	66.1 (56.4)	46.0	23.0 - 83.5
Lycopene	637.7 (306.5)	603.0	419.5 - 813.0
β -cryptoxanthin	159.0 (167.2)	120.0	73.0 - 182.5
Lutein-Zeaxanthin	303.3 (168.5)	244.0	180.5-391.5
Vitamin A (μ mol/L)	2.1 (0.7)	2.0	1.7 – 2.5
Vitamin E (α -tocopherol) (μ mol/L)	23.4 (5.6)	23.1	19.7- 27.7
Vitamin C (n=65) (μ mol/L)	49.1 (21.4)	49.0	33.0 – 66.0

4.3.3 Nutrient intake at baseline

150 children completed twenty-four hour diet recalls in the baseline assessments. One record was excluded as virtually no food intake was recorded due to illness. There were two diet recalls completed for infants <12 months and eight diet recalls completed for children aged 1-2 years. Due to the small numbers and to facilitate comparisons with other surveys, diet recall data from children under two years are not tabulated. Mean macronutrient intakes for children aged 2-17 years are shown in **Table 4.3**. Despite the small sample sizes in each age category, particularly the youngest and oldest categories, the macronutrient intakes were comparable to the macronutrient intake reported in the 2007 Australian National Children's Nutrition and Physical Activity Survey.¹⁹ The

Aboriginal children in this study tended to eat less protein in all age categories, and more total fat and saturated fat in the younger age categories and more total starch but less total sugar in the older two age categories, in comparison with the 2007 national survey results. Mean intake of micronutrients at baseline for children aged 2-17 years is shown in **Table 4.4**. In comparison with the micronutrient intake reported in the 2007 national survey, these children reported lower intake of folate, calcium and magnesium across all age categories. However, the children in this group reported higher vitamin C intake than those in the 2007 national survey.

Table 4.3 Macronutrient intake by age category and sex at baseline

Macronutrients Mean (SD)	Age Category											
	2-3 years			4-8 years			9-13 years			14-17 years		
	Males n=13	Females n=8	Total n=21	Males n=23	Females n=28	Total n=51	Males n=27	Females n=29	Total n=56	Males n=4	Females n=7	Total n=11
Energy (kJ)	6308 (3109)	7452 (2023)	6744 (2749)	7975 (2653)	6947 (1825)	7411 (2272)	8735 (3477)	8676 (3216)	8704 (3314)	12193 (5670)	7664 (2287)	9311 (4243)
Protein (g)	48.5 (30.0)	65.1 (21.6)	54.8 (27.8)	67.7 (31.7)	52.4 (19.5)	59.3 (26.5)	73.2 (35.0)	72.4 (36.6)	72.8 (35.5)	119.1 (43.6)	65.9 (23.5)	85.2 (40.3)
Total fat (g)	62.1 (36.4)	73.4 (27.3)	66.4 (32.9)	73.3 (33.3)	61.5 (21.7)	66.8 (27.9)	78.8 (33.9)	74.5 (34.0)	76.6 (33.7)	111.6 (55.1)	76.3 (35.8)	89.1 (44.7)
Saturated fat (g)	32.3 (18.5)	33.9 (10.1)	32.9 (15.6)	33.5 (15.6)	27.9 (8.2)	30.4 (12.3)	34.1 (15.4)	31.6 (14.9)	32.8 (15.1)	43.7 (22.9)	32.0 (16.8)	36.2 (19.0)
Monounsaturated fat (g)	20.9 (12.2)	25.9 (11.5)	22.8 (11.9)	25.5 (13.3)	21.4 (9.1)	23.3 (11.3)	27.4 (12.2)	26.4 (13.0)	26.9 (12.5)	39.1 (18.2)	27.6 (13.8)	31.8 (15.7)
Polyunsaturated fat (g)	6.3 (5.9)	8.6 (5.3)	7.2 (5.7)	8.9 (3.9)	7.6 (4.7)	8.2 (4.4)	11.2 (8.1)	10.5 (6.6)	10.8 (7.3)	20.8 (13.0)	12.0 (8.1)	15.2 (10.4)
Total carbohydrate (g)	185.9 (84.6)	209.3 (48.3)	194.8 (72.4)	238.1 (69.1)	219.3 (71.8)	227.8 (70.5)	264.4 (112.1)	271.2 (95.0)	267.9 (102.7)	343.2 (184.1)	216.4 (68.5)	262.5 (130.7)
Total sugars (g)	101.1 (63.7)	88.1 (23.2)	96.2 (51.7)	105.7 (42.2)	101.3 (58.8)	103.3 (51.5)	108.3 (40.5)	134.1 (72.8)	121.6 (60.4)	89.2 (35.8)	86.0 (38.2)	87.1 (35.6)
Total starch (g)	84.6 (39.6)	120.7 (42.2)	98.3 (43.4)	132.1 (51.9)	115.5 (41.0)	123.0 (46.5)	154.5 (94.8)	136.8 (53.5)	145.3 (76.0)	253.1 (149.5)	130.0 (62.2)	174.8 (113.5)
Fibre (g)	12.0 (6.6)	17.1 (6.5)	13.9 (6.9)	18.3 (7.9)	16.0 (5.8)	17.1 (6.8)	19.8 (10.6)	20.2 (7.4)	20.0 (9.0)	34.2 (13.0)	13.7 (7.3)	21.2 (13.7)

Table 4.4 Micronutrient intake by age category and sex at baseline

	Age Category											
	2-3 years			4-8 years			9-13 years			14-17 years		
	Males n=13	Females n=8	Total n=21	Males n=23	Females n=28	Total n=51	Males n=27	Females n=29	Total n=56	Males n=4	Females n=7	Total n=11
Thiamine (mg)	1.3 (0.7)	1.5 (0.4)	1.4 (0.6)	2.3 (1.0)	1.4 (0.6)	1.8 (0.9)	1.9 (1.2)	2.0 (0.9)	2.0 (1.0)	3.2 (1.8)	1.4 (1.0)	2.1 (1.5)
Riboflavin (mg)	1.8 (1.2)	1.7 (0.5)	1.8 (1.0)	2.7 (1.4)	1.5 (0.7)	2.0 (1.3)	2.1 (1.4)	2.2 (1.3)	2.2 (1.3)	3.6 (2.6)	1.5 (1.5)	2.2 (2.2)
Niacin equiv (mg)	23.3 (13.3)	29.8 (9.9)	25.8 (12.3)	33.7 (13.2)	25.1 (8.0)	29.0 (11.4)	34.4 (14.9)	36.4 (17.4)	35.4 (16.1)	59.9 (28.3)	31.4 (9.0)	41.8 (22.2)
Vitamin C (mg)	152.6 (109.1)	104.3 (72.5)	134.2 (97.8)	108.7 (76.7)	142.0 (109.1)	127.0 (96.4)	131.1 (106.7)	203.8 (179.2)	168.7 (151.9)	137.0 (123.1)	56.6 (46.3)	85.9 (86.5)
Folate equiv (mcg)	225.0 (109.7)	262.5 (69.3)	239.3 (96.2)	318.0 (114.8)	235.4 (78.4)	272.6 (104.1)	291.2 (141.2)	313.8 (129.0)	302.9 (134.2)	440.8 (136.9)	179.7 (98.4)	274.6 (169.6)
Vitamin A equiv (mcg)	627.0 (448.3)	915.3 (792.9)	736.8 (601.0)	731.4 (402.0)	638.4 (354.4)	680.3 (375.7)	858.8 (504.7)	903.9 (512.8)	882.2 (504.8)	1044.5 (366.1)	479.1 (290.8)	684.7 (415.1)
β-Carotene (mcg)	1687.6 (1215.6)	3332.4 (4734.6)	2314.2 (3066.3)	1370.1 (1130.4)	1417.4 (1561.4)	1396.1 (1370.9)	2462.4 (2459.2)	2421.1 (2520.9)	2441.0 (2468.7)	3456.3 (1712.9)	799.4 (885.6)	1765.6 (1774.1)
Sodium (mg)	1608.6 (847.5)	2075.6 (840.5)	1786.5 (855.7)	2195.0 (693.4)	2005.2 (758.5)	2090.8 (728.9)	2474.0 (1127.0)	2332.4 (1002.4)	2400.7 (1056.9)	3424.3 (2484.4)	2092.0 (1010.8)	2576.5 (1707.8)
Magnesium (mg)	187.4 (97.0)	225.1 (56.5)	201.8 (84.3)	247.1 (96.0)	202.8 (46.3)	222.8 (75.6)	261.6 (108.8)	265.9 (99.3)	263.8 (103.1)	395.0 (118.5)	195.0 (66.5)	267.8 (130.5)
Calcium (mg)	709.9 (513.4)	687.3 (289.8)	701.3 (433.2)	766.3 (387.7)	550.8 (223.4)	648.0 (323.8)	722.1 (393.0)	684.7 (387.1)	702.7 (386.8)	766.3 (229.6)	681.5 (544.0)	712.3 (441.9)

Mean (SD)	Age Category											
	2-3 years			4-8 years			9-13 years			14-17 years		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Iron (mg)	7.1 (3.6)	9.4 (2.3)	8.0 (3.3)	11.1 (4.2)	9.2 (3.2)	10.1 (3.7)	12.1 (5.2)	11.5 (4.9)	11.8 (5.0)	18.5 (6.3)	6.6 (1.1)	10.9 (7.0)
Zinc (mg)	6.0 (3.2)	7.7 (2.4)	6.6 (3.0)	10.6 (12.1)	7.7 (5.9)	9.0 (9.2)	9.8 (5.2)	13.6 (18.2)	11.8 (13.6)	16.2 (8.4)	6.8 (1.7)	10.2 (6.8)

4.3.4 Impact of the fruit and vegetable program on biomarkers and fruit and vegetable intake

The median period between baseline and follow-up assessment was 370 days (inter-quartile range 354 to 407 days).

In the overall sample of children, mean β -cryptoxanthin, lutein-zeaxanthin, and vitamin C were significantly higher after participation in the fruit and vegetable program for 12 months compared to baseline levels (**Table 4.5**). These changes remained significant after adjustment for gender, age and community (**Table 4.6**). There were no significant changes in α -tocopherol, γ -tocopherol or retinol (data not shown). There were also significant increases in mean β -cryptoxanthin and lutein-zeaxanthin observed in Coffs Harbour and in vitamin C and α -carotene in the Clarence Valley (**Table 4.6**).

Adjustment for total cholesterol did not alter the mean change in carotenoids overall or in each community. Adjustment for the baseline level of biomarkers did not alter the mean changes in carotenoids, vitamin C or red cell folate overall, however it did alter the mean change in β -cryptoxanthin (mean change -10.7 nmol/L, 95% confidence interval -57.4 - 35.9) and red cell folate (mean change 161.5 nmol/L, 95% confidence interval 39.9 - 283.0) in Bowraville. There were no significant differences in biomarkers by gender, although females did have greater mean change in β -cryptoxanthin than males (females 43.6nmol/L, males 2.4 nmol/L, $F=3.43$, $p=0.07$). The use of vitamin and mineral supplements was reported by 13% of children at baseline and 9% of children at the follow-up assessments. Given the low numbers, supplement use was not included further in the analysis.

Red cell folate increased in all three communities, although the only statistically significant increase was in the Clarence Valley ($p<0.001$) (**Table 4.6**). The red cell folate was measured using different methods in two laboratories; hence the overall results could not be combined directly. There were significant differences between the communities in the changes in mean lycopene and lutein-zeaxanthin. Lutein-zeaxanthin increased in Coffs Harbour and the Clarence Valley, but decreased in Bowraville; whereas lycopene increased in Coffs Harbour, while it decreased in the Clarence Valley and Bowraville (**Table 4.6**).

At baseline, the fruit and vegetable program participants reported that their mean intake of fruit was 1.0 serves/day and vegetables (excluding deep-fried potato) was 0.8

serves/day in the 24 hour recalls, but their mean intake of fruit was 2.2 serves/day and vegetables 2.5 serves/day in the short questions completed simultaneously (**Table 4.7**). There were no significant changes in fruit and vegetable intake reported using 24 hour recalls for the overall sample in either the crude analysis (**Table 4.7**) or after adjustment for gender, age and community (**Table 4.8**). However, there was a small but significant increase in fruit intake in the crude analysis and a small, but significant, decrease in vegetable intake reported using short questions in the crude analysis (**Table 4.7**) and after adjusting for gender, age and community (**Table 4.8**). There was a significant increase in fruit intake using short questions in the Clarence Valley and decreases in vegetable intake in Bowraville (24 hour recall) and Coffs Harbour (short questions), although the differences between communities were small and not statistically significant overall (**Table 4.8**).

Table 4.5 Biomarkers before and after the fruit and vegetable program

	Mean (SD) (nmol/L)		Mean Difference (After – Before) (95% confidence interval) (nmol/L)	Significance of difference
	Before	After		
β-carotene	346.6 (173.0)	338.9 (195.4)	-7.7 (-39.5, 24.0)	0.630
α-carotene	66.1 (56.7)	73.7 (53.3)	7.6 (-2.1, 17.3)	0.124
Lycopene	637.7 (306.5)	586.9 (295.1)	-50.9 (-106.8, 5.1)	0.074
β- cryptoxanthin	159.0 (167.2)	183.9 (167.0)	25.0 (2.9, 47.1)	0.027
Lutein- Zeaxanthin	303.3 (163.5)	337.8 (170.4)	34.5 (4.3, 64.6)	0.026
Vitamin C (μmol/L) (n=57)	49.1 (21.4)	59.6 (24.6)	10.5 (2.3, 18.7)	0.013

Table 4.6 Biomarker changes among F&V program participants overall and by individual communities

Biomarker (nmol/L)	Mean Δ -score (95% CI)	Adjusted mean Δ - score* (95% CI)	Community 1 Clarence n=68 Mean (95% CI) [†]	Community 2 Coffs Harbour n=23 Mean (95% CI) [†]	Community 3 Bowraville n=24 Mean (95% CI) [†]	Sig. of community comparison
β-Carotene	-7.7 (-39.5, 24.0)	-12.2 (-48.4, 24.1)	2.2 (-39.5, 43.8)	-1.6 (-76.4, 73.2)	-37.2 (-111.0, 36.6)	0.653
α-Carotene	7.6 (-2.1, 17.3)	4.3 (-6.7, 15.2)	14.1 (1.4, 26.8)	1.0 (-21.6, 23.6)	-2.2 (-24.6, 20.1)	0.331
β-Cryptoxanthin	25.0 (2.9, 47.1)	28.9 (4.2, 53.6)	13.9 (-14.5, 42.3)	69.8 (18.9, 120.8)	3.0 (-47.3, 53.2)	0.133
Lycopene	-50.9 (-106.8, 5.1)	-42.9 (-104.1, 18.3)	-55.0 (-125.3, 15.3)	107.9 (-18.3, 234.1)	-181.6 (-306.1, -57.0)	0.010
Lutein/Zeaxanthin	34.5 (4.3, 64.6)	39.3 (6.2, 72.5)	33.7 (-4.5, 71.8)	106.3 (37.9, 174.7)	-21.9 (-89.4, 45.6)	0.043
Vitamin C (μmol/L)	10.5 (2.3, 18.7)	10.1 (2.0, 18.1)	10.1 (2.0, 18.1)	-	-	-
Red cell folate	-	-	248.4 (197.2, 299.6)	91.6 (-52.4, 235.7)	121.6 (-26.5, 269.7)	-

* Adjusted for gender, age and community

[†] Adjusted for gender and age

Table 4.7 Fruit and vegetable intake before and after fruit and vegetable program

		Serves per day Mean(SD)		Significance of difference
		Before	After	
24 hour recall	Fruit	1.0 (1.4)	1.0 (1.1)	0.828
	Vegetables	0.6 (0.9)	0.5 (0.8)	0.443
	Vegetables (including potato)	0.8 (1.2)	0.7 (0.9)	0.272
	Fruit and vegetables	1.8 (1.8)	1.6 (1.6)	0.354
Short questions	Fruit (n=111)	2.2 (1.0)	2.5 (1.4)	0.050
	Vegetables (n=118)	2.5 (1.4)	2.2 (1.1)	0.046

Table 4.8 Changes in fruit and vegetable intake among fruit and vegetable program participants by community

Intake (Serves/day)	Mean Δ -score (95% CI)	Adjusted mean Δ -score* (95% CI)	Community 1	Community 2	Community 3	Sig. of community comparison
			Clarence n=80 Mean (95% CI) [†]	Coffs Harbour n=21 Mean (95% CI) [†]	Bowraville n=20 Mean (95% CI) [†]	
Fruit (24 hour recall)	-0.03 (-0.30, 0.24)	-0.10 (-0.42, 0.23)	0.03 (-0.30, 0.36)	-0.17 (-0.85, 0.51)	-0.15 (-0.85, 0.54)	0.792
Vegetable including potato (24 hour recall)	-0.15 (-0.42, 0.12)	-0.20 (-0.53, 0.12)	-0.10 (-0.42, 0.23)	0.19 (-0.49, 0.87)	-0.71 (-1.40, -0.02)	0.183
Fruit (Short questions)	0.23 (0.004, 0.46)	0.11 (-0.18, 0.39)	0.31 (0.05, 0.56)	0.27 (-0.30, 0.84)	-0.26 (-0.90, 0.39)	0.277
Vegetables (Short questions)	-0.27 (-0.54, 0.00)	-0.49 (-0.82, -0.16)	-0.08 (-0.40, 0.25)	-1.02 (-1.74, -0.30)	-0.38 (-1.05, 0.30)	0.057

* Adjusted for gender, age and community

[†] Adjusted for gender and age

4.3.4.1 Changes in macronutrient intake

There was a decrease in macronutrient intake in the follow-up diet recalls, particularly carbohydrates and total sugars (**Table 4.9**). To facilitate comparison with the large variation in intake among these children aged 0-17 years, macronutrients intake per megajoule were also analysed. In the analysis of macronutrients per megajoule, there were small but statistically significant decreases in total sugar (1.6g/MJ) and added sugar (1.2g/MJ) while other macronutrient intakes were unchanged (**Table 4.10** and **Figure 4.1**). However, after adjustment for sex, age and community, there were no significant changes in the any macronutrients per MJ overall (**Table 4.10**). There were significant decreases in total (2.3 g/MJ) and added sugar (2.4g/MJ) intake in the Clarence Valley but a significant increase in added sugar (3.4g/MJ) intake in Coffs Harbour (**Table 4.10**). There were significant differences between the three communities in the mean intake of all macronutrients per megajoule except starch, which reflected the variability in reported intake and the small numbers of recalls in Bowraville and Coffs Harbour (**Table 4.10**).

Table 4.9 Macronutrient intake before and after fruit and vegetable program

	Mean (SD)		Difference (After-Before) (95% confidence interval)	Sig. of difference
	Before	After		
Energy (kJ)	7570.0 (3155.5)	6481.7 (2197.1)	-1088.3 (1739.2, -437.4)	0.001
Protein (g)	62.5 (33.7)	54.8 (25.9)	-7.7 (-13.7, 1.6)	0.013
Total fat (g)	67.8 (31.3)	60.5 (23.0)	-7.4 (-13.9, -0.8)	0.028
Saturated fat (g)	30.7 (13.8)	26.9 (10.9)	-3.8 (-6.7, -0.8)	0.013
Polyunsaturated fat (g)	8.8 (6.5)	7.2 (3.6)	-1.7 (-3.0, -0.3)	0.016
Monounsaturated fat (g)	23.5 (11.7)	21.8 (9.1)	-1.7 (-4.1, 0.8)	0.179
Carbohydrate (g)	231.5 (100.2)	191.5 (72.9)	-40.0 (-61.7, -18.3)	<0.001
Starch (g)	123.1 (71.4)	105.7 (46.9)	-17.4 (-31.9, -2.9)	0.019
Total sugar (g)	107.4 (56.3)	84.8 (46.0)	-22.6 (-35.2, -10.0)	0.001
Added sugar (g)	77.4 (49.4)	61.1 (41.5)	-16.3 (-27.0, -5.6)	0.003
Fibre (g)	17.1 (9.2)	15.0 (7.4)	-2.2 (-4.2, -0.2)	0.031

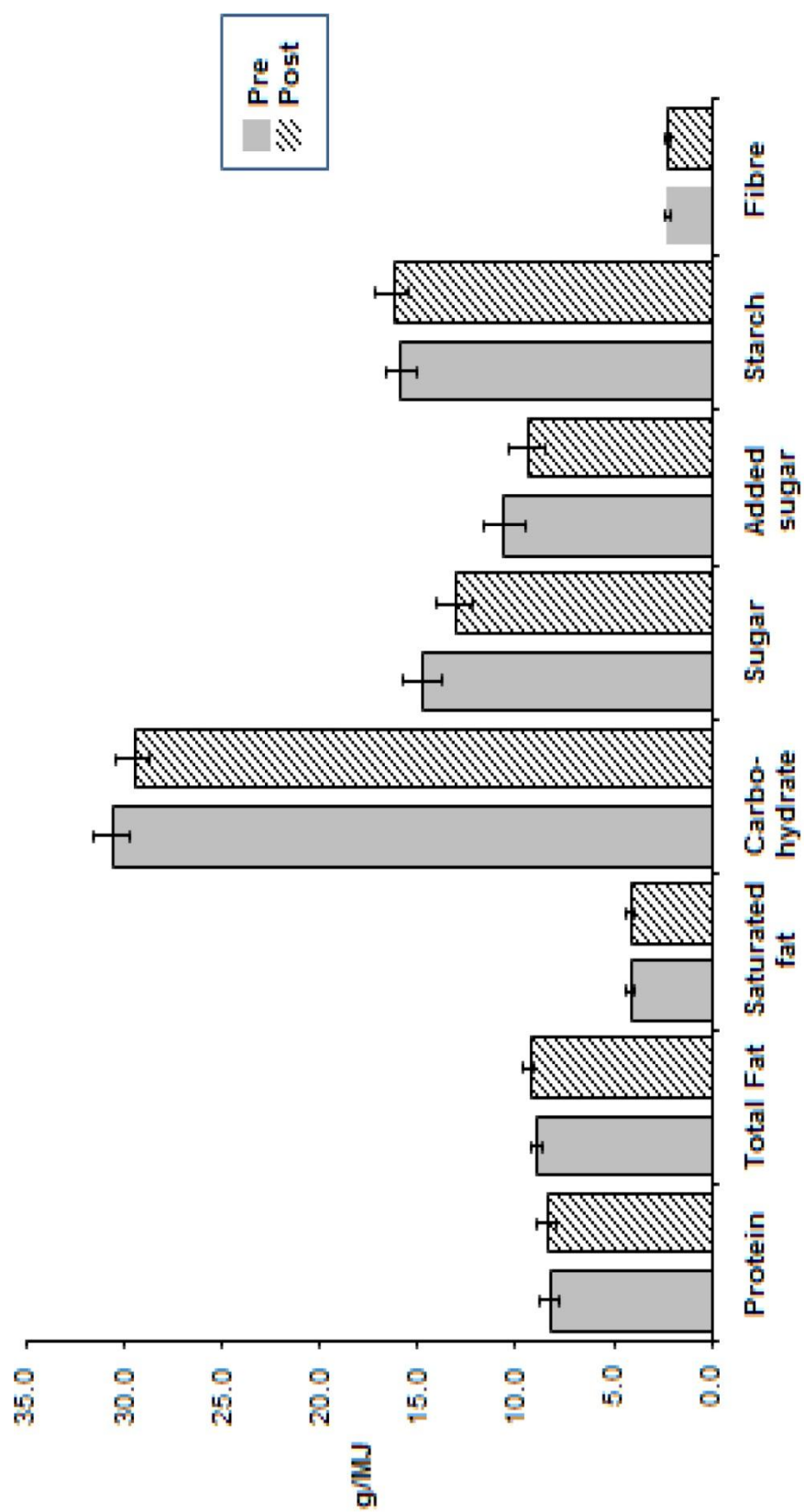


Figure 4.1 Macronutrient intake per megajoule before and after the fruit and vegetable program

Table 4.10 Change in macronutrients per megajoule among fruit and vegetable participants

Change in Macronutrients (g/MJ)	Mean Δ -score (95% CI)	Adjusted mean Δ - score* (95% CI)	Community 1 Clarence n=80 Mean (95% CI) [†]	Community 2 Coffs Harbour n=21 Mean (95% CI) [†]	Community 3 Bowraville n=20 Mean (95% CI) [†]	Sig. of community comparison
CHO	-1.1 (-2.2, 0.02)	-1.2 (-2.5, 0.1)	-1.0 (-2.3, 0.3)	2.2 (-0.4, 4.9)	-4.8 (-7.5, -2.1)	0.003
Total Sugar	-1.6 (-2.8, -0.4)	-1.0 (-2.4, 0.4)	-2.3 (-3.7, -0.9)	2.8 (-0.1, 5.7)	-3.6 (-6.5, -0.7)	0.005
Added sugar	-1.2 (-2.4, -0.001)	0.03 (-1.4, 1.5)	-2.4 (-3.9, -1.0)	3.4 (0.4, 6.5)	-0.9 (-3.9, 2.0)	0.003
Starch	0.5 (-0.7, 1.6)	-0.2 (-1.6, 1.2)	1.2 (-0.2, 2.6)	-0.5 (-3.4, 2.3)	-1.2 (-4.1, 1.7)	0.229
Total fat	0.4 (-0.01, 0.8)	0.5 (0.1, 0.9)	0.2 (-0.2, 0.7)	-0.5 (-1.4, 0.4)	1.8 (0.8, 2.7)	0.004
Saturated fat	0.02 (-0.2, 0.3)	0.2 (-0.1, 0.4)	-0.1 (-0.4, 0.2)	-0.2 (-0.8, 0.4)	0.8 (0.2, 1.4)	0.019
Protein	0.2 (-0.4, 0.9)	0.1 (-0.6, 0.9)	0.5 (-0.3, 1.2)	-1.1 (-2.7, 0.5)	1.1 (-0.6, 2.8)	0.145

* Adjusted for gender, age and community

[†] Adjusted for gender and age

4.4 Discussion

This is the first Australian study to report on fruit and vegetable subsidies for Aboriginal and Torres Strait Islander families. The staff at a rural Aboriginal community-controlled health service, in collaboration with local Aboriginal communities, developed a program to provide subsidised fruit and vegetables and promote preventive health care to disadvantaged families. The aim was to simultaneously address the manifest nutritional and health problems. This program was associated with significant increases in biomarkers of fruit and vegetable intake including β -cryptoxanthin, vitamin C, red cell folate and lutein/zeaxanthin. These findings are consistent with increased intake of fruit and vegetables. However, this contrasted with the lack of change in the self-reported intake of fruit and vegetables.

In addition to the discrepancy between the biomarkers and fruit and vegetable intake based on 24 hour recall, fruit and vegetable intake reported in the short dietary questions was considerably higher than the mean intake reported in the 24 hour recalls. This highlights the well-known limitations of self-reported dietary intake¹²⁰ and the role of biomarkers as an alternative more objective measure of fruit and vegetable intake.¹⁴¹ Self-reported dietary intake is particularly challenging in children, as the dietary intake is collected with input from both a parent/carer and a child, who may have different likelihood of bias due to difficulties with estimation of quantities and under-reporting.²⁸⁶ This study has shown that it is feasible to obtain blood biomarkers from children in a community-based intervention study. With appropriate community engagement and practical arrangements for the collection of specimens, there were very few children from whom blood samples were not able to be obtained.

The baseline levels of carotenoids in this study are comparable with those reported in a large population sample of children in the USA.¹⁵¹ No comparable published data were identified in Australian children. In contrast, Hodge et al¹³⁸ found that Indigenous Australian adults have lower carotenoid levels than non-Indigenous Australians. However, it is consistent with the observation that most children in high income countries do not consume recommended levels of fruit and vegetables.^{19, 31, 32, 188}

The changes in red cell folate, vitamin C and β -cryptoxanthin are consistent with an increase in fruit intake, which was described by parents (although not reflected in the self-reported dietary intake). Vitamin C increased by 10 $\mu\text{mol/L}$ (21%). Khaw et al²⁸⁷

reported that each quintile of plasma vitamin C (10-20 $\mu\text{mol/L}$) was associated with a 20-50g increase in fruit (and 10-20g increase in vegetables) in a large prospective study in adults. The mean level of β -cryptoxanthin, which is predominantly found in orange/red fruits and vegetables, especially pumpkin, oranges, mandarins, peaches, plums and corn,¹⁴⁶ increased by 18% consistent with an increased intake of these fruits. The interpretation of the substantial increase in red cell folate was complicated by the introduction of mandatory folate fortification of bread-making flour in September 2009, which is discussed further in Chapter 5. Lutein/zeaxanthin, which increased by 11%, is commonly found in vegetables such as pumpkins, leafy green vegetables, beans and corn, all of which are commonly included in communal meals consumed in contemporary Aboriginal communities.¹³⁶ The major dietary source of lycopene is processed and cooked tomatoes, which are commonly eaten as part of take-away meals.²⁸⁸ Thus, the significant decrease in lycopene may indicate reduced intake of take-away food, although this could not be confirmed from the data collected in this study. β -carotene, which is widely distributed in many fruit and vegetables, did not change in this study. This may reflect the more limited bioavailability of β -carotene compared to these other carotenoids.^{289, 149}

The findings of this study are consistent with a recent systematic review of the role of biomarkers in fruit and vegetable intervention studies, which found significant increases in 1 or more biomarkers in 35 of 36 fruit and vegetable provision studies and 14 of 16 nutrition counselling studies, most commonly β -carotene, vitamin C, α -carotene and lutein.¹⁴¹ The proportional increases in β -cryptoxanthin, vitamin C and lutein/zeaxanthin observed in this study were mostly greater than those reported in a nutrition counselling RCT¹¹¹ in which self-reported fruit and vegetable intake increased by 1.4 serves/day but less than those in a food provision RCT which compared the consumption of 500g with 100g of fruit and vegetables per day.¹⁶⁴ Although further work is needed to confirm the linear dose-response relationship between fruit and vegetable intake and the levels of these biomarkers, carotenoids and vitamin C are responsive to changes in fruit and vegetable intake.¹⁴¹

The follow-up diet recalls showed a decline in all macronutrient intakes compared to baseline. Lower reported dietary intake at follow-up has also been found in other nutrition intervention studies.^{29, 252} This may be related to recall bias due to social desirability,²⁹⁰ change in eating habits or decreased motivation of participants.^{29, 291} In

the analysis of macronutrients per megajoule, only the intakes of total and added sugar at follow-up were significantly lower than at baseline, which would be consistent with the displacement of high sugar snacks and/or drinks by fruit and vegetables. However, these differences were no longer significant after adjustment for age, gender and community. It is reassuring that no adverse impacts on dietary intake were demonstrated, as has been suggested in a modelling study.²²¹

Targeted fruit and vegetable subsidies, as additions to national food subsidy programs or as stand-alone interventions, have been shown to increase fruit and vegetable intake by 1-2 serves/day or 20-30% in women during pregnancy²⁴⁹ and other life stages.^{252, 254} There is limited evidence in families or children specifically (see Chapter 2). As discussed above, increased intake of fruit and vegetables of this magnitude is sufficient to improve long-term health outcomes.

The key question is whether the short-term benefits of healthy food subsidies demonstrated in this and other studies will produce sustainable impacts on nutritional behaviour. There is evidence of healthier dietary intake or food purchases persisting, although attenuated, for six months after participation in food subsidy programs,^{244, 252} though this was not noted in later follow-up of children whose families had previously participated in the Special Supplemental Nutrition Program for Women, Infants and Children.²⁶⁹ The evidence that price discounts were more effective at changing dietary behaviour than other strategies²⁴⁴ and that price discounts or increases are projected to have a larger impact on low income individuals or families^{219, 220} is important. Given the consistent evidence of the less healthy dietary behaviour among those of lower social-economic status,¹⁸⁰ it is likely that a range of complementary strategies will be needed to improve nutritional status among the most disadvantaged. It is unclear whether the nutritional challenges among Indigenous people who live in non-remote areas are different from other disadvantaged families in high income countries. It is clear though that Indigenous people have much earlier onset and higher rates of chronic diseases and thus have the most to gain from strategies which increase fruit and vegetable intake.

An obvious limitation of this study was the lack of a control group. This would have been difficult to implement given the clear economic benefit of the fruit and vegetable subsidy, irrespective of any nutritional or health impacts which were the focus of this evaluation study. However, a control group was contemplated as an equitable way to

manage the waiting list of eligible families for this fruit and vegetable subsidy program, but was ultimately considered impractical given the limited local research capacity in a busy Aboriginal community-controlled health service.²⁹²

The study design introduced a limitation in the analysis as families were recruited, while data were collected from individual children. In addition, a range of dietary and health outcomes were assessed, which increased the likelihood of statistically significant results occurring by chance. However, given the exploratory nature and hypothesis generating intentions of the study, analyses were not adjusted for the design effect or for multiple comparisons. Not accounting for multiple comparisons was deemed to be justified on the basis that the intention of this study was to estimate the extent of changes in biomarkers, consequent to the introduction of a fruit/vegetable intervention, rather than to formally test specific hypotheses about whether change occurred. The statistical procedures reflect this focus on estimation rather than hypothesis testing.

This study has demonstrated positive nutritional impacts associated with a healthy food subsidy, delivered as part of comprehensive primary health care, for disadvantaged Indigenous Australian families. The success of the program depended on community resources, particularly the availability of local greengrocers and the involvement of experienced dietitian/nutritionists to facilitate practical nutrition education. The program was conceived and embedded in a health promotion model that engages families in preventive health activities. In this way it reflects the implementation of the WIC program in rural Native American communities in the USA (Mindy Jossefides and Carole Farina, personal communication). In countries where food subsidy programs do not exist currently, this program demonstrates the potential role of community health services in the implementation of such programs.

The findings of this evaluation of the nutritional improvements associated with fruit and vegetable subsidies suggest there is a need for a more controlled study to verify these conclusions. Higher quality longitudinal data would also provide the opportunity for economic analysis of the health outcomes that could be used to inform decisions about investing in food subsidies. The validity of biomarkers as indicators of fruit and vegetable intake is well established in adults. It has been proposed that a panel of biomarkers, particularly carotenoids and vitamin C should be used in fruit and vegetable

intervention studies.¹⁴¹ International studies have established the normal range of carotenoids in children.^{151-154, 293} However, further studies are needed to confirm their validity and practicality as measures of fruit and vegetable intake in interventions involving children. This is important given the discrepancies between diet self-report and biomarkers observed in this study.

The most important implication of the findings of this study is the potential reduction in chronic disease risk due to increased fruit and vegetable intake. It would be useful to also assess the nutritional status of adults in future studies given the long time lag between improving fruit and vegetable intake in children and any manifestation of chronic diseases. The sustainability of any change in fruit and vegetable intake underpins any long-term health impacts. This program provided an 88% subsidy to an average-sized family, which may be necessary to engage the most disadvantaged families. However, it would be useful to trial the impacts of lesser subsidies on dietary intake or nutritional status which could inform the development of fruit and vegetable subsidy programs.

4.4.1 Conclusions

Fruit and vegetable subsidies improve the nutritional status of disadvantaged Indigenous Australian children. Biomarkers of fruit and vegetable intake, particularly carotenoids and vitamin C, are feasible to measure nutritional status in these children and may offer a more objective alternative to self-reported dietary intake. Improving vegetable intake appears to be more challenging than increasing fruit in these children and emphasises the need to link any subsidies with effective nutrition education to promote meal planning and preparation skills. The delivery of fruit and vegetable subsidies in a community health setting strengthens the link between preventive health activities and improved nutrition. A more controlled study of subsidised healthy food is warranted in to investigate the cost-effectiveness of this strategy to improve the both the nutrition and health of the most disadvantaged families.

5 Impact of subsidised fruit and vegetables and folate fortification

5.1 Introduction

Red blood cell (RBC) folate was one of the biomarkers used to assess fruit and vegetable intake in this study. As discussed in Chapter 1, RBC folate has been shown to correlate well with fruit and vegetable (F&V) intake in adults whose food supply does not contain folate-fortified foods.¹⁶² Thus, it was considered useful to include RBC folate in the panel of biomarkers in this study, given the limited evidence about the use of carotenoids as biomarkers in studies involving children.

The mandatory folate fortification of bread-making flour, however, commenced in Australia in September 2009. This coincidentally was between the before and after blood tests in this evaluation study and thus added a layer of complexity to the interpretation of results obtained. Hence, this chapter reports on the combined impact of the F&V program and mandatory folate fortification of bread-making flour on the RBC folate levels in this cohort of Aboriginal children. The secondary aim of this chapter is to investigate the extent to which any changes in RBC folate are related to the separate effect of either folate fortification or any increase in fruit and vegetable intake.

5.2 Methods

As described in Chapter 3, the cohort of children had a blood test and 24-hour diet recall prior to their participation in this fruit and vegetable subsidy program. The same assessments were repeated after 12 months participation in the program. The pathology samples from Grafton and Coffs Harbour/Bowraville were analysed in two different laboratories using different RBC folate assays (see section 3.4.1). This yielded results that could not be compared directly despite being in the same units. This is due to the different sensitivity of each assay which affects the detection of RBC folate (Ross

Brown & Karen Kennedy, personal communication). Thus, the RBC folate data were converted into z-scores, based on the mean and standard deviation for the combined before and after results at each location. After conversion to z-scores, the change in RBC folate before and after participation in the fruit and vegetable program was compared using paired t-tests and the General Linear Model function in SPSS Version 19 (IBM, New York, USA) to adjust for gender, age and community. Further details of the statistical analysis are presented in section 3.4.2. The correlation between the change in RBC folate and both bread intake and fruit and vegetable intake was assessed visually using scatter plots and statistically using a linear regression model of the change in RBC folate against both mean bread intake and change in fruit and vegetable intake.

5.3 Results

Mean red blood cell (RBC) folate levels increased in each community at the 12 month follow-up compared to the mean baseline levels, although only the 50% increase in the Clarence Valley (from 496 nmol/L to 744nmol/L, $p<0.001$) was statistically significant (**Table 5.1**). Adjustment for age and sex did not affect the mean change in each community substantially or the statistical significance of the increase in the Clarence Valley (**Table 5.1**). None of the children had low RBC folate at either baseline or follow-up, based on the reference ranges for the relevant assay (data not shown). Interestingly, whilst only one of 76 children (1.3%) in the Clarence Valley exceeded the relevant reference range for folate at baseline, 13/25 (52%) in Coffs Harbour and 19/24 (79%) in Bowraville exceeded the relevant reference range. A similar distribution was observed at follow-up, with no children exceeding the reference range in the Clarence Valley, but 15/25 (60%) in Coffs Harbour and 23/24 (96%) in Bowraville exceeding the upper bound of the reference range.

Table 5.1 Red cell folate before and after 12 months on the fruit and vegetable program by community[†]

	RBC folate (nmol/L) Mean (SD)		Change in RBC Folate (95% CI)	Adjusted change in RBC Folate* (95% CI)
	Before	After		
Clarence (n=76)	496 (224.2)	744 (185.4)	248 (195.5 – 301.3)	248 (197.2 - 299.6)
Coffs Harbour (n=25)	1050 (247.2)	1161 (237.9)	111 (-9.1 – 231.1)	92 (-52.4 - 235.7)
Bowraville (n=24)	1312 (376.4)	1414 (326.3)	102 (-39.2 -243.3)	122 (-26.5 - 269.7)

[†] Different assays were used in Clarence versus Coffs Harbour and Bowraville. The reference ranges were 156-1452 nmol/L in Clarence and 218-820 nmol/L (<11 years old) and >630 nmol/L (>11 years old) in Coffs Harbour/Bowraville.

*Adjusted for sex and age

The mean change in RBC folate z-score (after-before) was 0.55 (95% CI 0.36-0.74) after adjustment for gender, age and community (**Figure 5.1**). This mean change in RBC folate z-score is equivalent to a Cohen's d and thus represents a medium effect size. Among the individual communities, the mean RBC folate z-score increased significantly in the Clarence Valley and Bowraville (**Figure 5.1**).

Linear relationships were not apparent between mean fruit and vegetable intake or change in fruit and vegetable intake (from the two 24 hour recalls) and the change in RBC folate z-score (**Figure 5.2** and **Figure 5.3**). A linear relationship between mean bread intake (from the two 24 hour recalls) and the change in RBC folate z-score (**Figure 5.4**) was also not apparent. Linear regression models confirmed that change in fruit and vegetable intake (p=0.196) (**Table 5.2**) and mean bread intake (p=0.676) (**Table 5.3**) were not statistically significant predictors of the change in RBC folate z-score. In both models, baseline RBC folate z-score was a significant predictor of the change in RBC folate z-score (**Table 5.2** & **Table 5.3**).

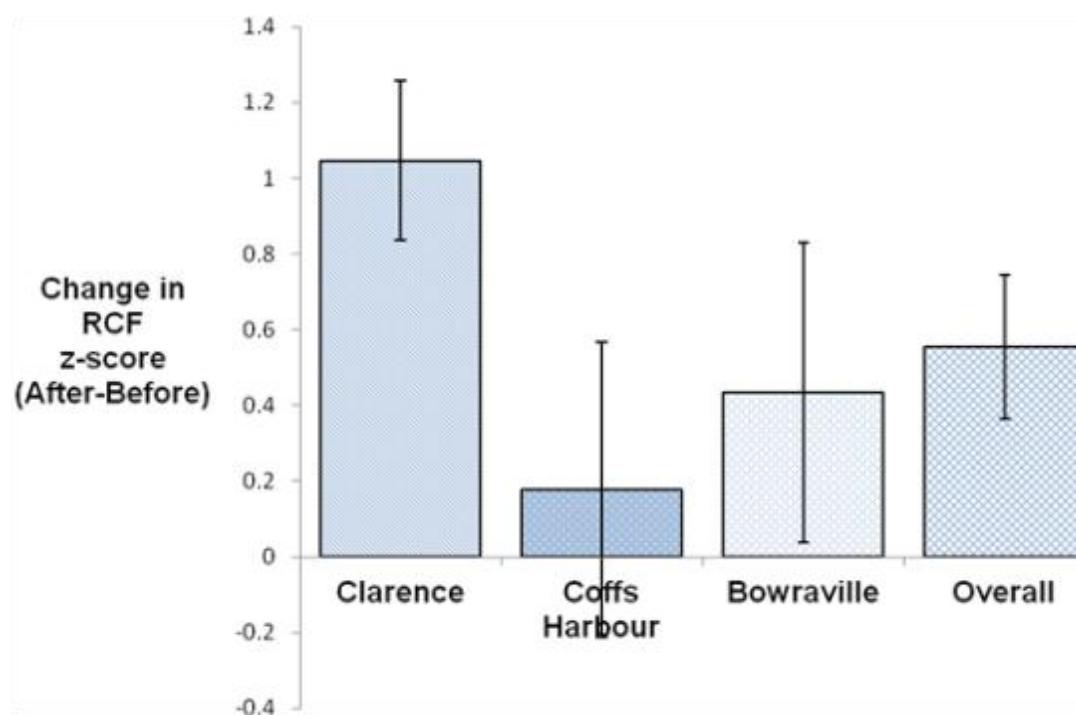


Figure 5.1 Change in RBC folate z-scores by community before and after 12 months of the fruit and vegetable program (Mean, 95% CI)*

*Adjusted for gender, age and community

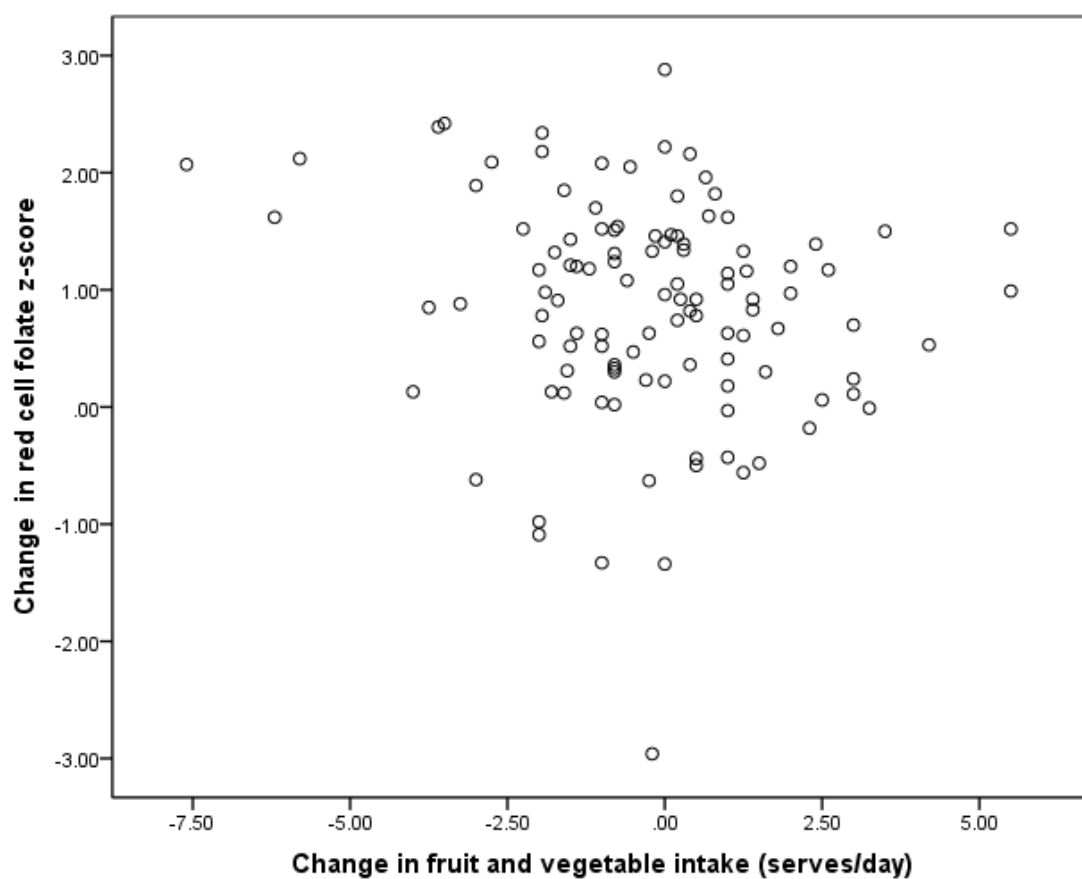


Figure 5.2 Scatterplot of change in fruit and vegetable intake by change in RBC folate z-score

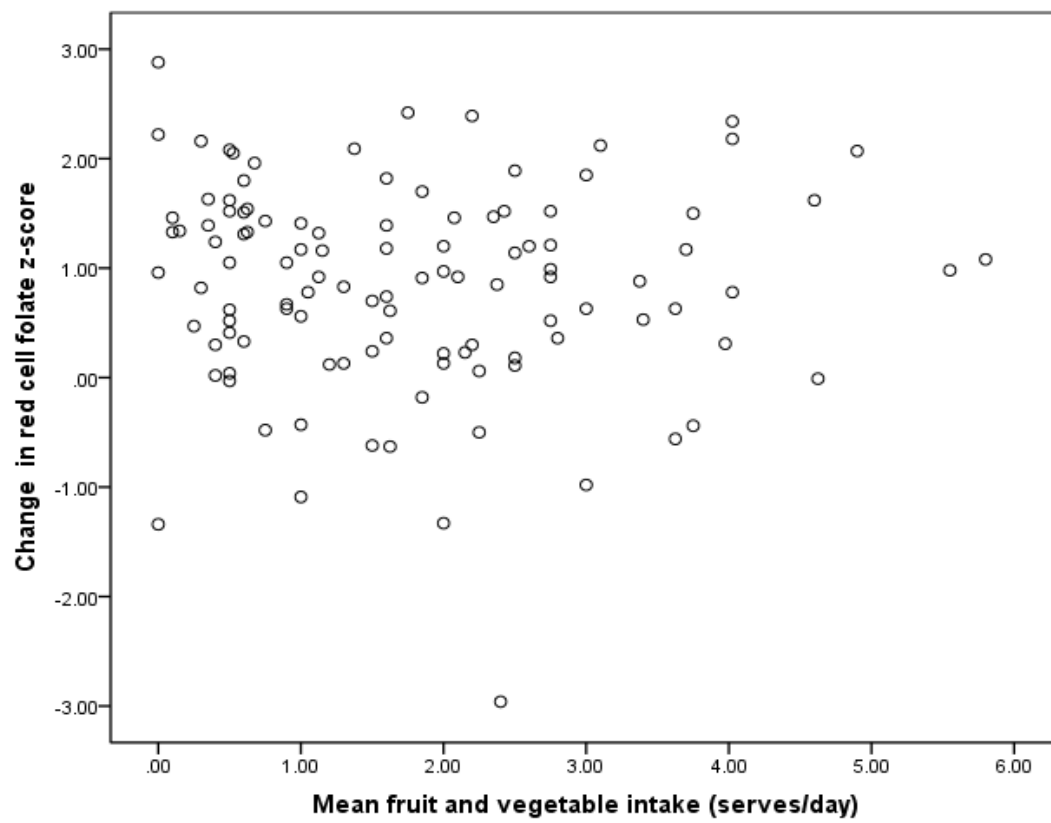


Figure 5.3 Scatterplot of mean fruit and vegetable intake by change in RBC folate z-score

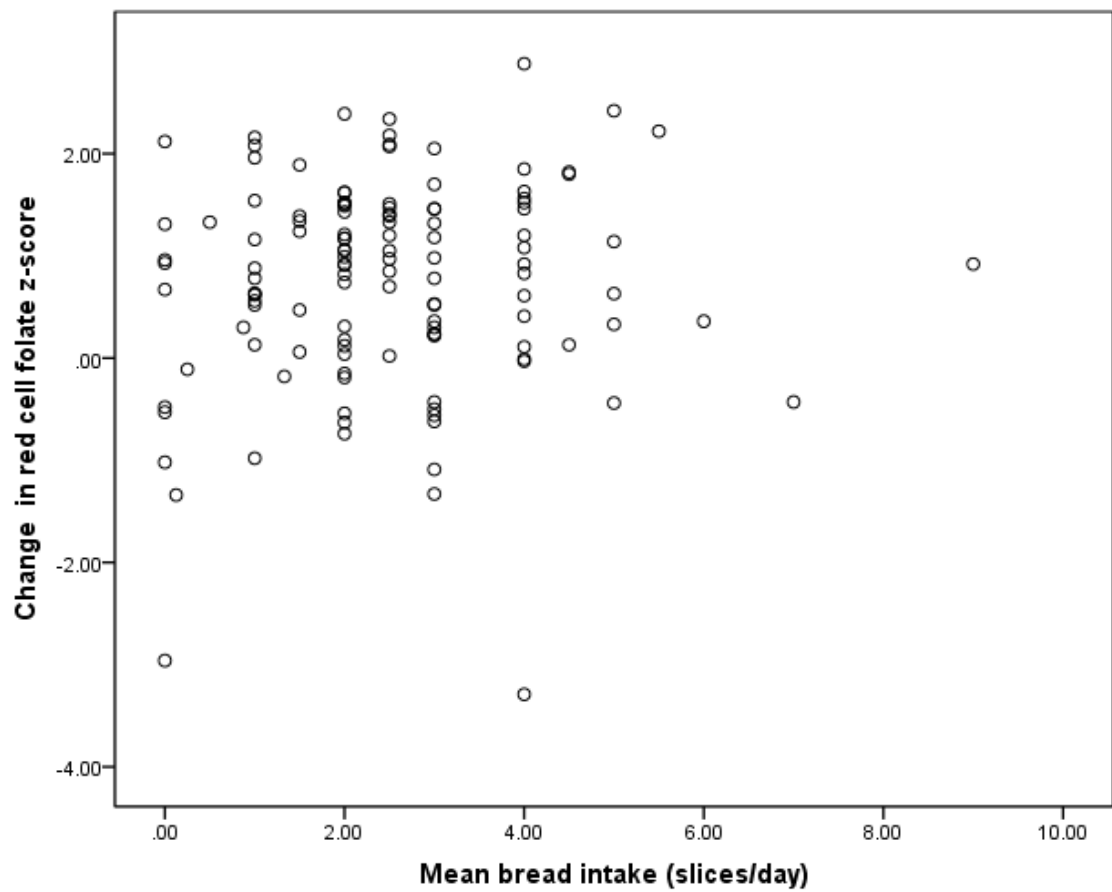


Figure 5.4 Scatterplot of mean bread intake versus change in RBC folate z-score

Table 5.2 Linear regression model of change in F&V intake and baseline RBC folate as predictors of change in RBC folate

	B	Standard Error of B	β
Constant	0.57	0.09	
Baseline RBC folate z-score	-0.57	0.09	-0.52*
Change in F&V intake	-0.05	0.04	-0.11

Note: $R^2=.30$ ($p<0.001$). Dependent Variable: Change in RBC folate z-score

* $p<0.001$

Table 5.3 Linear regression model of mean bread intake and baseline RBC folate as predictors of the change in RBC folate

	B	Standard Error of B	β
Constant	0.48	0.14	
Baseline RBC folate z-score	-0.66	0.07	-0.64*
Mean bread intake	0.02	0.05	0.03

Note: $R^2=.41$ ($p<0.001$). Dependent Variable: Change in RBC folate z-score

* $p<0.001$

5.4 Discussion

There was a moderately large and statistically significant increase in RBC folate in the follow-up blood tests compared to baseline levels among this cohort of Aboriginal children. This is consistent with the increase in other biomarkers of fruit and vegetable intake reported in this study (see Chapter 4), although the increase in RBC folate was larger than the increase in vitamin C and carotenoids. This additional increase was probably due to the impact of mandatory folate fortification of bread-making flour. There were no statistically significant relationships between the change in RBC folate and mean bread intake, mean F&V intake or change in F&V intake in the linear regression models. Thus, it was difficult to draw meaningful conclusions as to whether fruit and vegetable intake or the mandatory folate fortification of bread-making flour were more important in the increase in RBC folate observed.

There were no children with low RBC folate at either baseline or follow-up. However, 52% of children at Coffs Harbour and 79% of children at Bowraville exceeded the relevant normal range for RBC folate at baseline and this increased to 60% of children at Coffs Harbour and 96% of children at Bowraville at follow-up. The low reported intake of F&V at baseline and the observation by staff at these health services of many children's high intake of breakfast cereal, particularly Sanitarium brand Weet-Bix (Irina Holmes and Tracy Bradshaw, personal communication), suggest that folate fortification of foods including breakfast cereals contributed significantly to these high levels of RBC folate.

In Australia, the voluntary folate fortification of foods, including breakfast cereals, commenced in June 1995.²⁹⁴ Although breakfast cereals are the most common food voluntarily fortified with folate in Australia, folate-fortification of breakfast cereals has not been universal.^{295, 296} For example, folate-fortified breakfast cereals include Sanitarium brand Weet-Bix, but not some other common brands of wheat biscuit breakfast cereals (Uncle Toby's Vitabrits, Coles Whole Wheat Biscuits). Thus food choices, including both the type of foods consumed and brand loyalty within specific food types²⁹⁷ appear to be important in determining the intake of folate-fortified foods.

The absence of folate deficiency among the children in our study contrasts with the reported prevalence of low RBC folate (3.1%) in a large sample of Australian adults prior to mandatory folate fortification,²⁹⁸ although no comparable studies in Australian children were identified. The findings are consistent with the low level of folate deficiency (<1%) reported in US²⁹⁹ and Canadian children³⁰⁰ (who have been exposed to mandatory folate fortification of cereal and grain products since 1998³⁰¹) and the low levels of folate deficiency reported in Australian adults after mandatory folate fortification of bread-making flour.²⁹⁸ Thus, it would appear that voluntary folate-fortification was adequate to prevent folate deficiency in the disadvantaged Aboriginal children in this study.

The low prevalence of folate deficiency together with the high proportion of RBC folate above the recommended range in this and other studies^{298, 300} has underlined the importance of monitoring the impact of folate-fortification in populations. Despite the clear benefits of folate-fortification on reducing neural tube defects,^{302, 303} there remains uncertainty about the impacts of folate fortification on cancer and cardiovascular

disease risk.^{300, 304, 305} The potential for adverse impacts of high folate levels may be particularly relevant in children who will be exposed to folate-fortification throughout their lives and those of low socio-economic status, who may be more likely to consumer large amounts of folate-fortified foods, such as bread or cereals.³²

In addition to the impact of folate fortification, serum and RBC folate have been reported to vary with age, with higher levels in 6-11 year olds compared to 12-19 year olds, in Canada³⁰⁰ and the USA.^{299, 306} This difference was evident both before and after mandatory folate-fortification of enriched cereal grain products in 1998 in both countries. Thus, the impact of any decrease in RBC folate with age would have tended to bias towards the null any increase in RBC folate in this study. However, in both of these studies in the USA and Canada, mandatory folate-fortification had a more substantial impact on serum and RBC folate than any changes due to age.^{299, 300, 306} This emphasises the importance of identifying and monitoring the sources of folate in the diet given the substantial impact of folate-fortification on mean folate levels.³⁰⁷

These data highlight the difficulty of using RBC folate as a marker of F&V intake in populations exposed to folate fortification of the food supply. Folate may still have a role as a marker of F&V intake provided the intake of folate from fortified sources does not change during a study. As noted above, this requires knowledge of the sources of folate in the diet. It also depends on no changes to the specific foods fortified with folate and constant levels of folate-fortification during the study period, which was obviously not the situation during this study. Due to increasing impact of folate-fortification, it appears that other biomarkers particularly carotenoids and vitamin C will be preferred to monitor changes in F&V intake.¹⁴¹

In conclusion, this study has demonstrated increased RBC folate in Aboriginal children associated with the concurrent impact of a fruit and vegetable subsidy program and mandatory folate-fortification of bread-making flour. However, it also highlighted the difficulty of using folate as a biomarker of fruit and vegetable intake in populations exposed to folate-fortification of their food supply. In addition, the high proportion of children with RBC folate above the recommended reference range reinforces the need for monitoring both the folate levels in the population and the long-term impact of folate fortification.

6 The fruit and vegetable program and health outcomes

6.1 Introduction

The improvements in nutritional status among children whose families participated in this fruit and vegetable subsidy program, demonstrated in chapters 4 and 5, have implications for long-term health outcomes due to potential reductions in the prevalence of chronic diseases.^{45, 47} However, it was also a major goal of this study to investigate whether there were also short-term health benefits of this fruit and vegetable subsidy program, which may have been indicative of enhanced functioning of the immune system due to improved nutritional status.^{58, 59} Overall there is limited evidence of the impact of food subsidies on children's health outcomes in high income countries (see Chapter 2). Nevertheless, studies of the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) in the USA have shown a range of improvements in health, behavioural and developmental outcomes in young children associated with WIC participation including improved growth, lower rates of anaemia, improved performance on cognitive tests and reduction in behavioural problems.^{269, 308} Similarly, a UK study in the 1930s found supplementary foods for disadvantaged families improved growth of children age 2-14 years.²⁵¹

The aim of this chapter is to investigate whether there were improved health outcomes associated with this fruit and vegetable subsidy program. Specifically, we explore whether there were any changes in episodes of illness, episodes of common clinical conditions, prescription of antibiotics and rates of anaemia, iron deficiency and vitamin D deficiency as a result of participation in this program. It should be noted that due to the design of this program, with subsidised fruit and vegetable linked to preventive health activities at an Aboriginal health service, it is not possible to separate the impacts of the subsidies from the preventive and curative treatments and promotion of healthy lifestyles inherent in this program.

6.2 Methods

6.2.1 Study design

The fruit and vegetable subsidy program and the before and after evaluation of a cohort of Aboriginal children have been described in Chapter 3. In this analysis, retrospective health records audits were used to compare the 12 months prior to participation in the fruit and vegetable program with the 12 months during participation in the program. Health records were reviewed from participating Aboriginal health services, local hospitals and any other nominated general practice. The number of visits to any health service for illness or preventive health activities, the number of episodes of common clinical conditions and the number of antibiotic prescriptions were compared during each 12 month period.

In addition, each participant had a health assessment, based on Medicare Benefits Schedule Indigenous Child Health Check, at the local Aboriginal health service prior to participation in the fruit and vegetable program and after 12 months. The results of anthropometric assessment obtained initially and after 12 months were compared. Body fat was measured using a body composition monitor only in the Clarence Valley. Body fat was only measured for children aged ≥ 7 years, as recommended by the body composition monitor manufacturer. At these two health assessments, each participant had a blood test. The baseline and follow-up levels of haemoglobin, iron, ferritin and vitamin D were compared. Details of the blood collection and analysis were presented in sections 3.4 and 3.5.

6.2.2 Statistical analysis

The mean and 95% confidence interval of changes in the number of health service visits, common clinical conditions and antibiotic use, anthropometric measurements and levels of haemoglobin, iron, ferritin and vitamin D were evaluated using a paired sample t-test and a general linear model in to adjust for gender, age and community. Further details of the statistical analysis were presented in section 3.5.2. As described in section 4.2, the mean changes in these outcomes were assessed overall and by community, due to differences in program implementation in each community. The proportion of children who were underweight, normal weight, overweight and obese based on BMI before and after the fruit and vegetable program were compared using the Stuart-Maxwell test of marginal homogeneity. The proportion of children with low

haemoglobin, ferritin, iron and vitamin D before and after the fruit and vegetable program were compared using McNemar's test.

6.3 Results

6.3.1 Demographics

Of 174 children whose families were invited to participate in the fruit and vegetable program, retrospective clinical audits were completed for 170 children whose families received at least one box of subsidised fruit and vegetables. 167 of these children had clinical health assessments including anthropometry completed at baseline. The demographic details of these children are presented in Section 4.3.1. After 12 months, clinical health assessments were repeated for 143 children.

6.3.2 Anthropometric changes associated with the fruit and vegetable program

At the initial assessment of 134 children aged 2-17 years, 4.5% were underweight, 67.2% were normal weight, 14.9% were overweight and 13.4% were obese, based on an international classification of BMI centiles for age.^{21, 309} The proportion of children in each weight category by age at baseline is shown in **Table 6.1**. The proportion of children in each weight category by age after 12 months on the fruit and vegetable program is shown in **Table 6.2**. Of 125 children aged 2-17 years who were reassessed after 12 months, 4.0% were underweight, 66.4% were normal weight, 16.8% were overweight and 12.8% were obese. There were no significant differences in the proportion of children in each weight category after the fruit and vegetable program compared to baseline ($\chi^2(3, N=125)=1.33, p=0.721$). However, there were significant increases in height ($p<0.001$), weight ($p<0.001$) and BMI ($p<0.001$) among children after 12 months on the program compared to baseline as would be expected (**Table 6.3**). These increases remained statistically significant after adjustment for community, gender and age (all $p<0.05$). However, there was no significant change in body fat after 12 months on the program compared to baseline among the cohort of children aged ≥ 7 years who had this assessed in the Clarence Valley (**Table 6.3**). There were no statistically significant differences between communities in mean change in height, weight or BMI (data not shown).

Table 6.1 Proportion of children aged 2-17 years classified as underweight, normal weight, overweight or obese by age at baseline

		Age Category				Total
		2-3 years (n=19)	4-8 years (n=47)	9-13 years (n=58)	14-17 years (n=10)	
Underweight	n	1	3	2	0	6
	% within age category	5.3%	6.4%	3.4%	0%	4.5%
Normal	n	15	33	38	4	90
	% within age category	78.9%	70.2%	65.5%	40.0%	67.2%
Overweight	n	2	6	8	4	20
	% within age category	10.5%	12.8%	13.8%	40.0%	14.9%
Obese	n	1	5	10	2	18
	% within age category	5.3%	10.6%	17.2%	20.0%	13.4%

Table 6.2 Proportion of children aged 2-17 years classified as underweight, normal weight, overweight or obese by age at 12 month follow-up

		Age Category				Total
		2-3 years	4-8 years	9-13 years	14-17 years	
		(n=15)	(n=46)	(n=52)	(n=7)	
Underweight	n	1	3	1	0	5
	% within age category	6.7%	6.5%	1.9%	0%	4.0%
Normal	n	9	31	35	3	83
	% within age category	60.0%	67.4%	67.3%	42.9%	66.4%
Overweight	n	3	6	9	3	21
	% within age category	20.0%	13.0%	17.3%	42.9%	16.8%
Obese	n	2	6	7	1	16
	% within age category	13.3%	13.0%	13.5%	14.3%	12.8%

Table 6.3 Anthropometric changes among fruit and vegetable program participants at 12 month follow-up

	Mean (SD)		Mean Δ -score (95% CI)	Adjusted mean Δ -score* (95% CI)
	Before	After		
Weight (kg)	31.3 (17.9)	35.7 (19.3)	4.3 (3.8, 4.9) [§]	4.2 (3.6, 4.9)
Height (m)	1.26 (0.22)	1.33 (0.23)	0.06 (0.06, 0.07) [§]	0.06 (0.05, 0.08)
BMI (kg/m²)	18.2 (4.8)	18.8 (4.9)	0.6 (0.3, 0.9) [§]	0.5 (0.2, 0.8)
Body fat (%) [n=22]	22.1 (9.2)	22.5 (9.0)	0.4 (-1.4, 2.1)	0.2 (-1.4, 1.9)

* Adjusted for gender, age and community

§ p<0.001

6.3.3 Health outcomes after fruit and vegetable program participation for 12 months

The clinical audits for the overall sample, comparing 12 months prior to the program with program participation for 12 months, showed that there were statistically significantly fewer visits to the health service or hospital for illness (p=0.037), fewer hospital attendances (p=0.017) and less oral antibiotics prescribed (p=0.001) during program participation (**Figure 6.1**). There was a non-significant reduction in episodes of pyoderma during program participation (p=0.093). After adjustment for gender, age and community, there were still statistically significant reductions in sick visits to the health service or hospital and less oral antibiotics prescribed, however the reduction in hospital attendances was no longer statistically significant (**Table 6.4**). In addition, adjustment for the baseline value as a covariate in the model meant that the reduction in sick visits (-0.5, 95% CI -1.0, 0.03) was not statistically significant, but did not change the statistical significance of the other improvements in health outcomes. There was also a small but statistically significant reduction in well visits during program participation after adjustment for gender, age and community (**Table 6.4**). There were no statistically significant differences between the communities in the changes in these health

outcomes before and during program participation (**Table 6.4**). However, there was an increase in hospital attendances in Coffs Harbour but decreases in the other two communities during program participation, although the difference was not statistically significant ($p=0.064$).

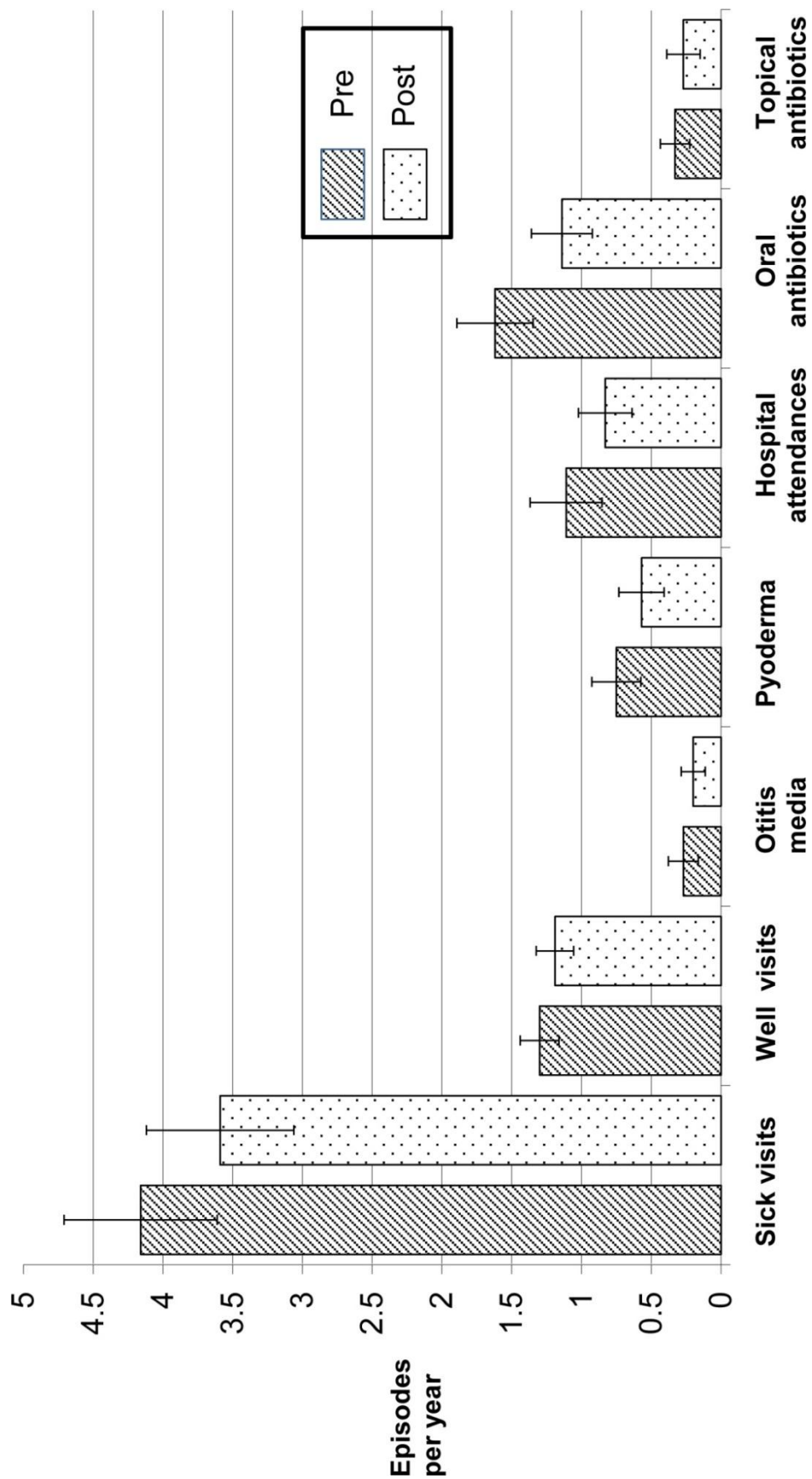


Figure 6.1 Health outcomes of participants before and after 12 months on fruit and vegetable program

Table 6.4 Change in health outcomes among fruit and vegetable program participants by community

Health outcome	Mean Δ -score† (95% CI)	Adjusted mean Δ -score* (95% CI)	Community 1 Clarence n=90 Mean (95% CI)§	Community 2 Coffs Harbour n=29 Mean (95% CI)§	Community 3 Bowraville n=48 Mean (95% CI)§	Sig. for community comparison
Sick visits	-0.6 (-1.1, -0.04)	-0.6 (-1.2, -0.001)	-0.6 (-1.3, 0.2)	-0.4 (-1.8, 0.9)	-0.8 (-1.8, 0.2)	0.906
Well visits	-0.1 (-0.3, 0.03)	-0.2 (-0.3, -0.01)	0.001 (-0.2, 0.2)	-0.3 (-0.7, 0.06)	-0.2 (-0.5, 0.1)	0.221
Otitis media episodes	-0.1 (-0.2, 0.06)	-0.1 (-0.2, 0.06)	-0.07 (-0.2, 0.1)	-0.2 (-0.5, 0.1)	0.03 (-0.2, 0.3)	0.518
Pyoderma episodes	-0.2 (-0.4, 0.03)	-0.2 (-0.4, 0.05)	-0.1 (-0.4, 0.2)	-0.1 (-0.6, 0.5)	-0.4 (-0.8, 0.1)	0.654
Oral antibiotics	-0.5 (-0.8, -0.2)	-0.5 (-0.8, -0.2)	-0.4 (-0.8, -0.01)	-0.6 (-1.3, 0.1)	-0.7 (-1.2, -0.1)	0.674
Topical antibiotics	-0.06 (-0.2, 0.1)	-0.1 (-0.2, 0.1)	-0.01 (-0.2, 0.2)	-0.06 (-0.5, 0.3)	-0.1 (-0.4, 0.2)	0.801
Hospital attendances	-0.3 (-0.5, -0.05)	-0.2 (-0.4, 0.1)	-0.4 (-0.7, -0.05)	0.4 (-0.2, 1.0)	-0.5 (-1.0, -0.1)	0.064

† Episodes per year during 12 months participation – Episodes in the year prior to program participation

* Adjusted for gender, age and community

§ Adjusted for gender and age

6.3.4 Changes in anaemia, iron status and vitamin D after fruit and vegetable program

There was an increase in haemoglobin of 1.5 g/L among fruit and vegetable program participants compared to baseline, although this increase was not statistically significant ($p=0.076$). However, after adjustment for community, gender and age, the increase in haemoglobin (3.1g/L) was statistically significant (**Table 6.5**). Comparing the individual communities, there was a large and statistically significant increase in haemoglobin at Bowraville (7.8 g/L) which was not found in Coffs Harbour or the Clarence Valley ($p<0.001$ for difference between communities). There were no significant differences in plasma ferritin and serum iron after the fruit and vegetable program compared to baseline with or without adjustment for community, gender and age (**Table 6.5**). The plasma ferritin did not differ between the communities significantly, however, serum iron did increase significantly more in Bowraville ($p=0.047$) (**Table 6.5**). The proportion of low haemoglobin, iron, ferritin and vitamin D before and after the fruit and vegetable program is shown in **Table 6.6**. The proportion of anaemia decreased among fruit and vegetable program participants by 3% compared to baseline. Iron deficiency was common at baseline - between 40-43% based on serum ferritin and iron and there were small decreases in the proportion of low ferritin and iron among fruit and vegetable program participants (**Table 6.6**).

Overall there were small and statistically non-significant decreases in vitamin D at follow-up compared to baseline, although the differences between the communities were statistically significant ($p<0.004$) with an increase in Bowraville of 11.6 nmol/L, contrasted with a decrease of 17.6 nmol/L in Coffs Harbour (**Table 6.5**). The proportion of fruit and vegetable program participants with vitamin D deficiency was low at both baseline and follow-up (**Table 6.6**).

Table 6.5 Changes in haemoglobin, iron status and vitamin D levels in fruit and vegetable program participants

	Mean (SD)		Mean Δ -score (95% CI)	Adjusted mean Δ -score* (95% CI)	Community 1 Clarence n=68 Mean (95% CI)**	Community 2 Coffs Harbour n=23 Mean (95% CI)**	Community 3 Bowraville n=24 Mean (95% CI)**	Sig. for community comparison
	Before	After						
Haemoglobin (g/L)***	126.8 (12.3)	128.2 (10.5)	1.5 (-0.2, 3.1)	3.1 (1.4, 4.8)	-0.7 (-2.6, 1.2)	2.3 (-1.1, 5.7)	7.8 (4.2, 11.3)	<0.001
Ferritin (μg/L)****	33.3 (24.2)	35.2 (22.5)	3.2 (-0.5, 6.2)	1.7 (-2.5, 6.0)	5.6 (1.0, 10.2)	-4.2 (-12.6, 4.2)	3.8 (-5.3, 12.8)	0.137
Iron (μmol/L) †	12.7 (6.0)	13.2 (5.3)	0.5 (-0.6, 1.6)	0.8 (-0.5, 2.0)	0.3 (-1.1, 1.7)	-1.4 (-3.9, 1.2)	3.4 (0.7, 6.1)	0.047
Vitamin D (nmol/L) ‡	98.4 (28.4)	95.4 (32.6)	-3.0 (-8.0, 2.0)	-2.8 (-8.4, 2.8)	-2.4 (-8.6, 3.8)	-17.6 (-28.9, -6.3)	11.6 (-0.3, 23.4)	0.004

* Adjusted for gender, age and community

** Adjusted for gender and age

*** Haemoglobin- normal range ≥ 5 years old 115-140g/L, <5years old 105-140g/L

**** Ferritin- normal range- males 20-200 μ g/L, females 29-200 μ g/L

† Iron- normal range 11-28 μ mol/L

‡ Vitamin D- normal range – 50-200 nmol/L

Table 6.6 Proportion of children with low haemoglobin, ferritin, iron and vitamin D before and after participation in the fruit and vegetable program (n,%)

	Before	After	Significance of change
Haemoglobin*	12, 8%	7, 5%	0.453
Ferritin[†]	63, 41%	51, 37%	0.440
Iron[§]	43, 28%	32, 23%	0.405
Vitamin D**	2, 1%	7, 5%	0.180

* Haemoglobin- normal range ≥ 5 years old 115-140g/L, <5years old 105-140g/L

[†] Ferritin- normal range- males 20-200 μ g/L, females 29-200 μ g/L

[§] Iron- normal range 11-28 μ mol/L

** Vitamin D- normal range – 50-200 nmol/L

6.4 Discussion

The Aboriginal children who participated in this fruit and vegetable subsidy program had significantly fewer episodes of illness, fewer emergency department attendances and less oral antibiotic prescriptions over 12 months compared to the 12 month period prior to their involvement in the program. In addition to these statistically significant findings, there was a decrease in episodes of pyoderma which was not statistically significant. The overall level of obesity, however, did not change in this cohort and it remained high before and after this program. Specifically, there were high rates of overweight and obesity in the older children (although with small numbers of 14-17 year olds) and the proportion of children who were underweight or overweight or obese did not change. Although height, weight and BMI all increased significantly at 12 months follow-up, as expected in a cohort of children, there was no change in the body fat percentage among a sub-group who had this assessed. The prevalence of iron deficiency at baseline was 40%, with anaemia in 8%. There was a small but statistically significant increase in haemoglobin and a reduction in the proportion of children with anaemia, but only a non-significant 4% decrease in iron deficiency.

It has been recommended that we need to do more than describe the health problems among Indigenous Australians.³¹⁰ This study adds to the small but growing number of studies which document or evaluate interventions in Aboriginal and Torres Strait

Islander communities. This study is an example of the potential to undertake evaluation studies in an Aboriginal community-controlled health service despite the inherent limitations in a busy community-oriented service organisation. It is also an example of Aboriginal community-directed programs, which are far more common than intervention research, although few are documented in academic literature. The strength of the partnership between the community and the health service is demonstrated by the ability to undertake this evaluation. The partnership is built on one of the strengths (and challenges) of Aboriginal community-controlled health services - the majority of the staff are from the local Aboriginal communities.

The nutritional challenges in this group of disadvantaged Aboriginal children are consistent with those reported in other rural towns in northern NSW as part of the Many Rivers Diabetes Prevention Project.³² The Many Rivers study found a low intake of fruit and vegetables and high intake of energy-dense nutrient-poor foods in both Aboriginal and Torres Strait Islander and non-Indigenous children aged 9-13 years, with particularly high intake of sodium, calories, fat, sugary drinks and white bread by Indigenous boys. The nature of the fruit and vegetable subsidy intervention in this study differed from other nutrition interventions in remote Aboriginal communities, such as the Looma Healthy Lifestyle program¹³⁶ in Western Australia and the Minjilang Health and Nutrition Program^{135, 311} in the Northern Territory, a common feature of these successful programs was the degree of community engagement. This together with ongoing relationships underpins a range of current Aboriginal community research programs.^{133, 312-314}

The community support for healthy food subsidies in the Clarence Valley was fostered by the 88% subsidy for fruit and vegetables. The subsidies in recent and ongoing healthy food subsidy research studies^{244, 285} and modelling studies^{218, 223} have been lower, around 10-20%. The higher subsidy used in this program reflects the substantial challenges and barriers to healthy nutrition faced by disadvantaged Aboriginal and Torres Strait Islander families in contemporary Australia. However, it is consistent with the WIC program in the USA and the Healthy Start program in the UK, which provide free healthy foods to low income pregnant women and young children. The WIC program, in particular, has been shown to improve the nutritional status of participating women and children and pregnancy outcomes.^{231, 233, 250, 252, 255, 256, 259, 269} As discussed in chapter 2, there are still questions about the cost-effectiveness of these healthy food

subsidy programs and whether the impacts on nutritional status are sustained.^{232, 237, 269, 315} Food subsidies remain topical in Australia given increasing concerns about food insecurity³¹⁶ and as a policy alternative between compulsory income management and cash entitlements for low income families.

The short-term improvements in health status observed in this study after participating in the fruit and vegetable program are consistent with fruit and vegetable intervention studies in adults. In a RCT of a nutrition education intervention, John et al¹¹¹ found a significant decrease in blood pressure (4.0mm Hg systolic and 1.5mm Hg diastolic) among those receiving the intervention after six months. In that RCT, the intervention group increased self-reported fruit and vegetable intake by 1.4 serves/day and had small but significant increases in β -carotene (7%), α -carotene (7%), vitamin C (7%), lutein (4%) and β -cryptoxanthin (25%) compared to controls. A small reduction in mean blood pressure is important to population health outcomes, for example a 2 mm Hg decrease in diastolic blood pressure in the population would reduce the prevalence of hypertension by 17% and reduce the risk of ischaemic heart disease by 6% and risk of stroke/transient ischaemic attack by 15%.³¹⁷ A small RCT (n=37) of subsidized F&V and nutrition education among overweight African-American women in the USA showed a significant decrease of 2.0kg weight in those receiving the intervention compared to a 1.1kg increase in controls after six months.²⁵⁴ In this study, those in the intervention group increased their self-reported intake of fruit by 1 serve/day and vegetables by 0.9 serves/day compared to no change in the control group. No directly comparable studies of children in high income countries were identified. However, RCTs of nutrition education in children have shown that lifestyle and nutrition education can significantly reduce cholesterol,³¹⁸ improve endothelial function³¹⁹ and reduce blood pressure.³²⁰

The proportion of children who were obese in this study (13%) was greater than the 6% of children who were obese in the Australian National Children's Nutrition and Physical Activity Survey 2007¹⁹ and the 7.1% of primary school-aged children in a 2009 NSW survey³⁴ in areas with large Aboriginal communities (55% of sample were Aboriginal). This may reflect a more disadvantaged cohort of children in this study, but also emphasizes the importance of early intervention in healthy lifestyles to reduce chronic disease risk. The high proportion of iron deficiency was consistent with earlier Australian studies.^{321, 322} The increase in haemoglobin without significant increase in

iron status was consistent with the findings of a study involving post-natal WIC participants, in whom haemoglobin increased significantly without significant change in ferritin.²⁵⁵ This may be due to the overall impact of improved nutritional intake and/or increased recognition and management of anaemia.

The before and after study design without a control group limits the strength of the conclusions that can be drawn from these data. The impact of regression to the mean due to the use of paired data and the normal reduction in rates of childhood illnesses in older children may have contributed to the findings. Regression to the mean is the tendency for a particularly high (or low) measure of an outcome in an individual to be followed by a measure closer to the individual's mean on a repeated measure.³²³ The impact of regression to the mean was adjusted for by including baseline value for each outcome as a covariate in the general linear model. The improved health outcomes and their statistical significance were unchanged after the baseline value was included as a covariate in the analysis, except for the reduction in the number of sick visits which was no longer statistically significant. It is also possible that other unrelated environmental factors contributed to the improvements in nutrition and health outcomes. For example there have been a number of early childhood and school nutrition programs in this area.^{130, 324, 325} As discussed in chapter 4, a RCT was not feasible in these busy Aboriginal community-controlled health services. The health outcomes are based on health record audit which may be subject to incomplete ascertainment, due to the ability of patients to potentially access more than one primary health care service and the lack of linkage of hospital records across area health services. It is not possible to predict the impact of this on the findings, however, it is likely to have impacted on the before and after data similarly. It is also important to consider that the sample size was determined by the available funding for this program. Although the study was powered to detect expected changes in biomarkers based on previous studies^{136, 266} as described in section 3.2.5, the numbers may have limited the power to detect changes in the outcomes reported in this chapter.

The analyses described in this chapter demonstrate a link between subsidised fruit and vegetables and short-term health improvements. A more controlled study would provide data to confirm these findings and investigate the cost-effectiveness of such a program. This would build on economic evaluations and modelling suggesting that the combination of junk food taxes and healthy food subsidies could possibly be cost

saving.²²³ The findings are consistent with prospective studies demonstrating an association between healthy nutrition and improved long-term health outcomes.^{60, 64} However, further studies are needed to establish the biological plausibility and applicability of these findings in children, such as the ongoing analysis in the Special Turku Coronary Risk Factor Intervention Project for Children to investigate the impact of diet and lifestyle counselling on reducing the development of atherosclerosis in children.^{318, 319}

The findings of this impact evaluation suggest the need for a larger healthy food subsidy program to establish the feasibility and sustainability of the program. It could be adapted for other settings, such as community health centres to target low income families more generally. There is increasing evidence that less healthy nutritional intake is common throughout the Australian community, although those of low SES are likely to face the most difficulty with accessing healthier food choices.^{64, 65, 184, 205, 326} An additional issue of relevance to the design of future healthy food subsidies is the relative contribution of the fruit and vegetables to the improved outcomes, as distinct from the preventive health care available at Aboriginal community-controlled health services. This is relevant given the cost of food subsidies and the need to target effective interventions. Food subsidy programs in the USA operate independently of health services, although the WIC program in particular, explicitly assists low income women and families to access available health and social services.²³⁵

6.4.1 Conclusions

This fruit and vegetable subsidy program was associated with improvements in short-term health status in this cohort of disadvantaged Aboriginal children. These health outcomes and the associated improvements in biomarkers of fruit and vegetable intake (described in Chapter 4) have the potential to reduce health disparities in the population. A larger trial with concurrent evaluation is warranted to investigate the sustainability and feasibility of healthy food subsidy programs in Australia.

7 The fruit and vegetable program: development, implementation and evaluation

7.1 Introduction

There is a long history of community-based programs being developed, operating in local communities with varying degrees of success and then ceasing. Furthermore, the effectiveness of a number of programs has been impacted by a variety of factors, including the lack of long term funding as well as competing priorities in the community where they have operated. Often, the lessons of these past experiences, whilst understood at the local level, have not been shared more widely. Consequently, this chapter aims to selectively describe the development, implementation and evaluation of this fruit and vegetable subsidy program, with a focus on issues that may be relevant to those involved in similar community nutrition programs.

The Bulgarr fruit and vegetable program will also be contrasted with my personal experiences of food subsidy programs, particularly the Special Supplemental Nutrition Program for Women, Infants and Children (WIC), in Native American communities in the USA. These national food subsidy programs in the USA, although operating in a different social system, provide a perspective on the challenges of implementing food subsidy programs on a much larger scale.

7.2 The establishment of the Bulgarr fruit and vegetable program

The success of the Baryulgil School nutrition program, described by Jones and Smith,^{210, 211} led to interest in how the nutrition of disadvantaged Aboriginal families in Yamba could be improved. Many of the children from these families frequently attended Bulgarr Ngaru Medical Aboriginal Corporation (BNMAC) outreach visits with common childhood illnesses, particularly skin infections and otitis media. The problem

with establishing this program in Yamba was that these Aboriginal children only represented a small proportion of the children in the local schools. An attempt to establish a school fruit program was unsuccessful due to the need to provide fruit to all the children rather than only the Aboriginal children. This led to a trial of the current fruit and vegetable program for families with weekly boxes of fruit and vegetables (F&V). The initial program was established with one-off funding from the Australian Government Department of Health and Ageing via the Indigenous Coordination Centre in Coffs Harbour. However, after the successful establishment of the fruit and vegetable program in all of the Aboriginal communities in the Clarence Valley), BNMAC was able to incorporate funding for a nutrition program into the new Healthy for Life program established by the Office for Aboriginal and Torres Strait Islander Health in the Department of Health and Ageing. BNMAC committed to subsidising weekly fruit and vegetable boxes for 50 families across all the Aboriginal communities in the Clarence Valley, using additional funding from the Medicare revenue generated by the health service.

The link between the subsidised fruit and vegetables and the preventive health care was based around the need to have an annual health assessment (based on the Medicare Benefits Schedule items for Aboriginal and Torres Strait Islander people) with hearing tests and dental check-ups for all children. This requirement for children to have health assessments was supported by the community, as many people are keen to prioritise their children's health. As the program became established, there were difficulties with ensuring families attended for annual health assessments. This is due to a range of social and cultural factors, particularly many people frequently changing their telephone contact details and high levels of family stress, which meant that non-urgent appointments, such as health assessments, are often a lower priority than more immediate concerns. The expansion of the fruit and vegetable program also created an increased administrative workload for the health service, which largely needed to be undertaken by the clinical staff.

As a result of the success of the Baryulgil school nutrition program, BNMAC obtained funding to employ a dietitian. This greatly strengthened the nutrition promotion at Baryulgil School and then in the other communities. The dietitian assisted with the introduction of the program in each community and was able to establish good rapport with many of the families. There were cooking programs at local schools and for

parents, including young mothers, in the community. The dietitian strengthened the link between clinical services and health promotion in the health service.

There are two local greengrocers in the Clarence Valley- one operating in Grafton and the other in Yamba and Maclean. Both greengrocers have been supportive of the fruit and vegetable program and this enabled the program to operate in its current format. This has been important to the sustainability of the program, as it allows the BNMAC staff to focus on providing health services and not have to also undertake a wholesale fruit and vegetable operation. Each greengrocer collects the family's \$5 contribution and then packs up a box of seasonal fruit and vegetables for later collection by the family (with home-delivery available in Grafton). It is obviously a commercial operation for these businesses and they bill BNMAC for the balance of the cost of the fruit and vegetables. However, the staff at both businesses have recognised the value of this program and made the effort to engage with these families, many of who were not regular customers previously.

The BNMAC fruit and vegetable committee provided basic guidelines to the greengrocers about the contents of the boxes- they were requested to pack boxes of value-for-money seasonal produce containing more vegetables than fruit as per Australian dietary guidelines.³²⁷ A suggested list of basic options is shown in **Appendix E**, although the actual contents of the boxes was at the discretion of the greengrocers based on what was available and good value each week.

The small size of the Baryulgil school and the ready access to the children meant that it was relatively straightforward to do a before and after comparison of the children's health status incorporating blood biomarkers, such as vitamin C, haemoglobin and iron studies, and audits of regular hearing screening tests. The positive impacts of this school program on nutritional status and health outcomes have been published elsewhere.^{210, 211} The expansion of the program made it more challenging to undertake evaluation of the impacts in the other communities. This was important given the different perspectives among stakeholders about the aims and management of the program. The program was obviously popular in the local Aboriginal communities and had strong support from the BNMAC board- comprised of community representatives. The BNMAC staff, particularly the chief executive officer, supported an evaluation as a way to ascertain

whether we were achieving the program's aims and whether it was an effective way to use the health service's funding.

7.2.1 *The role of the Bulgarr Fruit and Vegetable committee*

The management of the Bulgarr fruit and vegetable program involved a committee with representatives from all areas of the health service. This facilitated the dissemination of nutrition promotion information to all sections of the health service and ensured that healthy food is central to the work of this health service. It has strengthened and promoted links within the health service. The fruit and vegetable program requires significant coordination and participation in the committee by a range of staff has underpinned the ongoing success of the program. The majority of the committee are local Aboriginal people. This has ensured that there is a real community focus to the program and that relevant community issues are known and considered in the administration of the program. The committee has also been able to build on pre-existing relationships with the staff in local schools and other service providers which has strengthened the profile and operation of the fruit and vegetable program.

7.3 Considerations in the design of the program evaluation

The Bulgarr fruit and vegetable program represents an opportunity to investigate the impact of the healthy food subsidies on the health and nutrition of disadvantaged families. Various aspects of this have been discussed in earlier chapters in this thesis. This information is of interest to many external stakeholders involved in improving nutrition among disadvantaged families in Australia. BNMAC and the local Aboriginal communities have a particular interest in how the program operates and which aspects could be improved to better target local needs. In undertaking the evaluation, I was aware of the need to ensure that the evaluation was useful for the BNMAC staff and the local community.

7.3.1 *Obtaining ethics approval and balancing community needs*

The design of the evaluation involved considerable discussion with the BNMAC staff and the human research ethics committees at the University of Melbourne and the Aboriginal Health and Medical Research Council (peak body for Aboriginal community-controlled health services in NSW). The BNMAC Board was consulted on several occasions. A randomized controlled trial was considered for two main reasons.

It is the most rigorous study design for minimising the impact of known and unknown confounders. However, it was also seen as an equitable way to manage the waiting list that had developed for the program, given the popularity of the fruit and vegetable program among the families who use the health service and the limited funding for the program. There was very useful input from the two ethics committees (and external experts consulted by the Aboriginal Health and Medical Research Council ethics committee) which helped to clarify aspects of the research. The decision to undertake a before and after cohort study was made after assessing the limited staff time available to assist with the evaluation at BNMAC, although this was informed by the various perspectives about the feasibility of the different study designs within the ethics committees.

The most challenging ethical aspect to arise while planning the study involved balancing the need to maximize the number of families participating in the evaluation to obtain a sample size which provided acceptable statistical power, while providing participants with a free choice to participate in the study. The problem was that given the limited funding for the fruit and vegetable program, it was necessary to get all new families joining the program to participate in the evaluation. There were divergent views about the issue. The BNMAC staff and the BNMAC Board were supportive of the requirement that the evaluation would be an integral part of the fruit and vegetable program for all new participants. Thus, families had the free choice as to whether to participate in the program including the evaluation. However, there were members of one of the ethics committee who considered this unethical. It highlights the difficulty with quality evaluation research in smaller community organisations with limited resources, but who are nonetheless interested in understanding how effective their programs are. The decision of the ethics committees was to support the wishes of BNMAC and the community in the design of the evaluation.

In addition to the two ethics committees discussed above, it was also necessary to obtain ethics approval from the North Coast Area Health Service Research Ethics Committee. It is important to consider the need to obtain multiple ethics approvals when establishing Aboriginal community-based research. This has implications in terms of the time and capacity required to undertake each ethics approval.

7.3.2 Impact of the choice of study design

The fruit and vegetable program evaluation was always envisaged as a pragmatic evaluation. The focus was on measuring outcomes for which data could realistically be obtained. These data were then used to estimate the impact on the nutritional biomarkers, fruit and vegetable intake and selected health outcomes among program participants.

In this before and after study design, the lack of a control group raises the question of whether there are other factors that might have contributed to the improvements in nutritional biomarkers. In using repeated measures in one group, it is possible that regression to the mean contributed to the changes observed (as discussed in section 6.4). It is also possible that temporal changes, including but not limited to the increasing age of the participating children, also contributed to the outcomes. A control group would have addressed these concerns by demonstrating the temporal changes and regression to the mean in a similar group who did not participate in the program over the duration of the study. As noted above, a randomised controlled trial would also have minimized the likelihood of confounders affecting the association between program participation and any changes in nutritional or health status. Thus, it is clear that the strength of the conclusions from this study were limited by the study design utilised.

The drop-out rate at follow-up was less than 20% which is considered an acceptable level. However, if an RCT had been implemented and there had been a high and/or differential proportion of drop-outs from the control or experimental group, this would also have undermined the strength of the findings. These considerations impacted on the decision to employ a before and after study design and I was aware of the need to implement the study as rigorously as possible with a focus on maximising follow-up of participants.

7.3.3 The expansion of the fruit and vegetable program - a multi-site evaluation

Initially the evaluation was planned to involve only the Bulgarr Ngaru fruit and vegetable program. During 2008, the Mid-North Coast Division of General Practice obtained funding for a nutrition program (based on the Bulgarr Ngaru model) from the Department of Health and Ageing. This funding was divided between the BNMAC, Galambila Aboriginal Health Service in Coffs Harbour and Giingan Darrunday

Marlaanggu Health Clinic in the Nambucca Valley. These other two health services were keen to participate in the evaluation as their staff considered that this would enhance the value of their nutrition programs. It was considered that the Aboriginal communities in these locations and the three health services were sufficiently similar that it was reasonable to combine the results. The enlarged sample size was obviously useful.

The involvement of different locations introduced additional complexity, which is common to most multi-site studies. The most difficult challenge for introducing fruit and vegetable subsidy programs in these other locations however, was finding and organizing the local greengrocers. In the Nambucca Valley, the only greengrocer was at Macksville, while the Aboriginal families were in Bowraville, Nambucca Heads and Macksville. Giingan Darrunday Marlaanggu health service was required to collect the families' \$5 contributions and transport and deliver the F&V boxes to the families in each community. In Coffs Harbour, the only greengrocer who would participate in the program would also not collect the contribution from the families and would not pack boxes of F&V. Hence, the families in Coffs Harbour had to pay their contributions at the health service and then were able use vouchers to choose their own F&V up to the specified value. This experience highlighted the central role of the greengrocer in enabling this program, as discussed in Section 7.2. These differences in implementation at each location led to a change in the analysis of the data. The changes in nutritional and health outcomes were assessed by individual community first and then the overall impact was assessed in a model that adjusted for community.

7.4 Community feedback from the focus groups

Three focus groups were held - in Baryulgil/Malabugilmah, Grafton and Yamba/Maclean. The participants were members of the local Aboriginal communities, who were either on the fruit and vegetable program or wished to join the program. The purpose of the focus groups was to provide an opportunity for the participating families to give feedback and suggestions about the program and to provide a summary of the evaluation results to the community. The discussion was framed around relevant themes and questions for the group (**Appendix F**). The Grafton and Yamba/Maclean focus groups involved families whose children had participated in the evaluation and these groups were conducted after the data were collected and analysed, so that this would not

bias data collection and a summary of results could be presented. The Baryulgil/Malabugilmah families did not participate in the evaluation as they had joined the fruit and vegetable program prior to the implementation of the evaluation. This summary of the focus groups presents important ideas selectively.

The focus groups were part of a process evaluation; however, there was no structured qualitative analysis as this was beyond the scope of the current research presented in this thesis. As indicated above, the focus groups were intended to both collect information and provide feedback to the community, particularly the participating families. Ensuring a sense of community ownership and understanding of the research undertaken in Aboriginal community settings is important. The presentation of the results was also used as a strategy to boost attendance at focus groups (along with a cooking session). It is recognised that presenting summary results at these groups may have biased the responses from the focus groups. However, this evaluation could only have been undertaken by those involved with the program and relied on the relationships between each health service and the local communities.

Most participants indicated that the program had greatly improved the availability of F&V in their household. The boxes (either \$40 or \$60 worth depending on the number of children) were reported to last 4-7 days and the F&V was generally consumed by all members of the household including visitors. The larger families in particular had found that the fruit was very popular and did not last as long as the vegetables. Some families reported buying additional F&V to supplement the boxes. The boxes contained seasonal fruit and vegetables selected by the staff at the greengrocer, with flexibility to accommodate the preferences of each family. This had meant that families had tried several unfamiliar F&V which was seen as a positive aspect. However, many people would prefer to be able to choose their own F&V to minimize wastage.

The families who participated in the focus groups had all been on the F&V program at least 12-18 months prior to the focus groups. At least half of those present indicated that they would still participate in the program if the contribution from families was increased to \$10-\$15. This was discussed in the context of the sustainability of the program and allowing it to be expanded to include more families. One participant felt strongly that a school nutrition program was needed to meet the needs of disadvantaged

children from food insecure families, although it was unclear if this was in preference to the current F&V program for families.

The seasonal recipes included in the boxes were useful to some of the families. In addition, most families indicated that they supported more nutrition education/cooking demonstrations. These have been run by the two part-time BNMAC dietitians in the local communities aimed at different groups within the community. Younger mothers were indicated as the most appropriate target group for these sessions. Many participants were aware of concerns about the need for adequate macronutrient and micronutrient intake (e.g. iron). However, during the cooking demonstrations that accompanied the focus groups, the influence of other factors, such as taste, social norms and habits, that interact with knowledge about healthy nutrition to determine what is consumed were evident. Many participants had a strong preference for salt.

7.5 Food subsidy programs in Native American communities in the USA

The literature review and the systematic review provided the opportunity to read widely from the published literature about the WIC program in the USA. This national program is administered at a state level with WIC clinics operating in local communities throughout the USA. However, WIC services for Native Americans are administered by tribal organisations and there is a paucity of published information about the WIC program in these communities. During my PhD candidature, I organised to visit the WIC clinics in several Native American communities in New Mexico and Arizona. I felt that a greater understanding of the dynamics of this food subsidy program would provide a useful perspective to interpret the Bulgarr Ngaru F&V program.

The reality of the vastly different social system was the most obvious and relevant issue that I observed as a first-time visitor to the USA. The food subsidy programs in the USA, such as the Supplemental Nutrition Assistance Program (formerly the Food Stamp Program), the WIC program, the Food Distribution Program on Indian Reservations and the National School Lunch and Breakfast Programs, are part of a social security system which is heavily weighted to non-cash transfer programs. In this regard the food subsidy programs have some similarities with the income management regimes introduced to the Northern Territory (at least in the requirement for people to spend money on food or other essential items). The non-proscriptive nature of the

Supplemental Nutrition Assistance Program and the Food Distribution Program on Indian Reservations gives people the choice of almost any foods, which softens the reality of having these choices determined as part of social security entitlements.

In the Native American communities in New Mexico, I was able to observe the political strength of these tribes, who negotiate with Federal and State Governments as autonomous entities. This meant that they were much less likely to have new programs or other changes imposed on them. It also created challenges due to not having the expertise or workforce to undertake functions which they were responsible for, such as environmental health. This was a contrast with the political structure for Aboriginal and Torres Strait Islander people in Australia. The authority of representative bodies in Aboriginal and Torres Strait Islander communities is often usurped in their interactions with Federal and State Governments. In other aspects, there were many similarities between the social and health issues in these Native American communities and those found in Aboriginal communities in NSW and other Australian states, as has been documented previously.³²⁸⁻³³⁰

As has been described in Chapters 1 and 2, the WIC program operates as a standalone service providing nutrition promotion and subsidised food or vouchers for pregnant or postpartum women and children up to 5 years old. The success of the WIC program since 1972 has resulted in additional health promotion activities being incorporated into the core WIC operations. The WIC staff in these Native American communities undertook roles that would normally be undertaken by primary health care or community health services in Australia, including home visiting and lactation support to new mothers in the immediate post-partum period. This reflects the reality of a relatively well-funded and successful community health program. In the smaller Native American communities, the WIC clinic had close links with the primary health care services and was often co-located in the health service buildings.

The key challenge in the WIC program was engaging young mothers in the nutrition promotion activities. This is a common experience in BNMAC also. Other activities are given priority and those most likely to benefit are often the hardest to engage. The WIC program employs people from the local tribe to fill many of the local WIC positions. As in Aboriginal community-controlled health services, this assists clients to feel that the service is attuned to their needs culturally and socially. It was obvious that personal

relationships were pivotal and allowed long-serving WIC staff (both tribal and non-Indigenous) to successfully engage with families.

The WIC program engages initially with pregnant and postnatal women. The staff are predominantly female and it is perceived to be women dealing with women's 'business'. However, there is a role for the fathers and I met a significant number of men who brought their children for the regular WIC review appointments. The other crucial role for men is in supporting their partner's breastfeeding. This is an important aspect of the efforts by the WIC clinic staff to foster breastfeeding. Partners are encouraged to attend the WIC antenatal appointments, where breastfeeding is discussed and promoted. In these Native American communities, I was able to observe that strengthening and supporting nutrition in families meant engaging all family members.

The WIC program in the early years developed a reputation as the 'baby milk' program. This reflected the decline in breastfeeding in the USA and the role that WIC played in providing infant formula to poor women who would not otherwise have been able to afford it. This problem has been addressed within the WIC program: - promotion of breastfeeding is now a key role and breastfeeding mothers now receive the most generous food package of all participants. Although infant formula is still provided, I observed that breastfeeding is clearly promoted as the preferred option for babies.

7.6 Food subsidy programs and concerns about sustainability, dependence and equity

There have been concerns expressed about the sustainability of the fruit and vegetable program by key Aboriginal stakeholders. This was a particular problem in the two health services that only had one-off funding for their programs. This evaluation of the program was seen as important given the limited evidence for food subsidy programs in Australia. The positive health and nutritional outcomes discussed in Chapters 4-6 were interpreted at BNMAC as supportive of the overall benefits of this program. This resulted in a decision to increase the allocated funding to allow up to 70 families to participate in the BNMAC program. The most important implication of the evaluation is the potential reduction in chronic disease risk if the improved F&V intake (indicated by the biomarkers) is sustained in the long-term. One stakeholder discussed the long running F&V program at the Redfern Aboriginal Medical Service in Sydney. Although this program targets people at nutritional risk, food security is an important criteria

determining participation. There are regular reviews and families that are not considered at risk are removed from the program. There has never been a formal evaluation of the Redfern AMS program (Gloria Strachan, personal communication). The evidence of the positive cost-benefit ratio of the WIC program in the USA, as discussed in Chapter 2, has been used to justify the expansion and ongoing support for the WIC program. An economic evaluation is beyond the scope of the data collected in this evaluation, but this type of data would assist if fruit and vegetable subsidy programs are to be expanded beyond these small local initiatives.

A related concern expressed by stakeholders was whether this program was creating dependence rather than fostering self-reliance among these disadvantaged families (Dave Kennedy, Gloria Strachan, personal communication). There were concerns about what would happen after participation in the program ceased. Some Aboriginal and non-Indigenous service providers have indicated a reluctance to take over the roles of parents with reference specifically to providing regular meals for children (Sam Davidson, Andrea Brown, personal communication). There were no data collected in this study about nutritional intake after participation in the fruit and vegetable program. However, in both the Nambucca Valley and Coffs Harbour, health service staff reported that families appreciated the opportunity to participate in the F&V program and no concerns were reported after the end of the programs. There are many low income Aboriginal families in these three locations. Clearly some of these have much better health and this is usually related to better social functioning and lower rates of alcohol or other drug use. In this context, a small number of stakeholders mentioned the equity of this program, which they claimed tended to ‘reward’ with participation those families with more of these social problems and less healthy children. These issues indicate the complexity of the balance in providing subsidised fruit and vegetables to these disadvantaged Aboriginal families.

7.7 Conclusions

This chapter has highlighted key elements that contributed to the successful implementation of this F&V subsidy program. The role of the local greengrocers was vital, without their support long-term operation of such a program would be difficult to sustain. The input of dietitians/nutritionists has greatly enhanced the nutrition promotion aspects of the program and provides the support necessary to families to incorporate

F&V into their regular diets. The extent of the subsidy has acted as a strong incentive to engage disadvantaged families in this nutrition program. There are concerns about whether the design of this program is fostering dependence or strengthening families' nutrition. However, participants at the focus groups were supportive of the positive impacts within their own families. Thus, the successful implementation refers to the commitment of BNMAC staff and those from other organisations and the local communities in working co-operatively to develop and sustain this program since 2005. Given the history of brief programs hampered by lack of ongoing funding in Aboriginal communities, this is a significant achievement.

The design of these community programs and subsequent evaluations are improved by input from both external stakeholders and the local communities. The establishment of relationships is critical to the success of these programs. The interactions between the fruit and vegetable committee members within the health service and in the community have been pivotal to the ongoing operation of the fruit and vegetable program.

The whole evaluation including the description of the development of both the program and its evaluation is an important step. It provides an accessible assessment of the processes and impact of this fruit and vegetable subsidy program. This has contributed to the decision-making at the local health services about whether the program is worthwhile and how it might be improved to enhance its effectiveness. The evaluation also provides evidence to inform the policy discussions about the most effective strategies to promote healthier nutrition and reduce social inequalities in health outcomes.

8 Discussion

8.1 Introduction

This evaluation of the Bulgarr Fruit and Vegetable Program, including the process evaluation, has provided important insights into the nutritional and health impact of subsidised fruit and vegetables to disadvantaged Aboriginal families and further highlighted the challenges of intervention research in Aboriginal community-controlled health services. In this chapter the key implications of the findings reported in this thesis are discussed along with the implications for future policy, practice and research. This chapter focuses on Aims 2-4 relating to the Bulgarr Fruit and Vegetable Program. Aim 1 relating to the systematic review of food subsidy programs in high income countries was discussed separately in section 2.4. However, this overall discussion will synthesize relevant findings from all chapters.

8.2 Key findings

The before and after comparison of children participating in the Bulgarr Fruit and Vegetable Program for 12 months demonstrated a pattern of changes in nutritional biomarkers in blood that are consistent with increased intake of fruit and vegetables, particularly fruit. There were statistically significant increases in red blood cell (RBC) folate (8-50%), vitamin C (21%), β -cryptoxanthin (16%) and lutein-zeaxanthin (11%) among participants at follow-up. An increase in α -carotene (11%) was also observed, although this was not statistically significant. Interestingly a non-significant decrease in lycopene (8%) was observed, whilst β -carotene levels remained the same. In contrast to the difference in the biomarkers, there was no change in self-reported intake of fruit or vegetables based on the 24 hour dietary recalls. There was, however, an increase of 0.23 serves of fruit/day and a decrease of 0.25 serves of vegetables/day in the short dietary

questions asked at the time of the 24 hour dietary recall, although only the decrease in vegetables was statistically significant after adjustment for gender, age and community.

In addition to these nutritional outcomes, there were also improvements in several short-term health outcomes among children after 12 months on the fruit and vegetable program. There were statistically significant decreases in episodes of illness (14%), attendances at the emergency department (25%) and prescriptions for oral antibiotics (30%). There was also a statistically non-significant decrease in pyoderma (24%). These findings support the conclusion that there may be short-term improvements in participant's health status along with the changes in biomarkers indicating increased fruit and vegetable intake after participation in this fruit and vegetable subsidy program. However, some caution needs to be exercised given the fact that the effect sizes were modest and that there were some limitations in the design of this evaluation that will be discussed later. It is also important to consider that a high proportion of the participating children were overweight or obese at baseline, particularly the older children (based on international classifications of BMI for age). Also the proportion of children who were overweight or obese did not change significantly after 12 months on the program.

In addition to the nutritional and health outcomes, interviews, personal observations and other data from the process evaluation indicate that this generous fruit and vegetable subsidy program, run by Aboriginal community-controlled health services, successfully engaged disadvantaged Aboriginal families. As a result these families were able to benefit from nutrition promotion, including obtaining a regular supply of fruit and vegetables, and the children attending the health services for preventive health assessments. This study also demonstrated that an evaluation incorporating blood tests and dietary recalls in a group of Aboriginal children is feasible provided there is strong engagement and ongoing relationships between the health service/research team and the local Aboriginal community.

8.3 Strengths and limitations of the study

This study was undertaken to assess the impact of healthy food subsidies for disadvantaged Aboriginal families. It demonstrates that evaluations of nutrition interventions employing multiple measures of nutritional status can be completed successfully among Aboriginal children in community based studies. This is consistent

with the recommendation to use multiple methods to improve the validity of dietary assessment in research studies.¹⁴²

This study reflected as much as possible the values espoused in the Guidelines for Ethical Conduct in Aboriginal and Torres Strait Islander Health Research.³³¹ Unlike descriptive studies, the local Aboriginal community appreciated that this evaluation study was linked to improving a local program and that there were much more likely to be benefits for the local Aboriginal communities as a result of this research. In addition, the research involved a strong connection to health service delivery, thus there were also benefits for participating individuals and families, as a result of the health assessments and resulting follow-up activities. While undertaking this research evaluation, I have worked part-time as a general medical practitioner at Bulgarr Ngaru Medical Aboriginal Corporation (BNMAC). This ensured that the research built on the reciprocal relationships that existed between the health service staff and the local community.

The use of biomarkers provided a more objective measure of nutritional status than self-reported dietary intake. The use of biomarkers avoids the systematic and random error due to respondent bias that affects all self-reported dietary intake.^{119, 120} The other strength of biomarkers is that they are more reflective of usual fruit and vegetable (F&V) intake in the medium term, particularly in comparison with a single 24-hour dietary recall.¹⁶¹ As recommended in a recent systematic review of biomarkers in fruit and vegetable intervention studies, a panel of biomarkers was used.¹⁴¹ This enables the pattern of changes in biomarkers to be assessed, which will vary depending on the particular fruits and vegetables consumed and the impact of other confounding factors, such as smoking exposure and lipids. This is important, as the systematic review found that no one biomarker increases in all intervention studies.¹⁴¹

There were a number of limitations in this study. The most obvious was the lack of a control group and more generally the use of a before and after study design rather than a randomised controlled trial (RCT). The RCT design would have accounted for the impact of both known and unknown confounders in this evaluation. Potential confounders such as age, gender, total cholesterol, baseline values were assessed in the analysis by including them as factors or covariates in the general linear model (see sections 4.3.4 and 6.3.2). However, other potential confounders, such as exposure to smoking in household, were not assessed as the data for this variable were not judged to

be sufficiently reliable. The use of a RCT was considered during the development of this study, as it would have allowed for stronger conclusions due to minimising the potential for confounding as described above. As discussed in section 7.3.1, the use of a control group would have helped to equitably allocate the families who wanted to participate in the Bulgarr Fruit and Vegetable program. The number of eligible families who wanted to participate in the program exceeded the available funding for the program. After the decision to expand the evaluation study to include the additional two Aboriginal health services in Coffs Harbour and the Nambucca Valley, thorough assessment of the available resources and the workload implications of engaging and motivating a control group in addition to the intervention group suggested that a before and after study design was the only feasible option.

It was also not possible to estimate the cost-effectiveness of the program due to the study design. Economic analysis generally relies on a true counterfactual, such as a control group, to provide the data needed to provide robust estimates of effect. This before and after study design did not provide direct information of what would have occurred in the absence of the fruit and vegetable program. Hence, the health and nutritional outcomes data were not used to compare the effectiveness of the program with the costs.

The discrepancy between the significant increases in biomarkers and the lack of change in self-reported fruit and vegetable intake further undermined the strength of the conclusions from the fruit and vegetable program evaluation. This discrepancy together with the lack of a control group raises a question about alternative explanations for the observed changes in biomarkers. As highlighted above, exposure to smoking and age impact on the level of specific carotenoids differentially. The commencement of mandatory folate-fortification of bread-making flour in 2009 had an important impact on the dietary sources of folate for the participants in this study. These known confounders were addressed in the analysis if possible. Importantly, the pattern of changes in dietary biomarkers was consistent with increase intake of fruit and to a lesser extent vegetables as observed by program staff and described by parents during health service visits. In addition, of the carotenoids measured, only β -carotene is known to be available in dietary supplements or multivitamins.

The difference between the fruit and vegetable intake reported in the short dietary questions and the 24-hour recalls highlights the limitations of self-reported dietary intake in this study. The 24-hour recall data should represent mean intake of foods including fruit and vegetables for a group of 50 or more people. There may have been bias in participant's 24-hour recall data due to the presence of clustering by family, so that the variability in daily intake for this group was reduced compared to unrelated individuals. It is also possible that there is greater variability in intake in these Aboriginal families, particularly related to availability of food in the household, as reported in remote Aboriginal communities.¹³⁴ The higher levels of fruit and vegetable intake reported in the short dietary questions may indicate difficulty with estimating average intake or it may represent bias due to social desirability, with respondents wanting to report intake of the 'right' foods.¹³⁴

Potential under-reporting of intake in 10-18% of the 24-hour recalls was a further limitation of the dietary intake data. This is a well described source of bias in self-reported dietary intake. Under-reporting of intake is an important issue in assessing associations between dietary intake and health outcomes, particularly the relationship with body weight. As described in the methods (section 3.4.3) in this study, 24-hour recalls were not excluded on the basis of potential under-reporting as data on physical activity level or energy expenditure were not recorded in this study. This was consistent with the approach in the 2007 Australian Children's Nutrition and Physical Activity Survey. In the 2007 survey, Rangan et al³³² reported that 5-6.7% of children under-reported energy intake and recommended that excluding this data should be considered when investigating the relationship between energy intake and body weight. However, given the scope and exploratory aspects of this study it was considered appropriate to use dietary data from potential under- and over-reporters in reporting changes in F&V and macronutrient intake.

The limitations of the self-reported dietary intake data led to the decision to restrict the analysis of these data to the overall changes in fruit and vegetable intake and macronutrient intake. This meant that the potential for selective under-reporting by age or gender could not be analysed. The small sample size in individual age and sex categories would have affected the validity of these findings. Using the same rationale, the dietary intake data were not analysed to determine the changes in micronutrient intake. This was particularly relevant to folate due to the commencement of folate-

fortification. However, it has not been possible to clarify when the AusNut 2007 Australian food database was updated to account for folate-fortification of bread-making flour, which ensured that it was more appropriate to focus on the correlations between RBC folate and bread intake or fruit and vegetable intake.

The strength of the findings of the study are also limited by the potential impact of regression to the mean, which is a feature of paired data.^{323, 333} It was not practical to reduce the impact of regression to the mean in this study, using either a RCT design or multiple baselines measures as suggested by Barnett et al.³²³ The impact of regression to the mean was assessed in the analysis by including baseline value as a covariate in the generalised linear model for both nutritional and health outcomes. There were no substantial changes to the estimates of effect and only the reduction in sick visits became statistically non-significant as a result of adding baseline value into the general linear model. The study findings could also have been explained partly by ageing of the children with biomarkers, dietary intake and episodes of illness all varying with age. This was also addressed in the analysis by including age as a covariate in the general linear model.

The research evaluation was undertaken at three different Aboriginal health services, working in seven different rural towns, which increases the generalizability of the findings, but also introduced challenges to the data collection and analysis which may have impacted on the internal validity of the data. The involvement of multiple sites had a number of practical impacts, such as the use of different pathology laboratories for some of the nutritional outcomes (e.g. haemoglobin, iron studies, vitamin D and RBC folate) which introduced the possibility of greater random and non-random error in these data. As discussed in Chapter 5, the RBC folate assays were different which impacted on the analysis of these data. The standardisation of data collection was also more difficult due to lesser involvement that I could have as the principal researcher at the health services in Coffs Harbour and the Nambucca Valley, despite the development of a standard protocol for assessments. This is reflected in the lower rates of follow-up data collection in these two locations.

The most significant limitation due to the use of multiple sites was the differences in the implementation of the program at each location, as described in section 7.3.2. This impacted on the assumption that the data from each community could be combined to

increase the sample size. This was addressed in the data analysis by including community as a factor in the general linear model. The data were then assessed by community before assessing the outcomes of the overall sample. Thus, the limitations described here suggest a balanced interpretation of the impact of fruit and vegetable subsidies on disadvantaged Aboriginal families in these rural locations is needed.

8.4 Comparison with previous research

The study described in this thesis extends previous research by investigating the nutritional impacts and health outcomes of a fruit and vegetable subsidy intervention for disadvantaged Aboriginal children. In this way, the study involved a novel approach to nutrition promotion in Australia; however, it drew heavily on the background of healthy nutrition programs in Aboriginal communities.^{135, 136}

The improvements in nutritional status observed in this study, as indicated by significant increases in plasma lutein/zeaxanthin, β -cryptoxanthin, vitamin C and RBC folate, are consistent with the findings of studies of children participating in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC). Rush et al²⁶⁹ reported that preschool aged WIC participants had significantly higher intake of targeted nutrients than non-participants, including iron, vitamin A and vitamin C without increased energy intake. More recent studies have confirmed the significantly higher nutritional intake of a range of micronutrients among child WIC participants compared to controls²⁶⁶ and beneficial effects on the intake of fat, added sugar and fruit in their diets.²⁶⁷ However, these studies all used a cross-sectional design and hence were excluded from the systematic review of food subsidy programs. Overall, there is limited high quality evidence of the impact of food subsidy programs on children's nutritional status (see Chapter 2).

The impact of other F&V interventions aimed at school-aged children have been more extensively studied. One systematic review included 15 controlled studies of F&V programs, with 10 studies reporting increased in F&V intake ranging from 0.3-0.99 serves/day.³³⁴ Another systematic review of school-based nutrition programs reported a mean increase in F&V intake of 0.45 serve/day based on a meta-analysis of 7 studies involving 8156 students.³³⁵ Thus, there is more evidence for the nutritional impact of school-based F&V interventions.

The sustainability of these improvements in nutritional intake is a critical issue given that the most important benefit of a moderate increase in F&V intake is the long-term impact on chronic diseases risk.^{42, 43, 45-47, 106, 108, 282, 336} Most studies only report on nutritional intake during participation in the nutrition interventions. Longer-term follow-up of both school-based interventions and the WIC program have found improvements in nutritional intake were only seen in current and not past participants.^{269, 337} In a study of 896 adolescents, Bere et al³³⁸ found that reduced access to F&V at home was the most significant factor in lower intake of F&V by the children of low SES families. Overall, the most successful interventions for promoting F&V intake are multifaceted and comprehensive.^{334, 338}

The findings of statistically significant improvements in short-term health outcomes including episodes of illness, hospital emergency department attendances and oral antibiotic prescriptions have not been commonly reported in high quality studies of healthy nutrition programs. One controlled, non-randomised study compared the health status and nutritional intake of 40 preschool aged African-American children in 2 childcare centres in the USA where one centre provided healthy meals and snacks through the Child and Adult Care Food Program.³³⁹ The children receiving the healthy meals had fewer days of illness (6.5 versus 10.5 over 7 months) but no difference in weight for height or dental caries compared to controls. The children receiving the healthy meals also had healthier nutritional intake, reporting higher intake of milk, vegetables and certain micronutrients including vitamin A and calcium and lower intake of fat and sweets compared to controls. In the national WIC evaluation study of infants and children, Rush et al²⁶⁹ reported significantly higher performance on literacy and numeracy assessments, in addition to the nutritional improvements described above, among WIC participants compared to controls.

Despite the limitations of these studies, it is clear that healthy nutrition is an important part of an overall lifestyle pattern which contributes to disease prevention.³⁴⁰ A cross-sectional study of 20,271 European children aged 7-11 years showed significant associations between respiratory symptoms and dietary intake. Low F&V intake was associated with persistent cough (OR 1.4, 95% CI 1.01 - 1.8) and low fish intake was associated with cough (OR 1.2, 95% CI 1.04-1.3) and current wheeze (OR 1.3, 95% CI 1.04 - 1.4). Studies in adolescents have shown that an inverse relationship between fruit and vegetable intake and markers of oxidative stress, including C-reactive protein,

interleukin-6 and urinary F2-isoprostane³⁴¹ and that a predominantly vegetarian diet is associated with significantly lower BMI, low density lipoprotein cholesterol and lower total cholesterol/high density lipoprotein cholesterol ratio.³⁴² The association between higher F&V intake and lower levels of CVS disease risk factors in adolescents is consistent with the long-term impacts of higher F&V intake on chronic disease risk in adults.

The carotenoid levels in this cohort of Aboriginal children aged 0-17 years are comparable to those reported in a representative sample of 4231 American children aged 6-16 years, except for lycopene (see section 4.3.2).¹⁵¹ The mean β -carotene in this study was slightly higher than the mean β -carotene (300nmol/L) reported in a sample of 467 Australian children aged 1-5 years.¹⁵⁴ This contrasts with the lower levels of carotenoids reported in Indigenous Australian adults compared to non-Indigenous Australians in a study in the Northern Territory.¹³⁸ The finding of comparable carotenoid levels in these different populations of children is consistent with the high prevalence of low fruit and vegetable intake among children in many countries,^{19, 188, 343} although F&V intake was not reported in the two studies involving children discussed above. It may also relate to lower exposure to smoking and lower rates of obesity in Indigenous Australian children compared to Indigenous Australian adults. In the large US study, exposure to cigarette smoking was inversely associated with β -carotene, α -carotene and β -cryptoxanthin and high BMI was inversely associated with all carotenoids except lycopene.¹⁵¹

The major dietary source of lycopene is tomatoes, particularly processed tomatoes. This reflects the higher bioavailability of lycopene when released from the plant matrix and consumed with oils or fats (see section 1.2.4.2.1). Thus, lycopene may be an appropriate biomarker of the consumption of processed foods. As discussed in section 4.4, the higher level of lycopene in this study compared to the mean lycopene in the representative sample of American children,¹⁵¹ may have indicated higher consumption of processed or take-away foods. The decrease in lycopene observed in this study could be interpreted positively in terms of improved dietary quality, although further studies are needed to clarify the dietary sources of lycopene in this population.

The fruit and vegetable intake reported at baseline in this study is consistent with those reported in the Many Rivers Diabetes Prevention program by 10-12 year old Aboriginal

children in other northern New South Wales towns.³² In this study, fruit intake was 95g/day for Aboriginal boys and 58g/day for Aboriginal girls and vegetable intake was 131g/day for Aboriginal boys and 96g/day for Aboriginal girls. However, it was slightly less than the fruit and vegetable intake reported in the 2007 Australian National Children's Nutrition and Physical Activity Survey which ranged from 133 - 186g/day for fruit and 95-202g/day for vegetables across age categories.¹⁹ Given the recruitment of a low socio-economic status cohort of families in this study, the lower F&V intake reported in this study compared to the national survey is consistent with the finding of a systematic review that parental SES is associated with lower F&V intake in older children.³⁴³ Overall, low levels of F&V intake and high intake of energy-dense nutrient poor foods are common in both Aboriginal and Torres Strait Islander children and non-Indigenous children in Australia.^{31, 32}

The generous subsidy for fruit and vegetables in this program is seen as important to overcome the many factors which favour less healthy nutritional patterns among disadvantaged Aboriginal families. Traditional foods were not a major source of energy reported by the children in this study. Indigenous adults participating in a nutrition program in Townsville similarly reported low intake of traditional foods.²⁹ In non-remote areas, there are social and practical restraints which limit the feasibility of obtaining traditional foods.²⁹ This emphasises the importance of addressing the facilitators and barriers to purchasing and consuming healthy foods, particularly fruit and vegetables. The available evidence suggests that the most important factors related to fruit and vegetable consumption by children include availability at home, parental intake and encouragement, socio-economic status - specifically parental education and occupational status and taste preferences.^{343, 344} In addition to these general factors, in Aboriginal families, social and cultural norms around sharing of resources combined with the high prevalence of poverty favours consumption of energy-dense takeaway foods over healthier home-prepared meals.²⁰⁸

8.5 Implications for policy and practice

Despite the limitations of this study, it suggests that fruit and vegetable subsidies can have positive health and nutritional impacts on disadvantaged children during participation in these programs. The impact on F&V intake in children of a 10-30% increase in biomarkers of F&V intake, such as carotenoids and vitamin C, cannot be

precisely quantified from existing evidence. However, the systematic review showed that increases of 1-2 serves of F&V/day are achievable in adults. An increase in F&V intake of this magnitude offers potential long-term health benefits through reducing chronic disease risk (for example an eight per cent reduction in cardiovascular disease risk). The benefits may be larger in a more disadvantaged population with worse baseline nutritional status and thus may contribute to reducing the social inequalities in health outcomes.

The link between the food subsidy and health was enhanced by the implementation of the program at an Aboriginal community-controlled health service. The evaluation study was focused on children, but the F&V program itself engages families in a primary healthcare setting. It offers an alternative to school-based nutrition programs which have been widely used to engage children in healthy nutrition promotion. Given the challenge of high rates of chronic diseases in Aboriginal and Torres Strait Islander communities, a larger trial of healthy food subsidies would complement other approaches to improving nutrition and promoting health.²⁰⁹ These programs have the potential to improve the nutritional status of the whole family, which supports parents or other adults to model healthier dietary patterns. In the context of changing dietary behaviour, family-based nutrition programs are theoretically better suited to integrating healthier dietary habits into the social and cultural context of each individual and his or her family. Such family-based programs, to the extent that they are able to produce sustainable improvements in nutritional status, could ultimately prove to be more cost-effective in the long-term than nutrition programs which only target children.

The provision of only fruit and vegetables was seen as a limitation of this program which did not address the wider issues of food insecurity in some of the participating families. Although data from nutrition surveys clearly demonstrates that F&V intake well below recommended levels is common in the Australian community, there are other challenges to improve the nutritional status of the general population, particularly low income families. Food subsidy programs would be improved by using the best available data to identify the most significant deficiencies in the diets of the target population and use this data to explicitly design and evaluate any new programs. This was the approach that was taken in the development of the WIC program.²²⁸

Another implication of this research is whether a larger trial of food subsidies should include low income families more generally. Aboriginal and Torres Strait Islander people are the most clearly identifiable disadvantaged group in Australia. However, as discussed earlier, international and Australian studies have suggested that less healthy nutritional intake is strongly related to the ability to afford healthier options.^{194, 196, 198} The aim of this study was to recruit the most disadvantaged families from an economic and nutritional perspective and these were probably the most important criteria determining eligibility. The WIC program is again a useful example; this program provides subsidised healthy foods to any low income families or pregnant women, but with specific programs for Native Americans developed within this larger program. The WIC program also highlights that pregnant women and young children are the target group who have the most to gain from improving nutrition and may be the most likely to adopt healthier behaviours.

The provision of free or very cheap healthy foods is a powerful enticement to participate in food subsidy programs. It is not only those on low incomes who are motivated by price.³⁴⁵ In the Supermarket Healthy Options Project RCT in New Zealand, which included participants across the socio-economic spectrum, the increase in subsidised healthy food purchased was not associated with household income or education.³⁴⁶ The use of the term price discounts rather than food subsidies may influence community perceptions of these programs and align them more with successful marketing strategies.

The upfront cost of food subsidy programs is an important issue that must be addressed when contemplating establishing such a program. If the purpose is to support long-term improvements in people's nutritional intake, then ongoing programs preferably with good linkages to other health and nutrition promotion are more likely to be effective. The WIC literature discussed in the systematic review highlighted the importance of economic evaluation to assess both the costs and benefits of food subsidies. The health care savings attributed to the WIC program, although not entirely robust, are part of the justification for the large amount of public funding invested in the program.

Although the Bulgarr F&V program did not provide robust data suitable for economic evaluation, it did show that families value this intervention. The program fostered a willingness to engage with preventive health activities and nutrition promotion, when it

was offered as an integrated program. This is important given the evidence from the United States that food subsidy programs are not sufficient to support healthy nutrition among low income families given the widespread availability, marketing and low cost of energy-dense, nutrient-poor foods.

8.6 Implications for future research

The limitations of the before and after study design used in this study have already been discussed (see Section 8.3). However, the findings of this study together with the systematic review support the need for more rigorous studies, such as a RCT, to investigate the findings of this study that a fruit and vegetable subsidy for disadvantaged Aboriginal children is associated with improvements in fruit and vegetable intake and short-term health outcomes. In countries such as the United States and the United Kingdom, there are ethical barriers to RCTs of existing food subsidy programs, as they are now components of welfare entitlements. Despite this there is considerable interest and resources devoted to evaluations of food subsidy programs in both the United States³⁴⁷ and the United Kingdom.^{232, 273, 274} The Supermarket Healthy Options Project²⁴⁴ in New Zealand demonstrated the usefulness of RCTs to strengthen the evidence base around price discounts for healthy foods. A 2005 report of housing insulation and respiratory health RCT,³⁴⁸ also in New Zealand, demonstrated the potential use of a RCT to provide strong scientific evidence and provide equitable access to the limited spaces on a program. The controls received housing insulation the following year under that program. In countries considering food subsidy programs as a policy option, a RCT would be useful to clarify whether there are improvements in the nutritional status or other proxy measures of chronic disease risk for low income participants. The most feasible outcomes to measure would be based on nutritional intake or short-term health outcomes.

The sustainability of any dietary changes due to food subsidy programs is also important if the long-term health effects are to be realised. The strongest evidence would be obtained from longitudinal studies which demonstrate that health outcomes are achieved as a result of sustained improvements in nutrition, such as the long-term follow-up studies of some early childhood programs in the USA.³⁴⁹ Ideally the introduction of a new food subsidy program would have an evaluation component to provide information on whether the program is achieving its aims or how it might be

improved to justify ongoing funding. This is more likely if the program evolves as part of a research project initially, such as the ongoing Special Turku Coronary Risk Factor Intervention Project which provides ongoing family nutrition education and monitoring in Finland.³¹⁸

As noted earlier, economic evaluation could use the robust data generated by a RCT together with existing prospective data on chronic disease risk to assess the costs and benefits of food subsidy programs. This would assist in the evaluation and would not depend on long-term health outcome follow-up studies. The cost of such food subsidy programs is another important aspect of the sustainability of such programs. There is an evolving body of research into economic incentives involving both subsidies and taxes to promote better nutrition.^{218, 220, 350, 351} It has been proposed that the acceptability of taxation would be enhanced by directing the revenue into cross-subsidising healthier foods. There is a need for experimental studies to confirm that taxes and subsidies improve nutritional status without having regressive impacts on low-income families given the limited price elasticity of many foods.³⁵⁰

The use of biomarkers as measures of F&V intake has expanded, as it provides an alternative more objective measure to complement dietary self-report in nutrition studies. In adults, large prospective studies and rigorous validation studies have established the relationship between changes in specific biomarkers and changes in F&V intake.^{287, 352} For example, Khaw et al²⁸⁷ have shown that vitamin C > 50µmol/L indicates F&V intake of at least 5 serves/day in adults. Similar data describing the relationship between changes in biomarkers and F&V intake needs to be established in children. This would enhance the usefulness of findings of increased carotenoids, vitamin C or RBC folate in studies involving children. The high levels of RBC folate described in Chapter 5 highlights that the folate-fortification of foods and the use of folate supplements has implications for the role of folate as a biomarker of F&V intake. This issue also needs to be considered for other biomarkers given the increasing use of supplements and further expansion of food-fortification programs. Finally, invasive testing is always more problematic in children. A recent report of resonance Raman spectroscopy to assess skin carotenoids indicates that less invasive alternatives to blood biomarkers may also assist in future dietary intervention studies in children.³⁵³

8.7 Conclusion

As with most research, this thesis has raised as many questions as it has answered. The major findings were that improved nutrition and some associated short-term health benefits were observed among children participating in this F&V subsidy program. The significance of 10-30% increases in biomarkers of F&V intake in children was obscured by the limited changes in self-reported F&V intake. Overall, the evidence from this evaluation and the systematic review indicate the potential benefits of a more controlled study to investigate the long-term health implications of subsidising healthier foods for low income Australian families.

Perhaps one of the most important findings is that this study demonstrated that it is possible to undertake a rigorous evaluation involving blood testing in Aboriginal children provided it is relevant to the local community and Aboriginal health service. This success was dependent on long-term relationships and interconnections between the Aboriginal community-controlled health service staff and the local Aboriginal community. It was also important to maintain a balance between service delivery and the research, given the immediate social and health needs of many families. The challenge of capacity-building research skills in this rural location with limited academic support was significant. As Aboriginal community-based research continues to expand, providing the resources to build local Aboriginal research capacity will improve the relevance and quality of this work.

Finally, the important challenge of this study goes beyond the potential health impacts of food subsidies, to the need for commitment to trial and evaluate new approaches to promote health throughout the community. The costs and benefits of preventive versus curative health strategies have been widely discussed. However, the potential of population-based strategies to have larger impacts on health outcomes than treating those already sick (or at high risk), as first espoused by Geoffrey Rose³⁵⁴, is yet to be fully tested. Any community-wide initiatives are more likely to be implemented effectively and improve health outcomes if they engage and support people to make healthier choices.

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Appendix A. Medline Search Strategy

- 1 exp Food/ (875770)
- 2 exp Health Food/ (1243)
- 3 exp Food Habits/ (15459)
- 4 exp Food Supply/ (5721)
- 5 Legislation, food/ (1648)
- 6 exp Nutrition Policy/ (4321)
- 7 food deprivation/ (6884)
- 8 food.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (295044)
- 9 Food choice.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (617)
- 10 Food Preferences/ (7206)
- 11 Fruit/ (18174)
- 12 Vegetables/ (13268)
- 13 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 (1044707)
- 14 Financing, government/ (16277)
- 15 subsidy.mp. (732)
- 16 incentive*.mp. (15378)
- 17 discount*.mp. (4979)
- 18 price*.mp. (16217)
- 19 Public Assistance/ (2155)
- 20 community health services/ (23648)
- 21 prevent* health service.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (33)
- 22 Financial assistance.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (465)
- 23 financial support/ (2590)
- 24 financial support.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (4238)
- 25 national health programs/ (20485)
- 26 ((policy or policies) adj3 (food* or fruit* or vegetable* or nutritio* or grocer*)).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (5066)
- 27 food program*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (311)
- 28 food supplement*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (1283)
- 29 food subsid*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (38)

- 30 subsidi*ed food*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (7)
- 31 (subsidy adj5 (fruit* or vegetable*)).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (3)
- 32 price discount*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (34)
- 33 (price* adj (discount* or reduction* or limit*)).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (143)
- 34 ((fruit* or vegetable* or grocer*) adj3 cost*).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (55)
- 35 (food box or food basket or vegetable box or vegetable basket).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (57)
- 36 ((voucher* or coupon* or subsid*) adj3 (food* or grocer* or fruit* or vegetable* or nutritio*)).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (145)
- 37 food stamp*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (246)
- 38 WIC.m_titl. (292)
- 39 WIC.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (683)
- 40 supplemental nutrition program*.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (260)
- 41 supplemental nutrition assistance program.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier] (4)
- 42 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 (106673)
- 43 13 and 42 (10912)
- 44 Nutrition Therapy/ (530)
- 45 Nutritional Status/ (17558)
- 46 nutrition.mp. (117016)
- 47 Diet/ec, sn [Economics, Statistics & Numerical Data] (1340)
- 48 "Outcome Assessment (Health Care)"/ (36562)
- 49 treatment outcome/ (429748)
- 50 Birth Weight/ (28590)
- 51 nutritional physiological phenomena/ or exp child nutritional physiological phenomena/ or exp maternal nutritional physiological phenomena/ or nutritional requirements/ or nutritional status/ (95160)
- 52 Health Status/ (45083)
- 53 health status disparities/ (2455)
- 54 "delivery of health care"/ or healthcare disparities/ (54630)

- 55 Healthcare Disparities/ (2573)
- 56 Program Evaluation/ (35513)
- 57 carotenoids/ or beta carotene/ (14735)
- 58 Biological Markers/ (103754)
- 59 plasma nutrient level*.mp. (15)
- 60 Folic Acid/ (17315)
- 61 Ascorbic Acid/ (31173)
- 62 Health Knowledge, Attitudes, Practice/ (50040)
- 63 Health Behavior/ (22984)
- 64 Risk Reduction Behavior/ (3844)
- 65 Healthy People Programs/ (559)
- 66 growth disorders/pc (379)
- 67 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 (997921)
- 68 43 and 67 (6820)
- 69 (Afghanistan or Bangladesh or Benin or Burkina Faso or Burundi or Cambodia or Central African Republic or Chad or Comoros or Congo or Eritrea or Ethiopia or Gambia or Ghana or Guinea-Bissau or Haiti or Kenya or Kyrgyz Republic or Lao or Liberia or Madagascar or Malawi or Mali or Mauritania or Mozambique or Myanmar or Nepal or Niger or Rwanda or Senegal or Sierra Leone or Somalia or Tajikistan or Tanzania or Togo or Uganda or Uzbekistan or Vietnam or Yemen or Zambia or Zimbabwe).ti. (45175)
- 70 (Albania or Angola or Armenia or Azerbaijan or Belize or Bhutan or Bolivia or Cameroon or Cape Verde or China or Cote d'Ivoire or Djibouti or Ecuador or Egypt or El Salvador or Guatemala or Guyana or Honduras or India or Indonesia or Iran or Iraq or Jordan or Kiribati or Kosovo or Lesotho or Maldives or Marshall Islands or Micronesia or Moldova or Mongolia or Morocco or Nicaragua or Nigeria or Pakistan or Papua New Guinea or Paraguay or Philippines or Samoa or Solomon Islands or Sri Lanka or Sudan or Swaziland or Syrian Arab Republic or Thailand or Timor-Leste or Tonga or Tunisia or Turkmenistan or Ukraine or Vanuatu or West Bank or Gaza).ti. (84152)
- 71 (Algeria or American Samoa or Argentina or Belarus or Bosnia or Herzegovina or Botswana or Brazil or Bulgaria or Chile or Colombia or Costa Rica or Cuba or Dominica or Dominican Republic or Fiji or Gabon or Grenada or Jamaica or Kazakhstan or Latvia or Lebanon or Libya or Lithuania or Macedonia or Malaysia or Mauritius or Mayotte or Mexico or Montenegro or Namibia or Palau or Panama or Peru or Poland or Romania or Russia or Serbia or Seychelles or South Africa or St Lucia or Suriname or Turkey or Uruguay or Venezuela).ti. (76532)
- 72 Developing Countries/ (54044)
- 73 69 or 70 or 71 or 72 (246990)
- 74 (America\$ or Andorra or Antigua or Barbuda or Aruba or Australia or Austria or Bahamas or Bahrain or Barbados or Belgium or Bermuda or Brunei Darussalam or Canada or Cayman

Islands or Channel Islands or Croatia or Cyprus or Czech Republic or Denmark or Estonia or Equatorial Guinea or Faeroe Islands or Finland or France or French Polynesia or Germany or Greece or Greenland or Guam or Hong Kong or Hungary or Iceland or Ireland or Isle of Man or Israel or Italy or Japan or Korea or Kuwait or Liechtenstein or Luxembourg or Macao or Malta or Monaco or Netherlands or New Caledonia or New Zealand or Northern Mariana Islands or Norway or Oman or Portugal or Puerto Rico or Qatar or San Marino or Saudi Arabia or Singapore or Slovak\$ or Slovenia or Spain or Sweden or Switzerland or Trinidad or Tobago or United Arab Emirates or United Kingdom or United States or Virgin Islands).ti. (288605)

75 73 not 74 (240615)

76 68 not 75 (6165)

77 randomized controlled trial.pt. (294421)

78 controlled clinical trial.pt. (81916)

79 intervention studies/ (4470)

80 evaluation studies/ (136804)

81 program evaluation/ (35513)

82 random allocation/ or clinical trial/ or single-blind method/ or double-blind method/ or control groups/ (544140)

83 (randomized or randomised or placebo or randomly).ab. (422391)

84 trial.ti. (87049)

85 (time adj series).ab,ti. (9275)

86 quasi-experiment\$.ab,ti. (3212)

87 (pre test or pretest or (posttest or post test)).ab,ti. (10496)

88 "before and after stud\$".ab,ti. (800)

89 controlled before.ab,ti. (376)

90 ((evaluat\$ or intervention or interventional) and (control or controlled or study or program\$ or comparison or "before and after" or comparative)).ab,ti. (981227)

91 ((intervention or interventional) adj5 evaluat\$).ab,ti. (6376)

92 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 (1707559)

93 76 and 92 (1183)

Appendix B Sample Size calculations

Carotenoids

Using 1 sided test to compare difference in average change in carotenoids between baseline and after 12 months on the program¹

Average cluster (family) size=2.6 Intraclass correlation coefficient=0.5

Design effect= $1 + [(w-1)ICC]$

where w=Average cluster size, ICC=Intraclass correlation coefficient

Carotenoid	Mean change (nmol/L)	SD (nmol/L)	Total number of participants required
Lutein/zeaxanthin	19	37	45
Beta-cryptoxanthin	56	40	9
Beta-carotene	62	81	22
Alpha-carotene	24	25	15
Lycopene	30	92	108

Sensitivity analysis

-Varying standard deviation for β -carotene and ICC

$\alpha=0.05$ $\beta=0.8$

s=81

ICC	Sample size required
0	12
0.2	16
0.5	22
0.8	27

s=128

ICC	Sample size required
0	28
0.2	37
0.5	50
0.8	64

24 hour recall

Fruit and vegetable serves

Using 1 sided test to compare difference in average change in fruit and vegetable intake between baseline and after 12 months on the program.¹

Average cluster (family) size=2.6 Intraclass correlation coefficient=0.5

Design effect= $1 + [(w-1)ICC]$

where w=Average cluster size, ICC=Intraclass correlation coefficient

	Baseline/control (Serves/day)	Mean change (Serves/day)	SD (Serves/day)	Total number of participants required
Fruit	0.6	1.0	1.5	29
Vegetables	1.5	1.0	1.6	32

Reference:

1. Lenth, R. V. Java Applets for Power and Sample Size [Computer software]. 2006. Retrieved 10/11/08, from <http://www.stat.uiowa.edu/~rlenth/Power>

Appendix C Dietary Assessment form

Bulgarr Ngaru Fruit and Vegetable Program Dietary Assessment

Interviewer

Name of participant

D.O.B

Date of Interview

Day of Week

When was last fruit and vegetable box picked up? _____ (days/weeks ago)

Delete whichever is not applicable.

Have you received Centrelink payments in the last 7 days? **Yes** **No**
(Ask to parent only)

CHECKLIST FOR 24 HOUR RECALL

INTRODUCTION

Establish rapport and set the scene

Explain what you are going to ask, how long it will take

Explain purpose and importance –

- to help us evaluate and improve the fruit and vegetable program
- to help us understand what you are eating and assist with nutrition advice.

Reinforce importance of accurate account of food

Confidentiality – it's a secret. We will not tell anyone what you say.

No right or wrong answers. We want to know what you eat and no one is going to mind what food that is.

Start with "I would like you to tell me what you had to eat or drink after you woke up yesterday morning"

STEP ONE

Obtain a quick list of food and drink

Obtain a quick list uninterrupted

Ask about commonly forgotten foods and drinks

Remember to ask about forgotten snacks or meals

STEP TWO

Get a detailed description of each food item

What time the food was eaten and eating occasion

Specific types of food, e.g. low fat milk

Specific brands

Amounts if discussed

Main ingredients in mixed dishes

What cooking methods were used, incl added fat

STEP THREE

Get estimates of amounts

Check amounts if already listed

Use graduated portion size aids to help respondents

Record in mls, cups, spoons, number, dimensions

STEP FOUR

Review and check interview data

Read over recall and clarify with child

Ask about any commonly eaten foods that are missing

Short questions about fruit and vegetable intake:

How many serves of vegetables do you USUALLY eat each day? (A 'serve' is a half-cup of cooked vegetables or 1 cup of salad vegetables). This includes all fresh, dried, frozen and tinned vegetables.

- ☐ I don't eat vegetables
- ☐ 1 serve or less
- ☐ 2 serves
- ☐ 3 serves
- ☐ 4 serves
- ☐ 5 serves or more

How many serves of fruit do you USUALLY eat each day? (A 'serve' is 1 medium piece or 2 small pieces of fruit, or a cup of diced pieces). This includes all fresh, dried, frozen, and tinned fruit.

- ☐ I don't eat fruit
- ☐ 1 serve or less
- ☐ 2 serves
- ☐ 3 serves
- ☐ 4 serves or more

The box of fruit and vegetables

How many people usually eat at the house? _____

How many people eat the fruit and vegetables? _____

How many days does the box of fruit and vegetables usually last for?

Appendix D F&V program Health record Audit

ID Number _____ Name _____

DOB _____

Date audit- 1. GP _____ 2. Hospital _____

Date commenced F&V program _____

Health service attendances (12 mths prior to and during program)

Attendance date	Location	1 ⁰ diagnosis	2 ⁰ diagnosis	Sick/well visit*	Treatment

*1= Well visit, 2=Sick visit 1st presentation, 3=Sick visit F/U presentation

Health status 12mths prior to program

Total number sick visits _____ Total number of well visits _____

Episodes URTI _____ LRTI _____ Otitis _____

Media _____ Asthma _____

Scabies _____ Pyoderma _____ Diarrhoeal illness _____

Other _____

Antibiotic prescriptions/dispensed 1. Oral _____

2.Topical _____

Hospital attendances _____

Hospital

admissions _____

Health status during 12mth on program

Total number sick visits _____ Total number of well visits _____

Episodes URTI _____ LRTI _____ Otitis Media _____

Asthma _____

Scabies _____ Pyoderma _____ Diarrhoeal

illness _____ Other _____

Antibiotic prescriptions/dispensed

1. Oral _____

2.Topical _____

Hospital attendances _____

Hospital

admissions _____

Health service attendances (12 mths prior to and during program) Continued

Attendance date	Location	1 ⁰ diagnosis	2 ⁰ diagnosis	Sick/well visit*	Treatment

*1= Well visit, 2=Sick visit 1st presentation, 3=Sick visit F/U presentation

Appendix E Fruit & Vegetable Program - Produce List

Fruit Options (choose a variety based on quality and price)

- Apples
- Bananas
- Mandarins
- Oranges
- Seedless grapes
- Watermelon
- Pears

Vegetable Options (choose a variety based on quality and price)

- Potatoes
- Onions
- Pumpkin
- Carrots
- Lettuce
- Tomatoes
- Cabbage
- Broccoli
- Cauliflower
- Celery
- Corn

Appendix F Focus group themes/questions

- **Why you joined the fruit and vegetable program.**
- **Features of the program which promoted participation.**
- **Suggestions for improvement or recommendations for the program.**
- **What actually happens to the box of fruit and vegetables in each house- who eats what, how long does it last etc?**
- **Is there a need for additional nutrition or cooking education to enhance the program? Who would most like this?**
- **Are there other issues or barriers preventing families from making full use of the fruit and vegetables through this program?**
- **What would the impact of increasing the cost of the fruit and vegetable box/ decreasing the subsidy on participation? How much would you be willing/able to pay for a box?**