Cognitive Impairment in Australia and Latin American and Caribbean Countries

Life Expectancy, Diet and Physical Activity, and the Potential for Prevention

A thesis submitted for the degree
of Doctor of Philosophy of
The Australian National University

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Statement of the Candidate's Contribution to the Research

Except where otherwise indicated, this Thesis is my own work carried out while studying at the Centre for Research on Ageing, Health and Wellbeing, Research School of Population Health, Australian National University.

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May 10, 2016

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I end by dedicating this thesis to the memory of my late grandparents Beryl Elma and Randolph Ashby who have always supported and encouraged me in all of my endeavours.

Publications Arising from this Thesis

I Ashby-Mitchell, K. (2015). The road to reducing dementia onset and prevalence – Are diet and physical activity interventions worth investing in? Deeble Institute issues brief No 10/2015. Deeble Institute for Health Policy Research, Canberra.

II Ashby-Mitchell, K., Jagger, C., Fouweather, T., & Anstey, K. J. (2015). Life Expectancy with and without Cognitive Impairment in Seven Latin American and Caribbean Countries. PLoS ONE, 10(3), e0121867. doi: 10.1371/journal.pone.0121867.

III Ashby-Mitchell, K., Peeters, A., & Anstey, K. J. (2015). Role of Dietary Pattern Analysis in Determining Cognitive Status in Elderly Australian Adults. Nutrients, 7(2), 1052–1067. doi: 10.3390/nu7021052.

IV Ashby-Mitchell, K., Magliano, D., Shaw, J., and Anstey, K.J. (2014). Life Expectancy in Australian Seniors with or without Cognitive Impairment: The Australia Diabetes, Obesity and Lifestyle Study Wave 3. Journal Gerontology and Geriatric Research, 3:166. doi: 10.4172/2167–7182.1000166.

Declaration

I certify that these publications were a direct result of my research towards this PhD, and that reproduction in this thesis does not breach copyright regulations.

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Thesis Abstract

The prevalence of moderate or severe cognitive impairment (CIm) rises steeply with age. It is well documented that our populations (both in developed and low- and middle-income countries) are ageing and that lifestyle factors may hold the key to preserving mental and functional status. This thesis adopts a cross-national approach between Australia and seven Latin American and Caribbean (LAC) countries and focuses on two modifiable lifestyle factors – diet and physical activity.

Two data sets are utilised in this thesis – the Australia Diabetes, Obesity and Lifestyle Study (AusDiab) and the Survey on Health, Well-Being, and Ageing in LAC (SABE). AusDiab represents the largest Australian longitudinal population-based study examining the natural history of diabetes, pre-diabetes, heart disease and kidney disease. Three Waves of data have been collected thus far with cognitive function examined at the most recent Wave only. The SABE is a 7-country survey conducted in LAC in 2000. The SABE represents the only comprehensive health-related data set for persons over the age of 60 in the region that takes into account cognitive status.

Using the Sullivan Method for calculating health expectancies, it was found that in Australia females live longer than males and males spend more time with CIm. In LAC, substantial differences in the absolute years lived and the proportion of remaining life spent free of CIm were observed. Total life expectancy (TLE) and cognitive impairment-free life expectancy (CIFLE) at age 60 years were highest in Brazil and Mexico and lowest in Uruguay and Cuba.

Both *a priori* and *a posteriori* methods were used to examine the relationship between diet, physical activity and cognition. In the first instance, greater adherence to the Mediterranean Diet (MeDi), engagement in physical activity, and television viewing time were not predictive of CIm among older adults in the Australian sample. In the second instance using principal component analysis (PCA), complex patterns of associations between dietary factors and cognition were evident in the Australian sample. The most consistent finding was the protective effects of high vegetable and plant-based food item consumption and negative effects of 'Western' patterns on cognition. Among LAC countries, weekly consumption of milk and cheese, eggs, peas and beans, meat, fish or poultry, and fruits or vegetables were significantly associated with CIm. Regular exercise or participation in vigorous physical activity such as playing a sport, dancing or heavy housework three or more times a week was significantly associated with CIm in Chile, Mexico and Uruguay.

Using a modified population attributable risk formula which accounts for non-independence of risk factors, an estimated 39.0% of dementia cases in Australia

may be attributable to five modifiable risk factors (excess alcohol consumption, midlife obesity, physical inactivity, smoking and low educational attainment). In the LAC region, diabetes mellitus, physical inactivity and smoking were estimated to be attributable to 21.9% of cases in Barbados, 14.7% in Mexico, and 26.2% in Cuba. If each risk factor were to be reduced by 10% and 20% every 10 years to 2050, dementia prevalence could be reduced by up to 24.7% in Australia and up to 16.3% in LAC countries.

This thesis highlights the need for greater investment in research, interventions and policies targeting modifiable lifestyle factors to reduce CIm risk factor prevalence at the population level. In addition, the need for more research in the LAC region (particularly longitudinal studies) is highlighted. Overall, the findings suggest that there is a need for further studies to better understand more nuanced topics, such as the effect of composite dietary patterns on cognitive decline and the nutrition-cognition link in different populations, as there is a general paucity of data sources designed to address these issues.

Contents

List of Figures

List of Tables

List of Abbreviations

AD Alzheimer's disease

ANU Australian National University

APOE Apolipoprotein E

AusDiab The Australian Diabetes, Obesity and Lifestyle Study

BMI Body Mass Index

CI Confidence Interval

CIm Cognitive Impairment

CIFLE Cognitive Impairment-Free Life Expectancy

CILE Cognitively Impaired Life Expectancy

CVLT California Verbal Learning Test

DASH Dietary Approaches to Stop Hypertension

DFLE Dementia-free Life Expectancy

GLM Generalised Linear Model

LAC Latin America and the Caribbean

MCI Mild Cognitive Impairment

MeDi Mediterranean Diet

MMSE Mini Mental State Examination

MUFA Monounsaturated Fatty Acids

OR Odds Ratio

PAR Population Attributable Risk

PCA Principal Component Analysis

RR Relative Risk

SABE Survey on Health, Well-being and Ageing in Latin America and the Caribbean

SD Standard Deviation

SDMT Symbol Digit Modalities Test

SE Standard Error

SFA Saturated Fatty Acids

STW Spot the Word

TBI Traumatic Brain Injury

TLE Total Life Expectancy

TV Television

WHO World Health Organisation

Chapter 1

Overview and Importance of Thesis

1.1 Chapter Summary

Studies have shown that both diet and physical activity exert some influence on cognition (Prince, Albanese, & Guerchet, 2014; Sofi et al., 2011). However, lack of consistency among findings makes it difficult for population-based policies to be developed. It is hoped that this author's work will add to the available literature by quantifying the impact of two modifiable risk factors (diet and physical activity) on disease outcome (cognitive impairment). It is also hoped that this work will provide evidence for policymakers to focus on diet and physical activity in an effort to reduce onset/prevalence rates and costs associated with treatment. Such costs have been shown to be quite a burden for governments (particularly in resource-poor settings) (ADI/BUPA, 2013).

1.2 Thesis Contribution

Promoting health and wellness including the maintenance of physical and mental function in older age are major challenges (Dangour & Uauy, 2006). Indeed, several studies have posited that a dementia epidemic lies ahead if there is no risk reduction at the population level (Anstey et al., 2010; Barnes et al., 2009). Risk reduction is especially important for dementia because there is currently no treatment or cure.

There are several modifiable lifestyle factors that have been implicated in the the development of cognitive impairment (Prince et al., 2014). Among these are diet and exercise. Clarification and consensus of the effect of both of these on cognition is important since there is a need for effective preventative treatment approaches and even a modest protective result can result in significant public health impact.

What makes this author's work novel is its cross-national approach examining developed and low- and middle-income countries. While in the developed country of Australia there is the systematic collection, analysis and reporting of data on countless domains of health and the ageing process, this has not been the experience of low- and middle-income countries like those of Latin America and the Caribbean (LAC). A data search for articles and studies examining the relationship of dietary and physical activity patterns and their relationship with cognitive function in LAC indicated that this thesis will be the first of its kind in the region.

Data for the Australian population were obtained from the Australia Diabetes, Obesity and Lifestyle Study (AusDiab) – the largest Australian longitudinal population-based study examining the natural history of diabetes, pre-diabetes, heart disease and kidney disease. While detailed diet and physical activity data for LAC were not available, a data set that contained some dietary data collected during a seven country survey entitled Survey on Health, Well-Being, and Ageing in Latin America and the Caribbean, 2000 (SABE) was utilised. Though limited in its nutrition and physical activity scope, it represents the only comprehensive health-related data set for persons over the age of 60 in the region that takes into account cognitive status.

A comparison between the Australian and Latin American realities reveals that there needs to be further interest and investment in ageing-related research in low- and middle-income countries. This is essential to assist policymakers, to raise public awareness, and to build support for policy changes (Cloos et al., 2010). It is hoped that this thesis will serve as a foundation for future ageing and health-related research in the LAC region particularly as it relates to the development and execution of comprehensive evidence-based longitudinal studies aimed to collect data on a wide variety of health domains adopting a life-cycle approach.

1.3 Focus of this Thesis

The prevalence of moderate or severe cognitive impairment rises steeply with age (Bruce, Davis, Starkstein, & Davis, 2014; Melzer, Ely, & Brayne, 1997). It is well documented that our populations (both in developed and low- and middle-income countries) are ageing and that lifestyle factors play a role in preserving mental and functional status (Dangour & Uauy, 2006; United Nations Department of Economic and Social Affairs - Population Division, 2013). Projections of epidemiological data show that delaying the onset of the clinical phase of Alzheimer's disease (AD) by just 1 year significantly reduces the prevalence of the disease and a 5-year delay in onset would decrease the prevalence by up to 50% (Brookmeyer & Gray, 2000; Gillette-Guyonnet, Secher, & Vellas, 2013). It is this thinking that underlies the increased interest in modifiable lifestyle factors as a viable approach to preventing/delaying cognitive impairment.

A growing body of evidence suggests that certain dietary components (for example, antioxidant nutrients, fish, mono- and poly-unsaturated fats and B-vitamins) may play a protective role in the risk of age-related cognitive decline (Anstey, Mack, & Cherbuin, 2009; Morris, 2009; Scarmeas, Stern, Mayeux, Manly, et al., 2009) while saturated fats and high midlife serum cholesterol are associated with an increased risk of disease (Anstey, Lipnicki, & Low, 2008). Several areas however require further investigation, for example, the effect of composite dietary patterns on cognitive decline. Additionally, there has also been a lack of consistency in findings leading to difficulty in developing population-based policies and programmes geared toward preventing disease. Nearly all of the data linking nutrition to cognitive impairment comes from observational studies. Results are sometimes conflicting because of methodological issues, heterogeneity of diets and not controlling for all potential confounding variables (Dangour & Uauy, 2006). Criticisms of the few intervention studies have centred on their small sample size and limited time frame (Dangour & Uauy, 2006).

Prevalence of inactivity typically increases with age (World Health Organisation, 2015d) and there has been consistent evidence in the literature of physical inactivity being a risk factor for cognitive impairment (Caspersen, Pereira, & Curran, 2000; Ferencz et al., 2014; Scarmeas, Luchsinger, et al., 2009).

This thesis explores the relationship of both diet and physical activity on CIm. The information presented can be used to inform policies particularly in resource-poor settings.

1.4 Thesis Aims

This thesis comprises 14 chapters. Chapters 2–4 represent a review of the literature as it relates to diet, physical activity and cognitive impairment while Chapters 5–13 present the four main studies of the thesis. Chapter 14 presents final discussions and conclusions.

The aim of study 1 (Chapters 5 and 6) is to conduct a cross-national examination of CIm prevalence and estimate disease burden using the Sullivan Method in Australia and seven LAC countries (Argentina, Barbados, Belize, Chile, Cuba, Mexico and Uruguay).

The aim of study 2 (Chapters 7–9) is to conduct an analysis of diet and physical activity factors that affect cognitive outcome among persons in Australia and LAC by assessing dietary patterns and time spent engaged in physical activity.

The third study (Chapters 10 and 11) aims to determine the population attributable risk of dementia in Australia and LAC for key modifiable lifestyle factors. Further, the effect of reducing the relative prevalence of each risk factor on the future prevalence of dementia is also calculated.

The aim of study 4 (Chapters 12 and 13) is to present issues briefs for policymakers and other stakeholders. In Chapter 12, a health issues brief for Australian stakeholders is presented which examines the literature on diet and physical activity in order to determine whether such interventions are worth investing in. In Chapter 13, a brief summary of the main studies examining the health of older adults in LAC is presented in order to build a case for further investment in research by policymakers in the region.

1.5 Thesis Perspectives

The structural underpinnings of this thesis are based on the following definitions and concepts which must be clarified in order to understand this research in a holistic way:

I ***Cognitive Impairment (CIm)*** – The definition of cognitive impairment supplied by The U.S. Department of Health and Human Services is utilised in this thesis. They define CIm as a condition where a person has trouble remembering, learning new things, concentrating or making decisions that affect their everyday life (U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011). It can be mild or can be severe enough to affect an individual's ability to live independently.

II ***Developed and Low- and Middle - income Countries*** – A low- and middle-income country is a nation with a lower standard of living, underdeveloped industrial base, and low Human Development Index (HDI) relative to other countries (Sullivan & Sheffrin, 2003). For this thesis, the classification of Australia as a developed country and of countries in LAC as low- and middle-income countries was based on the United Nations Statistics Division classification (United Nations Statistics Division, 2013).

III ***Physical Activity vs. Exercise*** – Physical activity refers to any movement produced by skeletal muscles that requires and expends energy (Caspersen, Powell, & Christenson, 1985). Theoretically, there is a difference between physical activity and exercise in that exercise is a subclass of physical activity that is planned, structured and repetitive and usually done to improve fitness – although all exercise is physical activity, all physical activity is not exercise (U.S. Department of Health and Human Services, 2008). This author regards both as being synonymous and does not attempt to highlight the effects of physical activity as being distinct from exercise.

IV ***Use of prevalence and not incidence data*** – While it is useful to identify new cases of disease in any population (i.e. incidence), prevalence data were used in this thesis since SABE only collected data at one time point and the AusDiab only measured cognitive function at the most recent Wave of data collection (Wave 3).

V ***Adoption of a dietary pattern approach versus the use of single nutrients*** – While the single nutrient approach to investigating diet-disease relationships has had some success (for example in identifying that a vitamin C deficiency is linked to scurvy), this approach in examining the relationship between diet and cognitive function has produced largely inconsistent results (Jacobs & Tapsell, 2007). Researchers suggest that this may be the result of the interplay of effects of the food matrix (the composite of naturally occurring food components) on human biological systems and the highly interrelated nature of dietary exposures (Jacobs & Tapsell, 2007; Scarmeas, Stern, Tang, Mayeux, & Luchsinger, 2006). Many researchers argue that examining the relationship between dietary patterns and disease may yield more meaningful results since people do not eat single foods or nutrients but rather combinations of these (Gu & Scarmeas, 2011). In light of the fact that this was a cross-national project it was felt that a dietary pattern approach would be useful due to expectations of greater heterogeneity in diet based on cultural, geographic and income differences.

VI ***Emphasis on those 60 years of age and older*** – The SABE in LAC collected data for persons in the population age 60 and older. For comparison, the same age-range was examined in the AusDiab study.

Chapter 2

Epidemiology of Cognitive Impairment

2.1 Chapter Summary

Cognitive function is influenced by a variety of factors. We are unable to change some of these factors since they are influenced by genetics and age for example, gender and ethnicity. Other factors, however, have to do with the way in which we live our lives and are called modifiable factors. Modifiable factors include smoking behaviours, alcohol consumption, diet and physical activity. The relationship between diet and physical activity will be explored in greater detail in subsequent chapters of this thesis.

2.2 Cognitive Impairment, Dementia, and Alzheimer's disease

The terms CIm, dementia, and AD can be confusing to grasp and many persons may assume that they all denote the same thing. A review of the literature can lead to even more confusion since the terms are often used interchangeably and each study may have its own interpretation. Fundamentally though, there is distinct delineation in their meanings (see Figure 2.1).

The U.S. Department of Health and Human Services describes CIm as a condition where a person has trouble remembering, learning new things, concentrating or making decisions that affect their everyday life. CIm can be mild or can be severe enough to affect an individual's ability to live independently (U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011).

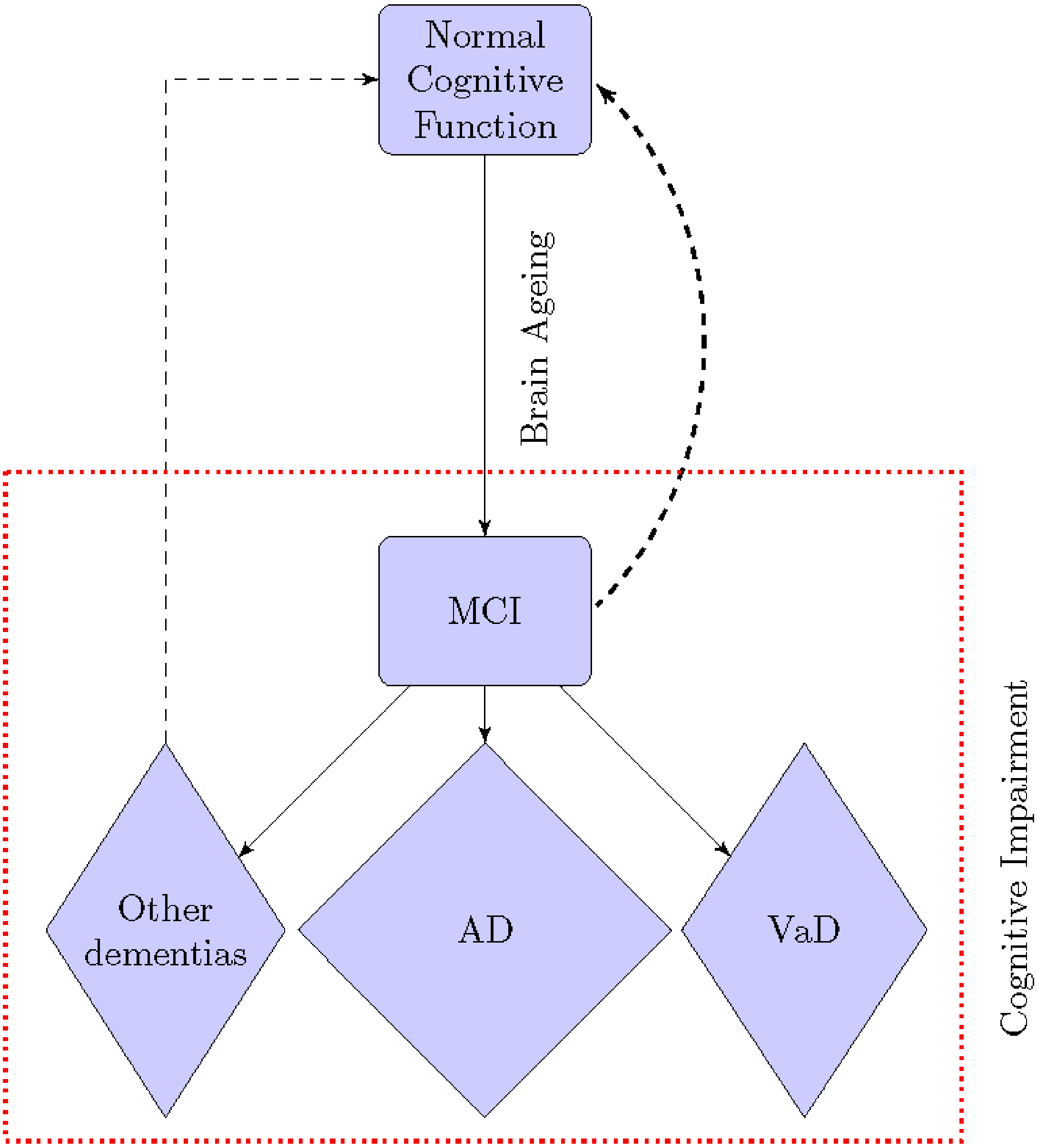
Mild cognitive impairment (MCI) refers to the transitional stage between normal forgetfulness due to age and development of dementia or AD (Scarmeas, Stern, Mayeux, Manly, et al., 2009). Persons with MCI are able to perform usual daily tasks with little difficulty. Symptoms include difficulty multi-tasking and short-term memory losses. Interestingly, not all persons with MCI go on to develop dementia and persons may remain stable without further decline in cognitive abilities for years (The Alzheimers Association, 2014).

Dementia is a generic term used to describe a wide range of progressive neurological disorders associated with impaired memory, behavior, and thinking abilities (Prince et al., 2014). In its most severe form, it can affect an individual's ability to independently conduct activities of daily living. Although dementia is more common in older adults, it is not a normal consequence of ageing (Torpy, Lynm, & Glass, 2010). Symptoms of dementia can include short- and long-term memory loss, personality and behavioural changes, delusions and difficulty coordinating movement. The Diagnostic and Statistical Manual of Mental Disorders (DSM) produced by the American Psychiatric Association and the International Statistical Classification of Diseases and Related Health Problems (ICD) produced by the World Health Organization offer a common language and standard criteria for the classification of mental disorders including neurocognitive disorders. Often used by health professionals, the DSM helps to determine and communicate a patient's diagnosis after evaluation (American Psychological Association, 2009). As the development of the ICD is global, multidisciplinary, and multilingual, it is frequently used by countries to help reduce the disease burden of mental disorders (American Psychological Association, 2009).

AD is the most common cause of dementia. Alzheimer's causes brain changes (abnormal protein deposits and tangled protein fibers) that lead to a steady decline in memory and mental function. The exact cause of AD is unknown but almost all cases of AD start with MCI.

There are other causes of dementia besides AD. Vascular dementia (VaD) for instance is caused when repeated strokes affect blood flow to areas of the brain related to memory and thinking (Torpy et al., 2010). Parkinson's disease and Huntington disease have also been implicated since they can exert effects on brain tissue.

Interestingly, some causes of CIm are related to health issues that may be treatable, for example, medication side effects and vitamin B12 deficiency (U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011). This underscores the need for careful screening, diagnosis and treatment.



⇢ *indicates reversal*
⟶ *indicates progression*

Figure 2.1: Defining cognitive impairment, MCI, dementia and AD.

2.3 Worldwide Incidence and Prevalence Data

At present, over 40 million people worldwide are estimated to have AD with over U$600 billion spent on treatment and management (Alzheimer's Disease International, 2013; World Health Organisation, 2015a). Further, this figure is projected to increase to well over 70 million people by 2030 (Alzheimer's Disease International, 2013). Age is currently the strongest known predictor for cognitive decline. As such, because of the rapid increase in demographical ageing in all world regions, global prevalence of dementia is predicted to double every 20 years to over 80 million people by 2040 (Morris, 2009). It is possible for these estimates to be provided as data from countries is made available and research studies are published. For some countries, there is an overwhelming amount of research being conducted in this area while in others there is a paucity of data. According to the 2015 World Alzheimer Report, good to reasonable dementia prevalence studies were identified in East Asia, Western Europe and the high-income countries in the Asia-Pacific region. Comparatively, there were few studies conducted in Central Europe, Eastern and Southern sub-Saharan Africa and Central Asia (Prince et al., 2015). The report indicates that there has been a notable increase in the number of dementia prevalence studies being conducted in low- and middle-income countries – from 10% in 1998 to 39% in 2009 and 76% from 2005 onwards (Prince et al., 2015). Figure 2.2 shows the dramatic increase in prevalence studies in low- and middle-income countries when compared to their developed counterparts.

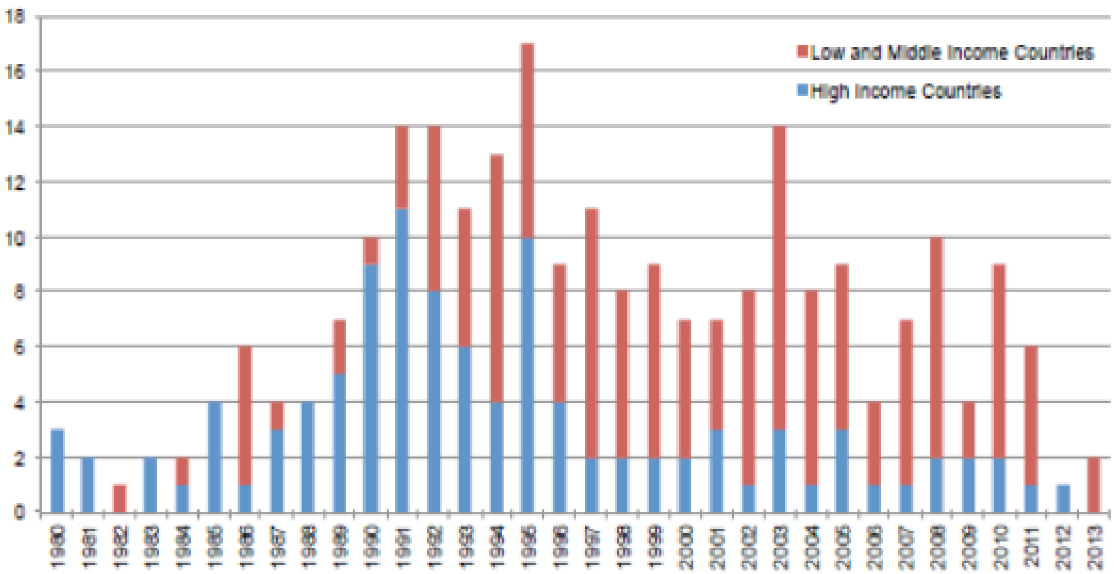


Figure 2.2: Numbers of prevalence studies, by year of data collection and income level of the country where the research was carried out reproduced from Prince et al. (2015).

Using meta-analytical methods, the most recent World Alzheimer Report concluded that in 2015, 58% of all people with dementia lived in low- and middle-income countries and that this figure would increase to 63% in 2030 and 68% in

2050 (see Figure 2.3).

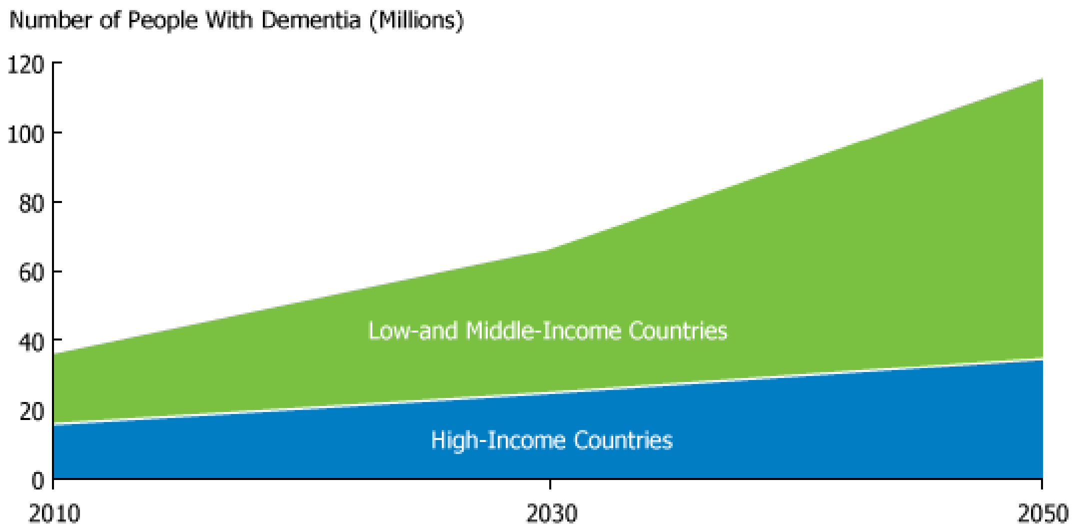


Figure 2.3: Estimated proportions of persons with dementia in high- vs. low-income countries reproduced from Prince et al. (2015).

This prediction is supported by changes in the age structure that have been observed in low- and middle-income countries, most notably, the increase in the over 60 population. This projected increase in those over 60 in low- and middle-income countries is anticipated to be 1.5 times faster than in developed countries leading to an increase in age-related diseases, including CIm (Dangour & Uauy, 2006).

Figure 2.4 shows the estimated prevalence of dementia for those aged 60 and over, standardised to the Western Europe population (Prince et al., 2015). These estimates show that the highest standardised prevalence values are observed in the North African region, Latin America, and the Caribbean. Experts postulate that this would be due to the moderate proportionate increase in dementia prevalence rates in developed countries compared to the rapid increase expected in low- and middle-income countries (Ferri et al., 2005).

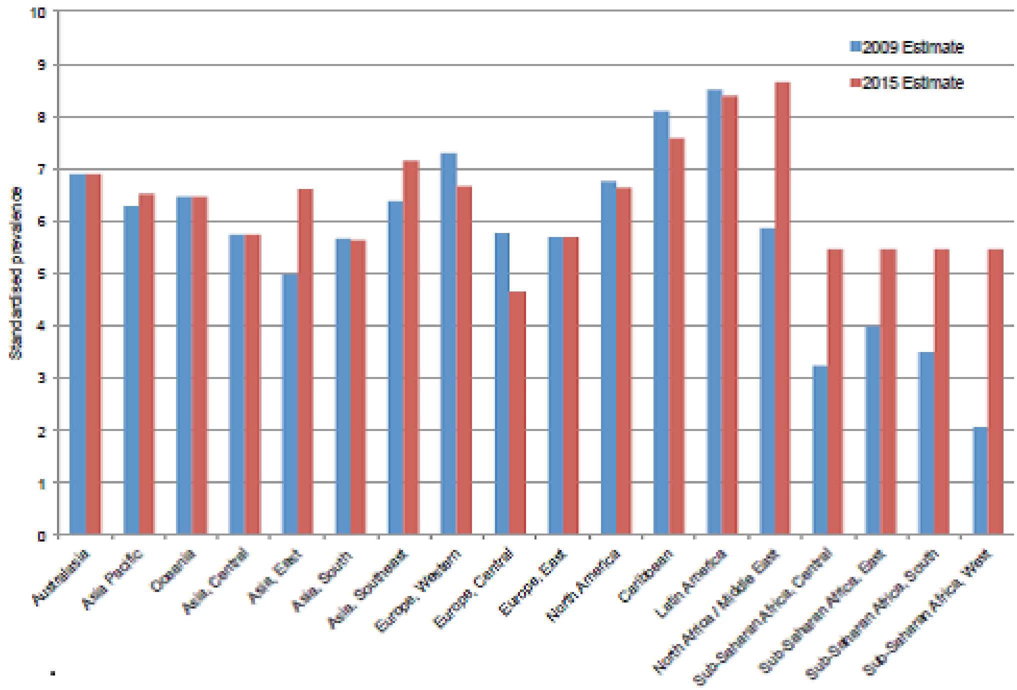


Figure 2.4: Estimated prevalence for those aged 60 and over, standardised to Western Europe population, by region reproduced from Prince et al. (2015).

2.4 Screening and Detection

New diagnostic criteria have been published in the DSM-5. In this revised version, dementia has been renamed 'major neurocognitive disorder' and a less disabling mild neurocognitive disorder (equivalent to MCI) has been recognised (Alzheimer's Australia, 2015a). In order to assist clinicians, a listing of cognitive domains has been provided in establishing the presence of dementia, distinguishing between the major and mild levels of impairment, and differentiating among subtypes (Alzheimer's Australia, 2015a). Diagnosing dementia though can still prove difficult because its symptoms can be due to a number of other possible causes such as medication side effects, metabolic disorders, and infection (Alzheimer's Australia, 2015e).

The Mini Mental State Examination (MMSE) or Folstein Test is the most commonly used method for evaluating cognitive impairment or screening for dementia (Folstein, Folstein, & McHugh, 1975). It is a sum-score evaluating various dimensions of cognition (memory, attention, and language) and used as an index of global cognitive performance. Scores range from 0–30 (Féart et al., 2009). In general, scores of 0–23 indicate probable dementia, 24–26 indicate MCI and over 26 is considered normal (Anstey et al., 2010). A low score is not always indicative of dementia but may highlight impaired mental ability as a result of another factor, for example, hearing difficulty which makes taking the test a challenge or lower educational levels. The MMSE test can be affected by level of education – some persons may find the questions quite easy or difficult depending on their education level (Matthews, Jagger, Miller, & Brayne, 2009). Cultural background and language fluency may also influence an individual's test score (Mungas, Marshall, Weldon, Haan, & Reed, 1996).

A list of some tests highlighted in the literature is presented below. These tests are often combined with each other in order to confirm dementia diagnosis.

- The Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE): This self-completion questionnaire consists of 26 items covering two aspects of memory – acquisition of new information and retrieval of existing knowledge. Each item is rated on a 5-point scale with 1 representing "much better" and 5 representing "much worse". Scoring involves summing the items and dividing by 26 to give a score from 1 to 5. A score of 3 means that the subject is rated on average as 'no change'. A score of 4 means an average of 'a bit worse'. A score of 5 an average of 'much worse' (Jorm & Jolley, 1998).

- Seven Minute Screen: Consists of four cognitive tests that are able to be administered quickly – Benton temporal orientation, Enhanced cued recall, Clock drawing and Verbal fluency (Koning et al., 2004).

- Abbreviated Mental Test: A 10-item test that asks questions such as 'How old are you?', 'What was the date of your birth?', 'Who is the present prime minister?' and asks the respondent to recognise two relevant persons, for example family members or a nurse/doctor. The maximum score is 10 points; a score of less than 8 is suggestive of CIm (Hodkinson, 1972).

- Bowles-Langley Test/Ashford Memory test: Designed to test both short- and long-term memory, and is conducted online. The test consists of a series of pictures of everyday items. A respondent is shown a series of pictures and asked to press the spacebar if an object that he has been shown before appears. Respondents are graded on accuracy and time (Ashford, 2005).

- Memory Impairment Screen: Respondents are provided with the names of items in four different categories (animal, city, vegetable, and musical instrument). After a short delay, respondents are asked to recall the name of the item in each category (Buschke et al., 1999).

- Memory Orientation Screening Test (MOST): Tests memory of three words, orientation to temporal changes, sequential memory of 12 common household objects and uses a pre-drawn clock outline to assess organisation and abstraction (Clionsky & Clionsky, 2014).

- Mental Alternation Test: This test uses an alternating pattern of numbers and letters, for example, '1A, 2B, 3C' and respondents are given 30 seconds to list as many correct alternations as possible. The maximum score is 52 (Jones, Teng, Folstein, & Harrison, 1993).

- Short and Sweet Screening Instrument: Consists of three standard cognitive tests that are able to asses various cognitive domains including memory, language, attention and visio-spatial (Belle, Mendelsohn, Seaberg, & Ratcliff, 2000).

- Short Test of Mental Status: Assesses orientation, attention, recall, calculation, abstraction, clock drawing, and copying. The maximum score is 38 and a score of 29 or lower indicates cognitive impairment (Kokmen, Nsessens, & Offord, n.d.).

- The 6-Item Cognitive Test: Respondents are asked to recall six items including the current year, current month, an address phrase and to say the months of the year in reverse. The test uses an inverse score and questions asked are weighted to produce a total out of 28. Scores of 0-7 are considered normal (Brooke & Bullock, 1999).

- The General Practitioner Assessment of Cognition: Involves a time orientation task, measurement of visio-spatial function, awareness of current events and a recall task. An informant questionnaire which asks the informant to compare the patients current state with 'a few years ago' is also incorporated (Brodaty et al., 2002).

- The Rowland Universal Dementia Assessment: Aimed to minimise the effects of cultural and language diversity on assessment of cognitive status. Respondents engage in a variety of tasks including a delayed recall, awareness of body orientation, ability to copy actions/exercises and language fluency task (Storey, Rowland, Conforti, & Dickson, 2004).

- Cambridge Cognitive Examination: Forms part of the Cambridge Examination of Mental Disorders of the Elderly (CAMDEX) and measures various domains of cognition including orientation, language, memory, abstract thinking and perception. The maximum obtainable total score is 107, and a cut-off value of 80 is recommended to distinguish between individuals with dementia and normal subjects (Lolk, Nielsen, Andersen, Andersen, & Kragh-Sørensen, 2000).

2.5 Dementia Risk Indices

Research has highlighted that as worldwide occurrence of dementia rises and extensive efforts for the prevention of dementia are needed, identification of individuals at increased risk of dementia would allow more efficient targeting of available preventive measures than currently possible (Kivipelto et al., 2006). The use of dementia risk indices can be used to predict an individual's future risk of developing dementia.

Risk indices are tools that combine information regarding the known (or hypothesised) risk factors for a particular outcome to produce risk estimates for individuals. The goal of a risk index is to determine which combination of factors is most predictive of future risk (Barnes & Yaffe, 2009).

Risk indices have been in use for decades for example, the Framingham Risk Score and Breast Cancer Risk Assessment Tool used to predict risk of experiencing a major coronary event within 10 years and risk of developing breast cancer within 5 years respectively. Risk indices that have been developed to determine dementia risk include:

I ***ANU-AD Risk Index (ANU-ADRI)*** – Developed at the Australian National University (ANU), the ANU-ADRI was developed to assess risk of AD based on self-reported measures of risk factors. This index comprises a questionnaire of approximately 150 items that assess a range of medical, health and lifestyle factors that have been linked to increased risk of AD in cohort studies – age, education, body mass index (BMI), diabetes, depression, high cholesterol, traumatic brain injury, smoking, alcohol intake, social engagement, physical activity, cognitive activity, fish intake and exposure to occupational pesticides (Anstey, Cherbuin, & Herath, 2013).

II ***Mid-Life Dementia Risk Score*** – Developed in Finland for those 40–64 years, the tool is used to predict risk of dementia 20 years later. Based on the theory that dementia shares many risk factors with cardiovascular diseases, this index was derived after analysis of data from the Cardiovascular Risk Factors, Ageing, and Dementia (CAIDE) study. It assigns a score based on a person's age, gender, education, physical activity and history of obesity, hypertension and hypercholesterolemia (Kivipelto et al., 2006).

III ***Late-life Dementia Risk Index*** – Developed to be a 'gold-standard' for predicting dementia risk in later life, it includes several measures that may be costly and time-consuming to obtain, for example, MRI, carotid artery ultrasound and APOE genotype that can accurately stratify older adults into those with a low, moderate, or high risk of developing dementia within 6 years (Barnes & Yaffe, 2009).

2.6 Aetiology

Diseases that affect cognitive ability have no single cause. Several factors affect their development and progression. Research has shown that the effects of some of these factors can be reduced since they are associated with the way in which we live our lives, for example, smoking habits, alcohol consumption, diet and physical activity – these factors are said to be modifiable (Anstey et al., 2009; Morris, 2009; Scarmeas, Stern, Mayeux, Manly, et al., 2009). Other factors cannot be changed since they are embedded in our DNA or are linked to chronological age. These factors are said to be non-modifiable.

2.6.1 Non-modifiable Risk Factors

I ***Age*** **–** Age is well established as the most important risk factor for dementia (Barnes et al., 2009; Dangour & Uauy, 2006). In a meta-analysis of nine epidemiological studies of senile dementia that included samples of elderly people over age 80, it was found that senile dementia is better conceptualised as an "age-related" disorder (i.e. occurring within a specific age range) rather than as an "ageing-related" disorder (i.e. caused by the ageing process itself) (Ritchie & Kildea, 1995). These findings have been supported by other works. For example, a meta-analysis of the age-specific incidence of all dementias, including AD and vascular dementia found that the incidence of dementia rises exponentially to the age of 90 years (Jorm & Jolley, 1998).

II ***Genetics*** **–** Apolipoprotein E (apoE) is the most important genetic determinant of non-familial, late-onset AD at present (Prince et al., 2014). ApoE has three forms but research shows that individuals carrying the e4 allele are at increased risk of AD compared with those carrying the more common e3 allele, whereas the e2 allele decreases risk (Liu, Kanekiyo, Xu, & Bu, 2013).

III ***Traumatic Brain Injury (TBI)*** **–** Research indicates that TBI in early to midlife is associated with an increased risk of dementia in late life, in the range of 2- to 4-fold compared with the general population and reduced time to onset of AD among persons at risk of developing the disease (Draper & Ponsford, 2008; Nemetz et al., 1999; Shively, Scher, Perl, & Diaz-Arrastia, 2012; Wang, Xu, & Pei, 2012).

IV ***Gender*** **–** Studies suggest an increased risk for AD in women (even when longevity is controlled for). It is important however to consider various confounding factors while examining this relationship, for example, the effect of sex hormones, ethnicity and lifestyle. In a sample of 472 post-or perimenopausal women followed for up to 16 years it was found that the relative risk for AD in estrogen replacement therapy users as compared with nonusers was 0.46 (95% CI, 0.209-0.997), indicating a reduced risk of AD for women who had reported the use of estrogen (Kawas et al., 1997). Results though have not been consistent. A later study conducted by Mulnard et al. (2000) failed to support the findings of Kawas et al. (1997) reporting instead that there was no improvement in cognition or disease progression after estrogen replacement therapy for 1 year in women with mild to moderate AD.

2.6.2 Modifiable Risk Factors

I ***Smoking*** – In a study examining the association between smoking history and cognitive decline over a 10-year peiod, smokers experienced faster declines in global cognition (OR -0.09; 95% CI: -0.15, -0.03) and executive function (OR -0.11; 95% CI: -0.17, -0.05) when compared with never smokers (Sabia, Elbaz, Dugravot, & et al., 2012). These results have been supported by other longitudinal studies. In a study by Anstey, von Sanden, Salim, and O'Kearney (2007), the authors assessed the association of smoking with dementia and cognitive decline in a meta-analysis of 19 prospective studies with at least 12 months follow-up. The authors concluded that when compared with people who have never smoked, current smokers have an increased risk of dementia and cognitive decline ranging from 40% to 80% depending on the outcome examined.

II ***Alcohol Consumption*** **–** In a meta-analysis of 15 prospective studies, Anstey et al. (2009) examined the relationship between alcohol consumption and dementia and cognitive decline. Results suggest that light to moderate alcohol consumption in older adults is associated with reduced risk of dementia. This seeming 'J' or 'U' shaped relationship has been highlighted in case-control studies. A study of 373 cases with incident dementia and 373 controls of adults 65 years and older who participated in the Cardiovascular Health Study in four U.S. communities revealed that compared with abstention, consumption of 1 to 6 drinks weekly is associated with a lower risk of incident dementia among older adults (Mukamal et al., 2003). Associations between "former drinkers" and risk of CIm remains unclear in the literature though since it is possible that they may have stopped drinking for reasons such as health issues that also predispose to CIm (Daviglus et al., 2011). This highlights the difficulty in developing public health messages concerning alcohol consumption which unlike smoking which has no benefits, has been shown to have beneficial effects in moderation (Anstey et al., 2009).

III ***Body Mass Index (BMI)*** **–** In a meta-analysis of 16 articles reporting on

15 prospective studies it was reported that in midlife, underweight BMI, overweight BMI and obese BMI were all associated with increased risk of dementia compared with normal BMI (Anstey, Cherbuin, Budge, & Young, 2011). They suggest a U-shaped relationship between midlife BMI and dementia risk.

IV ***Diet*** – A review of the literature shows that studies examining the relationship between nutrients and dietary patterns on cognitive function have increased within the last decade. There has been much research on the role of dietary fats (Engelhart et al., 2002; Kalmijn et al., 1997), omega-3 fatty acids (Lauritzen, Hansen, Jørgensen, & Michaelsen, 2001; Morris, Evans, Bienias, Tangney, Bennett, Aggarwal, Schneider, & Wilson, 2003), antioxidants (Engelhart et al., 2002; Morris et al., 2002) and dietary supplements (Laurin, Foley, Kh, White, & Launer, 2002; Zandi et al., 2004) on cognitive function. The discourse into whether single nutrients versus dietary patterns should be studied has also continued. A critical review of the impact of diet on CIm will be provided in Chapter 3 of this thesis.

V ***Physical Activity*** – Studies suggest that more physical activity is associated with a reduction in risk for developing AD (Larson et al., 2006; Scarmeas, Luchsinger, et al., 2009). The role of physical activity in CIm will be examined in detail in Chapter 4 of this thesis.

VI ***Education Level*** – Years of formal education (higher educational level) has been put forward as a risk factor for AD development (Bennett et al., 2003; Matthews et al., 2009; Stern et al., 1994). Stern et al. (1994), set out to determine whether limited educational level and occupational attainment are risk factors for incident dementia. In their study, a total of 593 non-demented individuals aged 60 years or older in Manhattan, New York were identified and followed up over a period of 1–4 years. The data suggest that increased educational and occupational attainment may reduce the risk of incident AD, either by decreasing ease of clinical detection of AD or by imparting a reserve that delays the onset of clinical manifestations (Stern et al., 1994).

There is a need for further research in this area since the relationship between educational level and cognitive function can be quite complex – educational level may influence a subject's likelihood of participating in epidemiologic studies, responding correctly during testing and may also affect health care usage.

VII ***Socioeconomic Status (SES)*** – SES has been associated with CIm risk. In the Interdisciplinary Longitudinal Study on Adult Development and Aging, 381 subjects were followed after a 12-year period to determine the effect of socio-economic status on the development of MCI and AD. High socio-economic status was found to independently reduce the risk of MCI and AD (Sattler, Toro, Schonknecht, & Schroder, 2012). The effect of SES status on dementia rates between black and white older persons has also been examined with findings suggesting that SES may contribute to the higher rates of dementia seen among black people compared with white older people (Yaffe et al., 2013). The link between SES and CIm has also been examined using education as a proxy since education is an indicator of SES. The effect of education on CIm has been highlighted above.

VIII ***Lung Function*** – Research has highlighted that impaired lung function is associated with increased risk of CIm (Albert et al., 1995). In a study of 904 adults (47 – 70 years) enrolled in the Artherosclerosis Risk in Communities Study, dementia risk was higher among individuals with an obstructive ventilatory pattern (HR 1.6, 95% CI 1.0 – 2.6). Researchers highlight though that significant associations between lung function and CIm may exist because risk factors that are known to increase the risk of CIm, for example, smoking and hypertension, are often common in those with respiratory limitations (Dodd, 2015).

IX ***Childhood IQ*** – Socioeconomic status, educational level and IQ are closely intertwined. In a study based on the 1932 Scottish Mental Survey, the links between childhood mental ability and dementia were examined. Late-onset dementia was found to be associated with lower mental ability scores in childhood (Whalley et al., 2000). This link between childhood IQ and CIm has been linked to inequalities in socioeconomic circumstances which affect overall health and development and the concept of 'cognitive reserve' where aspects of brain structures and functions can buffer the effects of CIm in later life.

2.7 Chapter Conclusion

The occurrence of CIm is rising substantially worldwide. As no curative treatment exists, extensive prevention efforts are needed. The projected faster rate of increase in low- and middle-income countries compared to developed countries is cause for concern and highlights the need for effective risk reduction strategies to be developed in tandem with early screening and detection.

Chapter 3

Diet and Cognitive Impairment

3.1 Chapter Summary

Studies aimed to elucidate the association between diet and CIm have utilised both the single nutrient and dietary pattern approaches. Traditionally, single nutrient approaches have been useful in identifying particular nutrients/food items that predispose an individual to risk of disease, for example, Vitamin C and scurvy, and folic acid and neural tube defects. Proponents of the dietary pattern approach argue that food items engage in a dynamic interplay with each other making it nearly impossible to implicate particular nutrients in diet-disease relationships and not others. Evidence on the effect of dietary lipids, B-vitamins, antioxidants, fish, alcohol, vegetables, and legumes have all produced varying results in relation to cognitive function. Further research is needed that looks at biomarkers for particular nutrients and cognitive endpoints in order for any definitive population-based conclusions to be made. Diets low in saturated fat, high in legumes, fruits and vegetables, moderate in ethanol intake, and low in meat and dairy have also been highlighted as being beneficial to neurological function. One of the most studied dietary patterns is the Mediterranean Diet (MeDi) which describes a diet rich in cereals, olive oil, fish, fruits and vegetables and low in dairy and meat with a moderate consumption of red wine. This diet has been linked to increased survival, reduced risk of cancers, cardiovascular disease and CIm, and increased longevity. (Martinez-Lapiscina et al., 2013; Scarmeas et al., 2006; Sofi, Cesari, Abbate, Gensini, & Casini, 2008).

It is important to consider that there may be other dietary patterns, yet to be identified, that may have similar benefits and that can be applied to various sociocultural and demographic settings. The use of *a posteriori* methods which do not take into consideration prior scientific evidence of dietary patterns can detect possible beneficial patterns. Cluster analysis, principal component analysis and reduced rank regression are the most frequently referred to *a posteriori* methods in the literature. Promotion of these methodologies must be encouraged in nutritional epidemiology research so that cross-national comparisons can be conducted which could bring about further understanding of the nutrition-disease link in different populations.

3.2 Introduction

Preservation of cognitive abilities is central to the maintenance of independence and quality of life among older adults (Shatenstein et al., 2012). As with any other organ, the brain needs nutrients to build and maintain its structure, both to function harmoniously and to be protected from diseases or premature ageing (Wärnberg, Gomez-Martinez, Romeo, Díaz, & Marcos, 2009). The potential role of dietary factors on CIm has become topical and has opened up many interesting perspectives particularly about whether it is best to look at single nutrients and/or food items or dietary patterns as a whole.

3.3 The Effect of Individual Nutrients and Food Items on Cognitive Function

The single nutrient approach to investigating diet-disease relationships has been useful in addressing various public health problems for centuries (Willett, 1998). The discovery of the link between Vitamin C and scurvy and folate in the prevention of neural tube defects illustrate the study of single nutrients and their relationship to health (Jacobs & Steffen, 2003). In like manner, this approach has been utilised in the study of diet and cognitive function. Results though have largely been inconsistent. Possible reasons for inconsistencies among studies include short follow-up times, and lack of sufficient trials able to replicate cross-sectional study findings (Prince et al., 2014). Yet another plausible reason for these inconsistencies may be the interplay of effects of the food matrix (the composite of naturally occurring food components) on human biological systems and the highly interrelated nature of dietary exposures (Jacobs & Tapsell, 2007; Willett, 1998). For example, while some studies have shown that higher intake of antioxidant nutrients such as vitamin C, vitamin E, and flavonoids have been related to a lower risk for AD or slower cognitive decline, other studies have found that the risk for AD is not associated with intake of antioxidants, making it difficult for any clear conclusions to be derived (Scarmeas et al., 2006). Willett (1998) suggests that due to the complexities involved in dietary analysis, an approach that utlises both singluar nutrients and foods is optimum. Evidence pertaining to some key food and nutrient components is presented below:

I ***Dietary Lipids***: Studies have predominantly centred on the mono- and poly-unsaturated fat to saturated fat ratio and suggest that higher ratios of saturated fat to mono and polyunsaturated fats are predictive of negative cognitive outcome. It is this thinking that is touted by proponents of the MeDi that is traditionally rich in olive oil (a good source of monounsaturated fat). More specifically, higher saturated fat intake has been consistently associated with higher rates of cognitive decline and worse trajectory in global cognitive function and verbal memory while increased intake of monounsaturated fats has been linked to decreased rates of cognitive decline (Naqvi et al., 2011; Okereke et al., 2012; Vercambre, Grodstein, & Kang, 2010). In a study by Naqvi et al. (2011), greater mono-unsaturated fatty acid intake was associated with mean cognitive deline (standard error) of 0.21 (0.05) in the lowest and 0.05 (0.05) in the highest quartiles. This effect was observed mainly in the visual and memory domains. Okereke et al. (2012) also found that there was a higher risk of worse cognitive change comparing highest vs. lowest saturated fat quintiles. The multivariate-adjusted odds ratio was 1.64 (95% CI: 1.04 – 2.58) for global cognition and 1.65 (95% CI: 1.04 – 2.61) for verbal memory.

The association of cholesterol and AD has also been studied since the most important genetic risk factor for AD is the APOE-e4 allele, the protein product of which is the principal cholesterol transport in the brain (Morris, 2009). There is evidence that elevated mid-life serum total cholesterol levels are associated with increased risk of AD in old age (Morris, 2009).

II ***B-vitamins:*** The evidence implicating Vitamin B and cognitive function has been mixed and is thought to be related to homocysteine. This is so because low levels of B-vitamins have been associated with increased homocysteine levels and have been observed in the cognitively impaired in several large population-based studies (Nelson, Wengreen, Munger, Corcoran, & Investigators, 2009; Tucker, Qiao, Scott, Rosenberg, & Spiro, 2005). Additionally, deficiencies of some micronutrients (especially B1, B2, B6 and B12) commonly described in older ages have been found to be significantly associated with CIm (Solfrizzi, Panza, et al., 2011). However, there has been great inconsistency between the findings of randomised controlled trials and prospective cohort studies. For example, several randomised controlled trials examining the effect of B-vitamin supplementation have shown that while this may lower homocysteine levels it does not result in slower cognitive decline or improvement in cognition (Hankey et al., 2013; Jager, Oulhaj, Jacoby, Refsum, & Smith, 2012; Kwok et al., 2011). In contrast, a study conducted by Luchsinger, Tang, Miller, Green, and Mayeux (2007) among 965 persons 65 years and older examining effects of folate on prevention of AD revealed that low intake of folate was associated with increased risk of AD. The highest quartile of total folate intake was related to a lower risk of AD (HR 0.5; 95% CI: 0.3 – 0.9; $p = 0.02$). Such inconsistent findings suggest that further studies are needed that examine the relationship between dietary intakes of B-vitamins, biomarkers of B-vitamin status and cognitive endpoints (Nelson et al., 2009).

III ***Antioxidants:*** There is evidence that oxidative stress and inflammation can lead to AD because of an increase in free radicals and the damage they cause to neuronal cells. Antioxidant nutrients (vitamin C, vitamin E, carotenoids, flavonoids), found in many fruits and berries are thought to hold the key to mediating this mechanism since they can hinder the effects of dangerous free radicals. Growing evidence also implicates oxidative damage in the pathogenesis of AD, with neurons at risk for AD degeneration having increased lipid peroxidation, nitration, free carbonyls, and nucleic acid oxidation (Wärnberg et al., 2009).

New research has also emerged on the association between natural antioxidants such as gingko biloba and cognitive function; however, there is no conclusive evidence that it has predictable and clinically significant benefit for people with CIm or dementia (Gillette-Guyonnet et al., 2013).

IV ***Fish (Docosahexaenoic acid, Omega-3 Polyunsaturated Fatty Acids):*** Fatty acids are thought to be linked to cognitive function through atherosclerosis, thrombosis or inflammation via an effect on brain development and membrane functioning or via accumulation of β-amyloid (Gu, Nieves, Stern, Luchsinger, & Scarmeas, 2010). The beneficial effect of poly-unsaturated fatty acids on human health has been well established (Wärnberg et al., 2009) however their precise association with cognitive function remains a hotly-studied area. Polyunsaturated fats comprise two major classes, the n-6 class (for example, linoleic acid and arachidonic acid) and the n-3 class [for example, β-linolenic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)] (Gillette-Guyonnet et al., 2013). Fish is one of the best sources of the n-3 class of polyunsaturated fatty acids.

In a study of 6,150 Chicago residents aged 65 and older aimed to examine whether intakes of fish and the omega-3 fatty acids protect against age-related cognitive decline, it was reported that fish consumption may be associated with slower cognitive decline with age (Morris, Evans, Bienias, Tangney, Bennett, Wilson, et al., 2003). Participants who consumed fish once per week or more had 60% less risk of AD compared with those who rarely or never ate fish (RR 0.4; 95% CI: 0.2 – 0.9).These findings echo those of an earlier study by Kalmijn et al. (1997) which found statistically significant decreased risks of AD with higher fish consumption (RR 0.4; 95% CI: 0.1 – 0.9). Conversely, Cherbuin and Anstey (2012) reported that in a prospective study involving 1,528 subjects, higher fish consumption was associated with an increased risk of cognitive disorder (OR 1.47; 95% CI: 1.11 – 1.95). This the authors asserted may have reflected the influence of cooking styles and type of fish consumed which may modulate the benefits of fish consumption.

The relationship between omega-3 fatty acids and cognition also has achieved mixed results. For example, Morris, Evans, Tangney, Bienias, and Wilson (2005) reported that in their Chicago based study there was little evidence that the omega-3 polyunsaturated fatty acids were associated with cognitive change. However, this was in contrast to their findings in a previous study making it difficult for any hard and fast conclusions to be drawn.

V ***Vegetables & Legumes:*** Diets rich in vegetables and legumes have been associated with better cognitive outcome in the literature. Chen, Huang, and Cheng (2012), in a study of 6,911 illiterate Chinese subjects, aged 65 and older who formed part of the Chinese Longitudinal Health Longevity Study, reported that lower intakes of vegetables and legumes were associated with cognitive decline when using MMSE as a measure of cognitive function. Multivariate logistic regression showed that always eating vegetables and always consuming legumes were inversely associated with cognitive decline (OR 0.66; 95% CI: 0.58 – 0.75 and OR 0.78; 95% CI: 0.64 – 0.96, respectively) (Chen et al., 2012). This association may be the result of the high concentration of antioxidant nutrients present in vegetables and fruits and their role in suppressing inflammation. This finding was also supported by a study of 2,148 community-based elderly subjects without dementia in New York which indicated that higher intakes of cruciferous and dark and green leafy vegetables may be associated with a decreased risk of developing AD (Gu et al., 2010).

VI ***Alcohol:*** As discussed in Chapter 2, there has been much work focused on the relationship between alcohol and cognitive function with most studies yielding inconsistent results. Results suggest though that moderate alcohol consumption is associated with reduced dementia risk and that abstainers have about a two-fold increase in odds of dementia when compared with moderate drinkers (Mukamal et al., 2003). These findings point to the unique relationship between alcohol and health outcome that is seemingly "J" or "U" shaped (Anstey et al., 2009). Anstey et al. (2009) in their meta-analysis (conducted on samples including 14,646 participants evaluated for AD, 10,225 for VaD and 11,875 followed for any dementia) pointed to the need to synthesise available data on alcohol consumption and cognitive function. Their findings support that of Mukamal et al. (2003) who concluded that moderate alcohol intake was associated with reduction in risk of AD and other dementias when compared with alcohol abstinence (Anstey et al., 2009). The pooled relative risks of AD, VaD and Any dementia for light to moderate drinkers compared with non-drinkers were 0.72 (95% CI = 0.61–

0.86), 0.75 (95% CI = 0.57–0.98), and 0.74 (95% CI = 0.61–0.91), respectively. When the more generally classified "drinkers", were compared with "non-drinkers", they had a reduced risk of AD (RR=0.66, 95% CI = 0.47–0.94) and Any dementia (RR=0.53, 95% CI = 0.53–0.82) but not cognitive decline (Anstey et al., 2009). Additionally, heavy drinking was also reportedly not associated with increased risk of dementia possibly due to the fact that heavy drinkers are less likely to participate in such studies or due to survival effects (Anstey et al., 2009). Associations between "former drinkers" and risk of CIm remains unclear in the literature though since it is possible that they may have stopped drinking for reasons such as health issues that also predispose to CIm (Daviglus et al., 2011).

VII ***Caloric Intake:*** There has been some interest in the relationship between caloric restriction and neurodegenerative disorders though data from randomised control trials are limited. Hypotheses linking caloric restriction to cognitive ability include increase in insulin sensitivity, anti-inflammatory mechanisms, reduction of neural oxidative stress, promotion of synaptic plasticity, and induction of various stress and neurotrophic/neuro-protective factors (Gillette-Guyonnet et al., 2013). In the GALERIE study, 48 participants were randomised into four groups in order to examine the effect of caloric restriction on cognitive function. Results however indicated that there was no association between daily energy restriction and cognitive test performance (Gillette-Guyonnet et al., 2013). Another study, the ENCORE study aimed to examine exercise and nutrition interventions for cardiovascular health. The researchers randomised participants (n=124) into three groups – DASH diet alone, DASH combined with a behavioural weight management programme including exercise and caloric restriction or a usual diet group. It was reported that participants on the DASH diet combined with a behavioural weight management programme exhibited greater improvements in executive function-memory learning (p=0.008) and psychomotor speed (p=0.023) when compared with the usual diet control (Gillette-Guyonnet et al., 2013). More recently, in an Australian prospective study, it was reported that energy intake was associated with greater risk of CIm with the effect being even more potent for a measure of excessive caloric intake. This effect was strongest for MCI but consistent trends were also present for the more general clinical categories (Cherbuin & Anstey, 2012). However, because the long-term effect of caloric restriction in older age groups is unknown, precautions should be taken before recommending this management route (Gillette-Guyonnet et al., 2013).

3.4 Examination of the Effect of Dietary Patterns on Cognitive Function

Traditionally, studies examining diet-disease relationships took into account the effect of single nutrients. However, many researchers now argue that dietary patterns reflect better every day dietary habits and capture the diet's multidimensionality because they can integrate complex or subtle interactive effects of many dietary constituents and bypass problems generated by multiple testing and the high correlations that may exist among these constituents (Scarmeas, Stern, Mayeux, Manly, et al., 2009). In summary, people do not eat single nutrients/foods but rather combinations of both. As such, health outcomes can only be predicted when the diet is examined as a whole.

A dietary pattern approach is useful in monitoring and surveillance to assess compliance with dietary guidelines and also to investigate exposure-disease relationships (McNaughton, Ball, Crawford, & Mishra, 2008). Two methodological approaches have been used in order to determine dietary patterns among study populations: (1) *a priori* and (2) *a posteriori*.

3.4.1 *A Priori* Approach to Defining Dietary Patterns

The *a priori* approach uses prior scientific evidence to define dietary pattern recommendations and aims to calculate a graded score or index that describes how well an individual adheres to it (Gu & Scarmeas, 2011; Hoffmann, Schulze, Schienkiewitz, Nöthlings, & Boeing, 2004). It is also referred to in the literature as the 'hypothesis-driven' or 'hypothesis-oriented' approach. Using this approach, dietary indexes are created either based on nutrition guidelines or recommendations, for example, the Health Diet Indicator (HDI) or using a recommended diet style such as the MeDi. There exist several pre-defined dietary indexes that allow for comparison with dietary data collected from a study sample. The following lists dietary indexes that have been examined in relation to cognitive function:

I ***Mediterranean Diet Score (MeDi Score):*** Assigns a value of 0 or 1 to pre-defined food group categories (dairy, meat, fruits, vegetables, legumes, cereals, fat, alcohol, and fish). Scores are added together to determine adhesion to the MeDi (theoretically ranging from 0–9) with a higher score indicating higher adherence (Scarmeas, Stern, Mayeux, Manly, et al., 2009).

II ***Healthy Diet Indicator (HDI):*** Based on a 0–9 point scale with a one point rise for adherence to each of pre-defined food groups/nutrients identified by the World Health Organisation for the prevention of chronic diseases. The food groups/nutrients include saturated fats, poly-unsaturated fats, protein, complex carbohydrate, dietary fibres, fruits and vegetables, pulses, nuts and seeds, mono-and di-saccharides, and cholesterol (Allès et al., 2012).

III ***Healthy Eating/Food Index:*** Emphasises plant foods and unsaturated oils and has been shown to reduce cardiovascular disease mortality in both men and women (Fung et al., 2009).

IV ***Dietary Approaches to Stop Hypertension (DASH):*** Emphasises high intake of plant foods, low intake of animal protein and low intake of sweets. Has been shown to be associated with lower risk of coronary heart disease and stroke (Fung et al., 2009).

V ***Dietary Guidelines Index:*** Typically based on country specific guidelines which provide age-and-sex specific recommendations for the consumption of core food groups.

VI ***Diet Quality Index:*** Developed as a composite assessment of diet and includes measures of 8 food group and nutrient-based recommendations from the Committee on Diet and Health of the National Research Council Food and Nutrition Board, as published in the 1989 report 'Diet and Health' aimed to reflect dietary diversity (Haines, Siega-Riz, & Popkin, 1999).

VII ***Elderly Dietary Index (EDI):*** Developed by Kourlaba, Polychronopoulos, Zampelas, Lionis, and Panagiotakos (2009) in a study aimed to develop an index that assesses the degree of adherence to nutritional recommendations for older adults. It examines consumption of 10 dietary components including meat, fish, fruits, vegetables, grains, legumes, olive oil, and alcohol as well as the type of bread and dairy products. Scores from 1 to 4 are assigned to all components of the index and the EDI total score has a range between 10 and 40.

VIII ***Recommended/Non-recommended Food Score (RFS/nonRFS):*** A simple approach based only on foods with beneficial effects on health where one point is assigned to each food item in the recommended list that is eaten a particular number of times per week and to non-recommended items eaten in moderation. A total score is computed with persons placed in high RFS or low RFS categories accordingly (Kaluza, Håkansson, Brzozowska, & Wolk, 2009).

A Closer Look at the Mediterranean Diet (MeDi)

The MeDi describes the traditional dietary pattern of populations bordering the Mediterranean Sea (Solfrizzi, Frisardi, et al., 2011). It is characterised by high consumption of fruits and vegetables, legumes, cereals, fish, olive oil; low consumption of meat and saturated fats and a moderate intake of alcohol (mostly in the form of wine). The MeDi has been widely reported to be associated with a number of favourable health outcomes including reduced risk of cancers, cardiovascular disease, and CIm and increased longevity (Scarmeas, Stern, Mayeux, Manly, et al., 2009; Scarmeas et al., 2006; Sofi, Abbate, Gensini, & Casini, 2010; Solfrizzi, Panza, et al., 2011; Trichopoulou, Costacou, Bamia, & Trichopoulos, 2003). The main composition of the diet is outlined below:

- Cereals – traditionally unrefined; wholegrains.
- Olive Oil – high intake of olive oil as the main source of fat; low intake of saturated fats.
- Dairy Products – low to moderate intake; mostly in the form of yogurt and cheese.
- Red Meat, Poultry – low intake.
- Vegetables, legumes, fruits, nuts – high intake.
- Fish – moderately high intake.
- Wine – regular but moderate ethanol intake; primarily in the form of red wines; taken with meals.

The MeDi score is used in the *a priori* approach of determining dietary patterns and is typically constructed in the following way. For the beneficial food groups (fruits, vegetables, legumes, cereals, fish, ratio of monounsaturated fatty acids/saturated fatty acids, and mild-moderate alcohol) a score of 1 is assigned to individuals who consume more than the sex-specific median of the population subjects. For meat and dairy products (components presumed to be detrimental), individuals whose consumption is below the sex-specific median are assigned a value of 1, and individuals whose consumption is at or above the median are assigned a value of 0. The MeDi score is then generated for each participant by adding the scores in the food groups (theoretically ranging from 0–9). A higher score indicates greater adherence to the MeDi (Gu & Scarmeas, 2011). Appendix A.1 highlights the characteristics of studies utilising the MeDi score approach to investigating the relationship between diet and health outcome.

One of the key areas of interest in studying dietary patterns will undoubtedly be whether the MeDi can and should be applied across varying socio-demographic and cultural settings or whether there is a dietary pattern yet to be identified that may reap even more cognitive benefits. Recent findings highlight that the MeDi does not translate to better health outcomes in all populations (Cherbuin & Anstey, 2012; Scarmeas et al., 2006).

3.4.2 *A Posteriori* Approach to Defining Dietary Patterns

The second methodological approach used to identify dietary patterns is known as the *a posteriori* approach. In the literature, it is also referred to as the exploratory/ empirically derived approach. It does not take into account prior scientific evidence of dietary pattern recommendations and as such is not limited by current knowledge in nutrition (Allès et al., 2012). The *a posteriori* approach utilises statistical methods such as principal component analysis (PCA), factor analysis or cluster analysis and reduced rank regression to derive dietary patterns collected from study participants (Gu & Scarmeas, 2011).

I ***Principal Component Analysis/Factor Analysis:*** Perhaps the most widely used dietary pattern identification technique in the literature. It searches for underlying traits that explain most of the variation in the data. In the case of food patterns, when a factor is heavily loaded with foods and nutrients, it means that these components of the diet are significantly qualifying it (i.e. where there is a large number of food variables that have been reduced to a smaller set of variables that capture the major dietary traits in the population) (Reedy et al., 2010). For a given individual, the higher a factor pattern score is, the closer the diet of this individual matches this pattern (Allès et al., 2012). Main critiques of this method are the seemingly arbitrary nature in determining the number of factors extracted and their interpretation and the relatively small percentage of variance in food intake explained by the extracted components (Hoffmann et al., 2004).

II ***Cluster Analysis:*** Results in subjects being grouped into clusters that minimise the sum of squares distances from each subject to the cluster mean – homogeneous non-overlapping groups (Allès et al., 2012). Each cluster can be qualified as a food pattern. Food choices common to all contribute less to cluster formation than those choices made by some and not by others (Reedy et al., 2010). The main limitation of the approach is its sensitivity to small sample size changes and that it involves the *a priori* definition of the number of clusters (Allès et al., 2012).

III ***Reduced Rank Regression (RRR):*** Determines linear functions of a first set of variables called predictors (typically food groups) by maximising the explained variation of a set of response variables (nutrients/biomarkers). The production of factor scores (similar to that used in PCA) can be interpreted as dietary patterns and are further related to health outcomes (Allès et al., 2012). Perhaps, the biggest strength of this approach is the ability to incorporate prior knowledge gained from studies and the possibility of choosing disease-specific responses (Hoffmann et al., 2004). However, some researchers postulate that application of RRR in nutritional epidemiology has several limitations including the fact that it is subject to considerable measurement error (Hoffmann et al., 2004).

Overall, while each has its strengths and limitations, the method employed in analyses should depend on the research question that needs to be answered. One limitation that applies to all methods though is the relatively small percentage of variation in food intake explained by the patterns identified which can make it difficult to derive dietary patterns that are predictive of disease (Hoffmann et al., 2004). Appendix A.2 highlights the key characteristics of the various approaches to examining dietary patterns.

3.5 Chapter Conclusion

The examination of diet-disease relationships has evolved from examining the effect of single nutrients to examining the effect of dietary patterns. While much is known about the relationship between diet and cognition, there is still much more left to be determined. For example, clarification of the relationship between B-vitamins and cognition and determining whether the purported benefits of the MeDi can and should be applied to different ethnic and cultural groups still warrant further investigation. Much more research is needed to examine these and other inconsistent findings between dietary intake and cognitive endpoints.

Chapter 4

Physical Activity and Cognitive Impairment

4.1 Chapter Summary

Physical activity refers to energy expending skeletal movement that promotes health and wellbeing. When reference is made to physical activity, a number of factors must be considered including the type, level of intensity, and duration. Different types of physical activities are performed in order to target particular body systems. For example, aerobic activities cause the lungs to work harder and the heart to beat faster thereby promoting cardiovascular health. The type of physical activity that is undertaken also influences the size of benefit received. Research indicates that moderate and vigorous activities such as climbing and walking uphill accrue more health benefits than sedentary activities that require far less energy such as reading.

In order to make recommendations at a population level, some surveillance data are needed. This data can be obtained through the use of questionnaires that typically ask an individual to recall their activity levels over a period of time, via direct observation and measurement using electronic devices, for example, pedometers or videotaping or using activity diaries where all activities undertaken and the time spent engaging in them is recorded in a log book.

The benefits of physical activity in the prevention of disease has been widely studied with evidence highlighting reduction in risks of developing multiple diseases including cancers and other non-communicable diseases. Research has also focused on the role of physical activity in neurodegeneration. Studies suggest that adults who engage in physical activity have a reduced risk of CIm and have a higher functional status due to improved strength, endurance, and balance (Paterson, Jones, & Rice, 2007; Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010). There is at present insufficient evidence to conclude that for dementia sufferers physical activity is beneficial and also to conclusively state the relationship between frailty (which affects an individual's ability to engage in physical activity) and cognitive decline (Prince et al., 2014).

Global recommendations have been issued for physical activity by the World Health Organisation in light of global trends toward physical inactivity as our lifestyles become more westernised and technologically driven (World Health Organisation, 2010).

4.2 Defining Physical Activity

Physical activity can be broadly defined as any bodily movement aimed to enhance health (U.S. Department of Health and Human Services, 2008). A review of the literature reveals that the terms 'physical activity' and 'exercise' are often used interchangeably. Theoretically, there is a difference in that exercise is a subclass of physical activity that is planned, structured and repetitive and usually done to improve fitness – although all exercise is physical activity, all physical activity is not exercise (U.S. Department of Health and Human Services, 2008). In this thesis, the author regards both as being synonymous and does not attempt to highlight the effects of physical activity as being distinct from exercise.

4.3 Classification of Physical Activity

Physical activity can be classed in a variety of ways. Some researchers have dichotomised its classification into baseline and health promoting activities. In this case, baseline activities refer to those usual activities associated with daily living while health promoting activities include exercise and leisure done with the purpose of improving quality of life (U.S. Department of Health and Human Services, 2008). Other studies have classified physical activity based on its role in an individual's life. For example, occupational physical activity would be dependent on job description and could include typing, hammering or walking and driving; domestic physical activity could include household chores such as cooking, cleaning and making beds, transportation physical activity relates to how we traverse to and from destinations – walking, riding, jogging, driving, and leisure-time activity refers to those that are done for enjoyment purposes and may include social activity and hobbies.

4.4 Types of Physical Activities

I ***Aerobic activities:*** Typically make the heart beat faster and the lungs work harder thereby improving cardio-respiratory fitness. They are typically done in a rhythmic pattern, for example, jogging, jumping rope, and walking.

II ***Muscular strength activities:*** Refers to those activities that make the muscles do more work than they are used to, for example, climbing and weight lifting.

III ***Muscular endurance:*** Activities that test the ability of a muscle to conduct repeated movements over a period of time, for example, push-ups and squats.

IV ***Flexibility activities:*** Promote stretching and limberness, for example, touching the toes with knees straight.

V ***Bone strength activities:*** Refers to those activities that produce a force on the bones commonly by impact with the ground, for example, jumping and playing netball.

VI ***Balance activities:*** Activities that are aimed to reduce falls by controlling or maintaining postural position. These activities become particularly important in older age, for example, backward and sideways walking.

4.5 Levels of Physical Activity

Physical activity is divided into levels based on the amount of energy expended for its conduct. While various levels have been identified, one of the most used has been examining activities as being sedentary, moderate or vigorous. Research has shown that it is participation in greater levels of moderate and high levels of physical activity that produce a number of positive health outcomes, including reduced risk of heart disease, certain types of cancer, and overall mortality (Miller, Freedson, & Kline, 1994). Sedentary activities are those that require very little energy expenditure such as watching television and reading. Moderate activity requires more energy output than sedentary activity but less than vigorous activity – as a general rule of thumb, 2 minutes of moderate-intensity activity counts the same as 1 minute of vigorous-intensity activity (U.S. Department of Health and Human Services, 2008). Examples of moderate activities include tennis (doubles), ballroom dancing, and general gardening while examples of vigorous activities include race-walking, swimming laps, and hiking uphill (U.S. Department of Health and Human Services, 2008).

4.6 Assessing Physical Activity

The use of questionnaires, observation and direct measurement and physical activity diaries have all been used to assess individual physical activity levels and to make recommendations at the population level.

A review of the literature reveals that many studies have utilised questionnaires of varying complexity designed to elicit their participants' usual or recent physical activity profiles (Jacobs, Ainsworth, Hartman, & Leon, 1993). This may be based on the fact that they are cost-effective given that the data are self-reported. More recently, there has been an interest in the assessment of physical activity through mechanical and electronic monitoring such as use of pedometers, heart monitors, wrist actigraphs and acticals (Ainsworth, Cahalin, Buman, & Ross, 2015). Using these techniques, estimates or indicators of energy expenditure or indices of physical activity are obtained.

Performance tests have also been incorporated into surveys and studies examining cognitive disease incidence and progression and have generally been accepted to supplement, rather than replace self-reported disability (Guralnik et al., 2000). Below are some commonly used methods of assessing physical activity:

I ***Questionnaires:*** Physical activity questionnaires measure activities by asking a respondent to recall and report recent or usual participation in activities or in sedentary behaviours, usually over a set period of time (Centers for Disease Control and Prevention, 2012). Typically responses to questionnaires are summarised by computing physical activity scores that place respondents into those who meet or do not meet physical activity recommendations. These scores take into account the duration, type and intensity of the activities engaged in. Commonly used physical activity questionnaires include the International Physical Activity Questionnaire (IPAQ) used in national and regional surveillance systems and the Active Australia Questionnaire used to measure engagement in leisure time activity (Australian Institute of Health and Welfare, 2003; The International Physical Activity Questionnaire Group, 2004).

II ***Observation and Direct Measurement:*** Methods of observation and direct measurement include electronic devices (for example, pedometers, motion detectors, heart rate monitors) designed to record an individual's movements or physiological responses to movement and direct observation (for example, watching and recording playground use during school recess) (Centers for Disease Control and Prevention, 2012).

III ***Diaries:*** Diary assessment of physical activity involves an individual recording all activity for a defined period of time (usually a week or a day) (Centers for Disease Control and Prevention, 2012).

4.7 Benefits of Physical Activity

The term physical inactivity refers to low levels of physical activity that does not meet recommended guidelines (Australian Institute of Health and Welfare, 2015b). Physical inactivity is now identified as the fourth leading risk factor for global mortality (World Health Organisation, 2010). The benefits of physical activity on overall health and quality of life cannot be disputed. A barrage of studies have focused on the role of physical activity on premature death, chronic diseases including obesity, metabolic health and musculoskeletal health and functioning. Strength of evidence surrounding such studies is presented in Appendix A.3.

4.8 Physical Activity and Cognitive Function

Maintaining brain health and plasticity is an important public health goal particularly after middle age when the brain faces a series of challenges that can include the pathogenesis of neurodegenerative diseases like AD (Cotman & Berchtold, 2002). Physical activity/exercise promotes functional neuro-protective changes in the hippocampus of the brain – a region central to learning and memory (Cotman & Berchtold, 2002). In addition, physical activity lowers cardiovascular disease risk, decreases blood pressure, and increases high density lipoprotein cholesterol levels and glucose tolerance, each of which may be related to neuronal integrity and cognitive function (Podewils et al., 2005).

Researchers have also highlighted that those who engage in physical activity may be more engaged with life and are inherently social beings. Persons with more developed social networks may have a lower risk of all-cause mortality as the activities they engage in promote mastery, efficiency, and overall health (Podewils et al., 2005). An interesting paradox has also been highlighted in the literature – exercise can result in improved health and increased longevity; increased longevity, however, is also associated with increased time with CIm (Anstey, Eramudugolla, & Dixon, 2014).

When looking at the ability to participate in physical activity, both functional status and frailty must be assessed. Functional status refers to the ease with which an individual is able to perform a task independently and has been linked with progression to dementia (Wang, Larson, Bowen, & van Belle, 2006). Research indicates that physical frailty (which takes into account strength, endurance, walking speed, fatigue, and body composition) in old age is associated with AD pathology in older persons without dementia (Buchman, Schneider, Leurgans, & Bennett, 2008).

4.8.1 Physical Activity and Risk of Dementia/Alzheimer's disease/Cognitive Impairment

Many studies have examined the relationship between physical activity and cognitive function. Results of recent systematic reviews have pointed to the beneficial effect of physical activity on cognition but more research is needed to address methodological issues which affect result comparability among studies (Lautenschlager, Cox, & Cyarto, 2012). In a 2014 review including 24 cohort studies, all studies except one found that physical activity could be a strongly protective factor for cognitive decline and dementia in elderly persons and reported that high physical activity was associated with a 42% reduced risk of AD (Beydoun et al., 2014). These findings support those of a 2008 review including 16 studies which found that higher physical activity in cognitively healthy adults was associated with lower risk of dementia, AD and cognitive decline [HR = 0.72 (95% CI: 0.60 – 0.86), HR = 0.5 (95% CI: 0.36 – 0.84)] for dementia and AD respectively, for those in the highest vs. lowest physical activity group (Hamer & Chida, 2009). Results from some prospective cohort studies though have been conflicting. For example, findings of a study comparing leisure-time and work-related physical activity from the Caerphilly Prospective study (CaPS) with dementia and cognitive impairment not dementia (CIND) after 16 years of follow-up found no real association with dementia and a possible increased risk for CIND (Morgan et al., 2012). Other studies have suggested that the protective effects of physical activity may be short-term. In the Rotterdam Study, 4,406 adults (average age 72.7 years) were followed for approximately 14 years and a higher level of physical activity was found to be associated with a lower risk of dementia. This association, however, was confined to follow-up up to 4 years (HR 0.82; 95% CI: 0.71–0.95), but not to longer follow-up (HR 1.04; 95% CI: 0.93–1.16) (de Bruijn et al., 2013). A similar pattern was present for Alzheimer's disease (de Bruijn et al., 2013). Findings of one randomised controlled trial conducted in Perth, Australia have shown that modest improvement in cognition can be obtained using a short-term physical activity intervention program among persons with subjective memory impairment (Lautenschlager et al., 2008). Further testing is needed however to conclusively state that physical activity is a protective factor against cognitive decline and dementia (Lautenschlager et al., 2012).

4.8.2 Physical Activity and Improving Functional Status

Function and cognition influence each other (Wang et al., 2006). Mobility is one aspect of physical function that is typically compromised as AD symptoms progress due to white matter changes of the brain associated with hippocampal atrophy (Wang et al., 2006). The effect of physical activity has been examined in terms of its use in rehabilitative therapy for dementia sufferers. Kemoun et al. (2010), observed that a 15-week physical activity programme, based on walking, equilibrium, and stamina exercises, induced a positive influence on the spatiotemporal variables concerning walking and cognitive capacities in aged persons suffering from dementia. Links between physical activity and improved walking speeds in AD sufferers have also been highlighted in the literature and have been linked to the fact that physical activity targets those walking parameters of AD that seem to be predictive indicators of falls (shortened stride length, slowing down, and increased double limb support time) (Kemoun et al., 2010). Further, a meta-analysis conducted by Heyn, Johnsons, and Kramer (2008) that included 21 exercise trials with cognitively impaired individuals and 20 exercise trials with cognitively intact individuals revealed that those with impaired cognitive function who participated in exercise rehabilitation programs had similar strength and endurance training outcomes as age and gender matched cognitively intact older participants.

Frailty also has some influence on an individual's functional status and has also been examined in the literature. Frailty has been defined as a biologic syndrome of decreased reserve and resistance to stressors resulting from cumulative declines across multiple physiologic systems and causing vulnerability to adverse outcomes (Fried et al., 2001). Markers of frailty therefore include declines in lean body mass and various components of physical activity such as strength, endurance, balance and walking performance (Fried et al., 2001). Two studies that have highlighted an association between frailty and incident MCI and AD have been conducted by Boyle, Buchman, Wilson, Leurgans, and Bennett (2010) and Buchman, Boyle, Wilson, Tang, and Bennett (2007). In a Chicago-based project among persons in retirement homes (n=750) without CIm at baseline and with 12 years follow-up, it was found that physical frailty was associated with a high risk of incident MCI, such that one-unit increase in physical frailty (judged using grip strength, timed walk, body composition and fatigue) was associated with a 64% increase in the risk of incident MCI (Boyle et al., 2010). Similarly, during a 3-year follow up study using the same cohort of dementia-free Chicago resident home dwellers, a higher baseline level as well as a more rapid increase in frailty were both associated with an increased risk of incident AD (Buchman et al., 2007). Only one LAC study was identified using data from 7 urban centres (n=10,891) and persons aged 60 and older. Findings indicate that there was a strong association between CIm and experienced difficulties carrying out basic and instrumental activities of daily living with declines in cognitive ability being linked to increased difficulty in performing instrumental activities of daily living (Menéndez et al., 2005).

4.8.3 Physical Activity in Cognitive Impairment Therapy

Physical activity may be able to prevent various devastating and frequent complications such as falls, behaviour disturbances, mobility disability or weight loss among persons living with dementia (Rolland, Abellan van Kan, & Vellas, 2008). The mechanism by which these effects may be achieved have not been clarified in the literature and some researchers suggest that it may be the result of an orexigenic effect when engaging in high amounts of physical activity that improves quality of life, mood, stamina, and cognitive function (Rolland et al., 2008). A Cochrane Review conducted in 2008 highlighted that there is insufficient evidence to be able to say whether or not physical activity programs are beneficial for people with dementia especially since there has been no inclusion of secondary outcomes relating to family caregiver outcomes and use of health services provided in any study (Forbes et al., 2008). This conclusion was based on the analysis of two randomised controlled trials in which physical activity programs were compared with usual care for the effect on managing or improving cognition, function, behaviour, depression, and mortality in people with dementia of any type and degree of severity (Forbes et al., 2008).

4.8.4 Physical Activity in those with Normal Cognitive Function

Results indicate that among cognitively normal older adults there are mental health benefits to be derived from physical activity as well. In a study by Rogers, Meyer, and Mortel (1990), the effects of different levels of physical activity on cerebral profusion was examined by dividing participants age 65 years into three groups (those who continued to work, those who retired but participated in regular physical activities and those who retired but did not participate in regular, planned physical activities). Results revealed that those who did not engage in physical activity had declines in cerebral blood flow and scored lower on cognitive tests after the 4^{th} year of follow-up. Similar findings were reported in a study examining the effects of aerobic fitness on the human brain (Colcombe et al., 2003). The authors reported that tissue losses in the frontal, parietal and temporal cortices of the brain were substantially reduced as a function of cardiovascular fitness (Colcombe et al., 2003). In addition, a Cochrane Review conducted in 2008 based on an analysis of 11 randomised controlled trials with participants older than 55 years of age was able to conclude that there is evidence that aerobic physical activities are beneficial for cognitive function in older adults. The authors point out however that there is not sufficient information to show that improved cognition was attributable to physical exercise (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008). Further research is needed to clarify these issues.

Concerns of the possible paradoxical relationship between physical activity and dementia (possibility that greater longevity can lead to higher dementia prevalence) was examined in a study using 8,403 persons who participated in the Canadian Study of Health and Ageing (CSHA) (Middleton, Mitnitski, Fallah, Kirkland, & Rockwood, 2008). The authors assert that as the majority of mortality benefit of exercise is at the highest level of cognition, and declines as cognition declines, the net effect of exercise should be to improve cognition at the population level, even with more people living longer (Middleton et al., 2008).

In a large, prospective study (n=18,766), aimed to examine the relation of long-term regular physical activity, including walking, to cognitive function, it was reported that higher levels of long-term regular physical activity were strongly associated with higher levels of cognitive function with the apparent cognitive benefits of greater physical activity similar in extent to being about 3 years younger in age (Weuve et al., 2004). Like Weuve et al. (2004), Tijhuis, Kromhout, and Gelder (2004) examined the effect of physical activity on cognition but placed emphasis on its duration and intensity. Results indicate that in a sample of 295 elderly Finnish men, participation in activities with at least a medium-low intensity may postpone cognitive decline and that a decrease in duration or intensity of physical activity results in a stronger cognitive decline than maintaining duration or intensity (Tijhuis et al., 2004).

Physical frailty has also been examined (though not very widely) in relation to cognitive decline in older adults. In a study of 1,370 Mexican-American men and women aged 65 and older without CIm at baseline and followed for 10 years, it was found that frail subjects had greater cognitive decline over the study period than those who were not frail (Samper-Ternent, Al Snih, Raji, Markides, & Ottenbacher, 2008). More studies are needed to clarify this relationship since prevalence of frailty increases with age and varies according to ethnicity and sex (Samper-Ternent et al., 2008).

4.9 Worldwide Physical Activity Data

The World Health Organisation reports that levels of physical inactivity are rising in many countries and have been contributing to increased disease burden (World Health Organisation, 2010). A study conducted using data from 76 countries (n = 300,000) provides the most comprehensive review of global physical activity trends available (Dumith, Hallal, Reis, & Kohl III, 2011). Figure 4.1 shows the results of this study and highlights that physical activity is more prevalent among wealthier countries and women.

Trends in functional status have also been examined by researchers. In the U.S., it is estimated that about 3–5% of persons aged 65–74 have difficulty with at least one instrumental activity of daily living (IADL) or activity of daily living (ADL) and that this percentage more than triples to 10–20% in those aged 75 and older (Reyes-Ortiz, Ostir, Pelaez, & Ottenbacher, 2006). These findings may be applied more widely to other countries as age profiles both in low- and middle-income and developed countries change as a result of increased life expectancies and ageing populations. In a 7-country study conducted in LAC countries the authors asserted that at least one third of the members of these populations will need help for self-care and to manage the household as the age profile continues to age (Reyes-Ortiz et al., 2006).

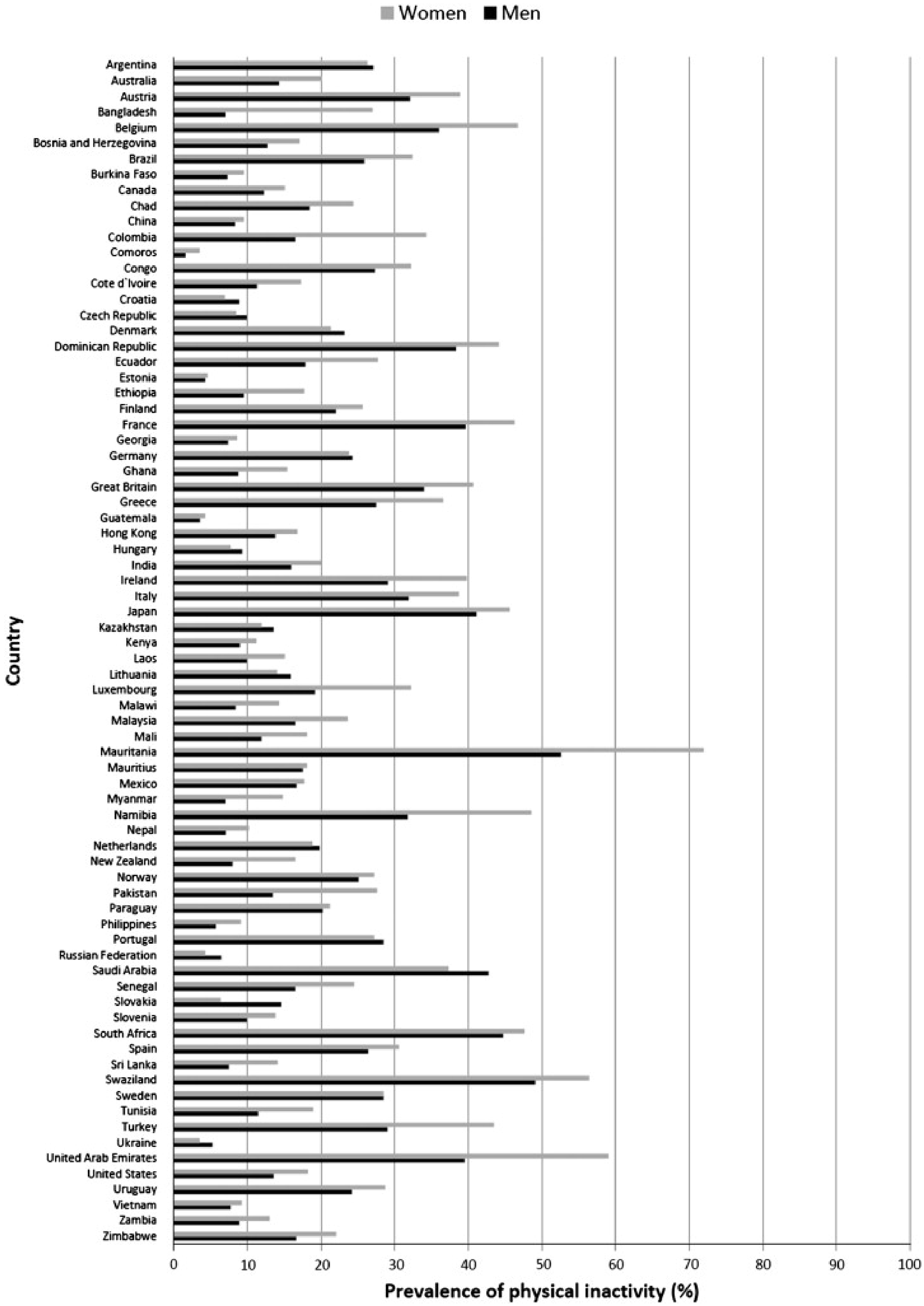


Figure 4.1: Prevalence of Physical Activity by Country and Gender (Dumith, Hallal, Reis, & Kohl III, 2011).

4.10 Global Recommendations for Physical Activity

In 2010, the World Health Organisation issued its Global Recommendations on Physical Activity for Health aimed to assist in the primary prevention of non-communicable diseases through physical activity at the population level (World Health Organisation, 2010).

Many countries have also issued some guidelines for physical activity for their populations based on their endorsements of two Resolutions at the World Health Assembly: WHA57.17: Global Strategy on Diet, Physical Activity and Health (in May 2004) and WHA61.14: Prevention and Control of Non-communicable Diseases: Implementation of the Global Strategy and the Action Plan for the Global Strategy for the Prevention and Control of Non-communicable Diseases (May 2008) (World Health Organisation, 2010). The global recommendations as issued by the World Health Organisation are presented in Appendix A.4. These recommendations vary based on stage in the lifecourse.

4.11 Chapter Conclusion

The beneficial effect of physical activity on health and wellbeing is well known. Less known however is the direct effect of physical activity on cognitive health, including risk of cognitive decline and dementia. While further research is needed to clarify this link, the 'Global Recommendations for Physical Activity' are founded on longitudinal studies that have been supported by the effects of regular exercise on other health outcomes such as cancer, diabetes and cardiovascular disease risk. A reduction in the risk of these health outcomes can indirectly reduce dementia risk (Prince et al., 2014).

Chapter 5

Estimating the Burden of Cognitive Impairment in Australia

5.1 Chapter Summary

Adults aged 60 and older participating in the 12-year follow-up of the Australia Diabetes Obesity and Lifestyle Study (AusDiab) were included in the sample (n = 1666). The mean age was 69.5 years, and 46.3% of the sample was male. The Mini-Mental State Examination (MMSE) was used to assess CIm. Logistic regression analysis was used to determine the effect of predictor variables (age, gender, education), measured at baseline, on CIm status. The Sullivan Method used for calculating health expectancies was used to estimate Total Life Expectancy (TLE), Cognitively Impaired (CILE) and Cognitive Impairment-free life expectancies (CIFLE). Odds of CIm were greater for males than females [OR 2.1, 95% confidence interval (CI): 1.2–3.7) and among Australians with low education levels compared with Australians with high education levels (OR 2.1, 95% CI: 1.2–3.7).

The odds of CIm also increased each year with age (OR 1.1, 95% CI: 1.0–1.1). It was found that in all age groups females have greater TLE and CIFLE when compared to their male counterparts. In Australia, females live longer than males, but males spend more time with CIm in Australia. The odds of CIm are greater in those with low education levels (OR 2.1, 95% CI: 1.2–3.7) when compared to those with high education levels (beyond high school level).

The calculation of healthy life expectancies allows for the estimation of the burden of disease in a given population and facilitates both within and between country comparisons.

5.2 Background

The calculation of health expectancies has become increasingly relevant to international health policy as emphasis is placed on healthy and active ageing. Healthy life expectancy is used to quantify burden of disease and enables researchers to monitor the overall health of the population (Matthews et al., 2009). CIm affects the survival, functional status and quality of life not only of sufferers but also of their relatives and carers (Dubois & Hébert, 2006; Matthews et al., 2009). Dementia is Australia's third leading cause of death and there is no cure (Alzheimer's Australia, 2013).

While data on mental health expectancies is scarce for most countries, previously published data are available for Australia but these are based on a regional study rather than data drawn from a national study (Nepal, Brown, & Ranmuthugala, 2008; Ritchie, Robine, Letenneur, & Dartigues, 1994a). Hence the aim was to produce the first Australian estimates of CIFLE using cognitive function data from a national and population-based study. Additionally, recently published findings have shown a reduction in late-life CIm in the UK, Denmark, and Sweden and this shift in dementia prevalence makes the conduct of this study worthwhile to investigate if similar changes have occurred in Australia (Christensen et al., 2013; Matthews et al., 2013; Qiu, von Strauss, Backman, Winblad, & Fratiglioni, 2013).

5.3 Aim

- To determine prevalence of CIm and to estimate life expectancy with and without CIm in the Australian population over age 60.

5.4 Methodology

5.4.1 Sample Selection and Survey Protocol and Procedures (AusDiab)

The AusDiab study is a population-based national survey of the general (non-institutionalised) Australian population aged 25 years and over residing in private dwellings in each of the six states and the Northern Territory. A stratified cluster sampling method was used and sample size selection based on estimates of national diabetes prevalence obtained from previous surveys (Dunstan, D. et al., 2002). The baseline examination was undertaken in 1999–2000 (n=11,247), with follow-up conducted in 2004–05 (n = 8,798) and 2011–12 (n = 6,186). Measurement of cognitive function was conducted on those who attended survey sites in the third Wave of data collection (n = 4,764). Data were collected using questionnaires, physical examinations, blood sampling, urine collection, anthropometry, and blood pressure reading. The sampling frame is shown in Figure 5.1.

Approximately 59.8% of the original AusDiab sample participated in Wave 3 of data collection. Table 5.1 highlights the characteristics of participants and non-participants at Wave 3.

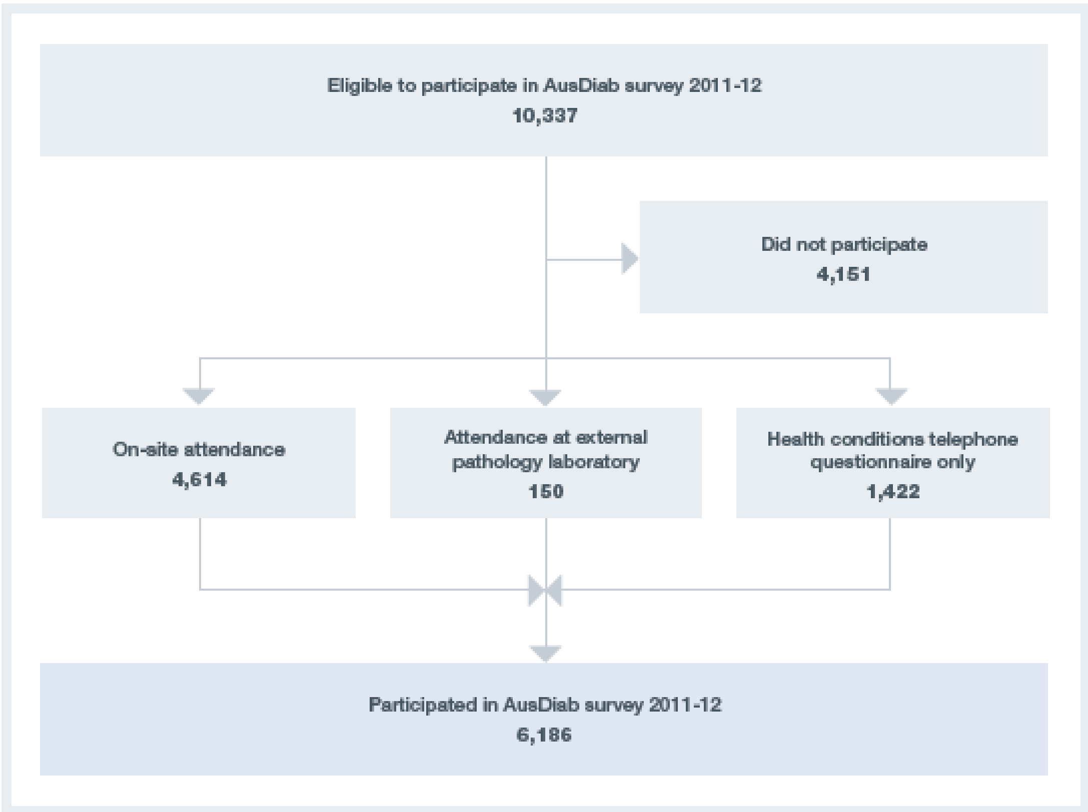


Figure 5.1: Sampling frame AusDiab follow-up reproduced from AusDiab Report, 2013

Table 5.1: Characteristics of participants and non-participants (AusDiab Wave 3) reproduced from Tanamas et al. (2013a).

	On-site Attendance	External Pathology Lab	Telephone Questionnaire Only	Non-attendees	P-value
n	4614	150	1422	4151	
Country of birth (%)					<0.001
Australia/New Zealand	3616 (78.4)	113 (75.3)	1125 (79.2)	3006 (72.5)	
United Kingdom/Ireland	497 (10.8)	26 (17.3)	166 (11.7)	452 (10.9)	
Other Countries	499 (10.8)	11 (7.3)	130 (9.2)	691 (16.7)	
Language spoken at home (%)					
English	4496 (97.5)	147 (98.0)	1384 (97.4)	3875 (93.4)	<0.001
Italian	19 (0.4)	0 (0)	3 (0.2)	50 (1.2)	
Greek	14 (0.3)	0 (0)	6 (0.4)	46 (1.1)	
Cantonese	6 (0.1)	1 (0.7)	6 (0.4)	33 (0.8)	
Mandarin	12 (0.3)	0 (0)	3 (0.2)	7 (0.2)	
Other	65 (1.4)	2 (1.3)	19 (1.3)	138 (3.3)	
Aboriginal/ Torres Strait Islander (%)	24 (0.5)	0 (0)	11 (0.8)	54 (1.3)	0.001
Marital Status (%)					<0.001
Married	3588 (77.8)	122 (81.3)	1074 (75.6)	2732 (65.9)	
De Facto	193 (4.2)	6 (4.0)	82 (5.8)	234 (5.6)	
Separated	94 (2.0)	2 (1.3)	36 (2.5)	137 (3.3)	
Divorced	255 (5.5)	5 (3.3)	74 (5.2)	276 (6.7)	

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Table 5.1 – Continued

	On-site Attendance	External Pathology Lab	Telephone Questionnaire Only	Non-attendees	P-value
Widowed	127 (2.8)	6 (4.0)	67 (4.7)	354 (8.5)	
Never married	355 (7.7)	9 (6.0)	88 (6.2)	416 (10.0)	
Highest level of Education (%)					
Secondary school qualification (includes attending primary school only)	1,522 (33.2)	58 (39.2)	599 (42.4)	1,877 (45.8)	<0.001
Trade, technician's certificate	1,357 (29.6)	51 (34.5)	428 (30.3)	1,253 (30.6)	
Associate, undergraduate diploma, nursing or teaching qualification	660 (14.4)	17 (11.5)	175 (12.4)	424 (10.4)	
Bachelor degree, post-graduate diploma	1,047 (22.8)	22 (14.9)	211 (14.9)	543 (13.3)	
Smokers (%)	1,792 (39.4)	68 (46.6)	688 (49.2)	1,935 (47.6)	<0.001
Exercise (%)					
Sufficient (?150 minutes/day)	2,484 (54.1)	91 (61.9)	732 (51.8)	2,117 (51.5)	0.01

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Table 5.1 – Continued

	On-site Attendance	External Pathology Lab	Telephone Question-naire Only	Non-attendees	P-value
Insufficient (1-149 minutes/day)	1,406 (30.6)	39 (26.5)	436 (30.9)	1,263 (30.7)	
Inactive	700 (15.3)	17 (11.6)	244 (17.3)	734 (17.8)	

5.4.2 Study Methodology

The MMSE was used in data collection 2011–12 (AusDiab Wave 3) to determine cognitive outcome with participants categorised as being either cognitively impaired (score of 0–23) or not cognitively impaired (score of 24–30) (Anstey, Von Sanden, & Luszcz, 2006). The MMSE is commonly employed by clinicians to screen for CIm and dementia (Woodford & George, 2007). It is a sum-score that evaluates various dimensions of cognition (memory, attention, and language) and used as an index of global cognitive performance (Féart et al., 2009). The MMSE test can be affected by level of education, cultural background, and language fluency (Jagger, Clarke, Anderson, & Battcock, 1992; Wood, Giuliano, Bignell, & Pritham, 2006).

In this study, a high education level was defined as any learning that occurred after completion of secondary school while a low education level was defined as having either primary and/or secondary school education only.

The Sullivan Method used to estimate population health indicators was applied to determine total life expectancy (TLE), life expectancy with impairment (CILE) and CIm free life expectancy (CIFLE) (Jagger, Cox, Le Roy, & EHEMU, 2006). This method requires age-specific prevalence (proportions) of the population in healthy and unhealthy states (often obtained from cross-sectional surveys), and age-specific mortality information taken from a period life table (Jagger et al., 2006). CIFLE reflects the number of remaining years, at a particular age, which an individual can expect to live in the absence of disease (Matthews et al., 2009). For this study, five-year age intervals were analysed with the final age group recorded as age 85+. Five-year age-specific prevalence of CIm in Australia was determined using data from the AusDiab 60+ cohort. Data were stratified based on gender. Confidence intervals using this method are only produced for the computation of CIm-free life expectancies.

Age-specific population and mortality data were obtained for 2012 from the Australian Bureau of Statistics (Australian Bureau of Statistics, 2012a) and cross-sectional prevalence data were obtained from the AusDiab Study (2011-12 Wave).

Logistic regression analysis was used to determine the effect of various predictors on cognitive status. The variables age, gender, education level, age^2, $age \times gender$, $age \times education$ and $gender \times education$ were all considered in developing the model. The final regression model contained 3 predictors (age, gender and education level) each of which had a unique statistically significant contribution.

5.5 Results

The age and gender distribution of the sample is given in Table 5.2. Overall 53.7% of respondents were female. The greatest proportion of participants (30.0%) was recorded in the 60–64 age group.

Table 5.2: Age and sex distribution of study subjects

	Number of Subjects		
Age (Years)	Men	Women	All
60–64	234 (14.0%)	266 (16.0%)	500 (30.0%)
65–69	187 (11.2%)	247 (14.8%)	434 (26.1%)
70–74	144 (8.6%)	170 (10.2%)	314 (18.8%)
75–79	109 (6.5%)	113 (6.8%)	222 (13.3%)
80–84	62 (3.7%)	63 (3.8%)	125 (7.5%)
85+	36 (2.2%)	35 (2.1%)	71 (4.3%)
Total	772 (46.3%)	894 (53.7%)	1666 (100.0%)

Males recorded higher CIm prevalence estimates than females in three of the six age groups. The CIm prevalence for males in the 60–64 age-group was 8.6% compared to 1.7% for females. The CIm prevalence for males in the 75–79 age-group was 20.7% compared to 8.6% among females and in the 80–84 age-group CIm prevalence for males was 13.8% compared to 6.9% among females. Further inferences can be drawn from Figure 5.2 below.

Logistic regression analysis showed that holding gender and education constant, the odds of CIm increase with age (OR 1.1, 95% CI: 1.0–1.1). The odds of CIm also vary depending on gender with males having higher odds (OR 2.1, 95% CI: 1.2–3.7). Finally, for those with a low education level the odds of CIm are higher when compared to the odds of CIm for those with a high education level (OR 2.1, 95% CI: 1.2–3.7).

TLE, CIFLE and CILE for the sample are shown in Table 5.3 below:

Females have longer life expectancy and also spend a greater proportion of their lives without CIm across all age groups when compared to their male counterparts. At age 60, males can expect to live a further 23.5 years. Of these, 21.1 years (95% CI: 20.8 – 21.4) are expected to be CIm-free and 2.4 years spent with CIm. Comparatively, females at age 60 can expect to live a further 26.8 years (95% CI: 25.0 – 25.6). Of these, 25.3 years are expected to be CIm-free and 0.5 years spent with CIm. Further inferences can be drawn from Table 5.3 as it relates to CIm and CIm-free life expectancies across sex and age groups.

Table 5.3: TLE, CIFLE, CILE and % of Total Life Spent CIm-free (CIF) for the Australian Population by Age and Sex

Age (years)	TLE	CIFLE	CILE	% of Total Remaining Life Spent CIm-Free (%)
MALES				
60–64	23.5	21.1	2.4	89.8
65–69	19.4	17.2	2.2	88.7
70–74	15.4	13.6	1.8	88.3
75–79	11.9	10.1	1.8	84.9
80–84	8.9	8.1	0.8	91.0
85+	6.5	6.1	0.4	93.8
FEMALES				
60–64	26.8	25.3	1.5	94.4
65–69	22.4	21.0	1.4	93.8
70–74	18.2	17.0	1.2	93.4
75–79	14.2	13.0	1.2	91.5
80-84	10.6	10.2	0.4	96.2
85+	7.7	7.4	0.3	96.1

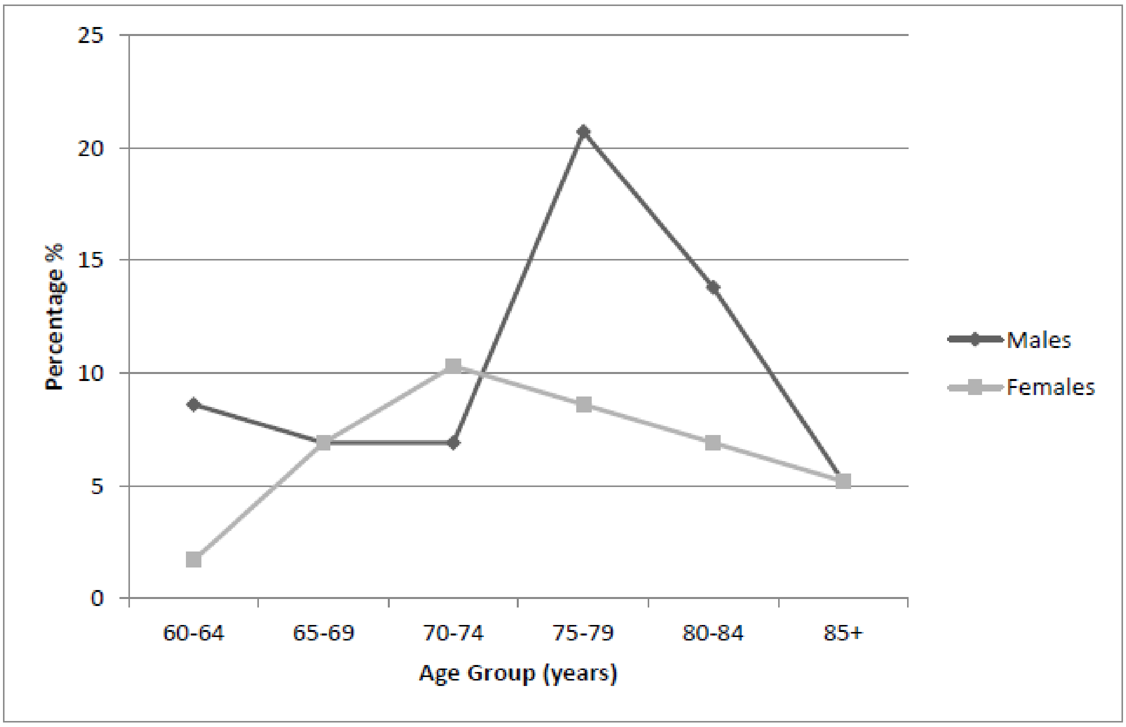


Figure 5.2: CIm Prevalence by Gender and Age-Group

5.6 Discussion

In this study, the odds of CIm were greater for Australian males (OR 2.06, 95% CI: 1.16–3.67) and among those with low education levels (OR 2.08, 95% CI: 1.18–3.69). The odds of CIm also increased each year with age (OR 1.09, 95% CI: 1.05–1.13). Females were shown to have longer life expectancies than males. For example, at age 60 females are expected to live a further 26.8 years compared with males who are expected to live a further 23.5 years. Females also spend a greater proportion of their lives without CIm across all age groups when compared to their male counterparts. For example, females at age 60 are expected to spend 94.4% of the remainder of their lives without CIm while males are expected to spend 89.8% of the remainder of their lives free of CIm.

The novelty of these results lie in the fact that this is the first time that national population-based data has been used to measure mental health expectancies in the Australian setting. These findings allow Australia to be compared with other countries for whom CIm data are available using the same outcome measure. This provides a basis for evaluation of health policy and planning and a benchmark by which to assess population-level changes in risk of CIm and changing CIFLE given increasing longevity of populations. The salience of this study is underscored by the fact that dementia is common, costly, and highly age related (Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001). CIm health expectancy data can be used to develop more meaningful guidelines and policies as it relates to the cognition of older adults and can serve to identify specific age groups that merit further study. More specifically, these results can also serve to inform the development of population health indicators – a useful marker for the health of a population. In the past, this health indicator centred primarily on physical functioning (Jagger et al., 1998). Recently though, there has been recognition of the need to also consider the mental health of populations in order to predict the services it needs (Jagger et al., 1998).

Comparison of AusDiab CIm prevalence with other Australian data

The CIm prevalence estimate obtained in the present study can be compared to estimates reported in a study that examined possible CIm in Australia using a pooled dataset of Australian longitudinal studies (DYNOPTA) and two Australian Bureau of Statistics National Surveys of Mental Health and Wellbeing (NSMH) (Anstey et al., 2010). When comparing the present study to DYNOPTA and the NSMH surveys, the probable dementia category was selected as the reference since it coincided with the MMSE score cut-off for CIm in the AusDiab i.e., <24. When compared to DYNOPTA, results differed greatly for both males and females between the studies. For example, males in the 65–69 and 70–74 age-groups recorded probable dementia rates of 3.02% and 6.90% respectively in DYNOPTA compared to estimates of 6.90% and 6.90% in AusDiab (Anstey et al., 2010). For females in the same age-group, probable dementia rates in DYNOPTA were recorded as 4.47% and 4.30% compared to 6.90% and 10.30% respectively in AusDiab (Anstey et al., 2010). Prevalence estimates for the 2007 NSMH Survey were also observed to be much lower than those in AusDiab. For example males in the 65–69 and 70–74 age-groups recorded probable dementia prevalence of 4.63% and 4.34% while females in the same age-groups had prevalence of 3.43% and 5.70% respectively (Anstey et al., 2010). Generally, the results of the present study are more closely aligned to the probable dementia estimates calculated using the 1997 NSMH Survey rather than the estimates calculated using DYNOPTA and the 2007 NSMH. Probable dementia prevalence recorded in 1997 among males in the 65–69 age-group and 70–74 age-group were estimated at 6.72% and 11.16% while for females probable dementia estimates were 5.70% and 7.66% (Anstey et al., 2010). Differences in the results obtained between the AusDiab and these studies may be due to differences in methodology and sample selection.

Comparison of Australian mental health expectancies with Australian and worldwide data

Previous mental health expectancy calculations in the Australian population have looked at dementia-free life expectancies (Nepal, Ranmuthugala, Brown, & Budge, 2008; Ritchie et al., 1994a). It is however important to quantify the burden of CIm in the population since this allows for a more comprehensive understanding of the effect of mental disability in older age groups. The availability of data for the cognitive domain, from the AusDiab Study at Wave 3 facilitated the calculation of CIFLE in this study.

Data on CIm-free life expectancies have been published for a few countries (for example, in Canada and the United Kingdom) however these data are typically representative of populations in the 1990s. It is useful to compare trends observed between these two developed countries and Australia (Dubois & Hébert, 2006; Matthews et al., 2009). Compared to their Canadian and UK counterparts, Australian males and females live longer and spend a greater proportion of their life without CIm. For example, at age 65 Australian males can expect to live a further 19.4 years of which 17.2 would be spent without CIm. In Canada, males at the age of 65 can expect to live a further 16.4 years of which 13.8 would be spent CIm-free and in the UK males at the age of 65 can expect to live a further 15.3 years of which 11.4 would be spent CIm-free (Dubois & Hébert, 2006; Matthews et al., 2009). In the case of females, Australian females 65 years of age can expect to live a further 22.4 years of which 21.0 would be spent without CIm. Comparatively, Canadian females at 65 are expected to live a further 19.1 years with 15.5 of these years spent without CIm while in the UK females at age 65 are expected to live a further 19.5 years with 12.9 years spent CIm-free (Dubois & Hébert, 2006; Matthews et al., 2009).

Dementia-free life expectancies previously published in Australia in 1994 and 2008 also help to put the burden of disease calculated in this study into perspective since 'CIm No Dementia' is considered an intermediate state between 'No CIm' and dementia (Dubois & Hébert, 2006). Using data from a field survey conducted in the over-70 population in Canberra and Queanbeyan in 1990–1991 (n=1,045) it was found that at 70 years of age, men were expected to live a further 12.0 years and women a further 15.1 years (Ritchie et al., 1994a). Of these years, 11.0 and 13.7 would be spent without dementia respectively (Ritchie et al., 1994a). More recently, using published dementia prevalence and complete life tables published by the Australian Bureau of Statistics, dementia-free life expectancy was calculated for the Australian population for the period 2004–2006 (Nepal et al., 2008). When the 2004–2006 study is compared to the 1990 results, TLE was observed to have increased among both males and females (14.5 years and 17.3 years respectively). Additionally, when both studies were compared, there was a slight increase in years of life spent without dementia in males and females (1.45 years for males and 0.18 years for females). This is consistent with recent findings showing reduction in late-life CIm in Denmark, Sweden and England and Wales (Christensen et al., 2013; Matthews et al., 2013; Qiu, De Ronchi, & Fratiglioni, 2007). These studies however utilised different methodologies. For example, the AusDiab unlike the other studies did not include those in institutions and this may explain some of the differences in the results obtained. Cut-off points for the MMSE used to classify those with CIm may also have influenced the results obtained. For example, in the UK study, a score of <26 was used to classify those with CIm (mild < 22–25 and moderate/severe ≤ 21) while the present study used a score of <24. Additionally, in the Canadian study there was independent assessment by a nurse, physician, and neuropsychologist to confirm the presence or absence of CIm which may have led to increased diagnostic accuracy. While inclusion of those in institutions may have led to increased CIm prevalence in AusDiab, the adoption of stricter diagnostic criteria may have led to many previously classified as ‘cognitively impaired’ being considered as ‘normal’.

The prevalence of CIm obtained in this study and reflected in logistic regression analysis showed an unexpected distribution particularly for males. This merits further analysis but the higher prevalence rates observed in males in the 75–79 and 80–84 age groups may be the result of selective attrition and also small numbers in the older age groups in the study. It was observed that the number of females and males analysed in this study fell disproportionately from 170 to 113 and 144 to 109 (in the 75–79 age group) and again from 113 to 63 and 109 to 62 (in the 80–84 age group). This may be indicative of the fact that more females requested no further contact in AusDiab, moved abroad or suffered from severe illness and as such were ineligible to continue in the study.

The influence of education on cognitive status

The association between education level and cognitive status in other studies has been published previously (Matthews et al., 2009; Sattler et al., 2012; Magaziner, Bassett, & Rebel, 1987). Education is known to affect both level of cognition and its measurement, though it is not clear whether the measure is better with or without adjustment (Matthews et al., 2009). It has been suggested that education improves health and encourages health-seeking behaviours and healthy lifestyles (Mirowsky & Ross, 2003). The role of education in screening tests such as the MMSE has been highlighted since education may influence a person’s ability to display the necessary skills measured (Mungas et al., 1996). In addition, the MMSE may lack sensitivity to early signs of dementia and present ceiling effects resulting in false-negative diagnoses (Sheehan, 2012). In the present study, education level was found to be a significant predictor of cognitive status. Similar findings have also been reported in studies conducted in England and Wales and the United States where it was found that differences in TLE by education groups are large in the elderly population (Matthews et al., 2009; Rogot, Sorlie, & Johnson, 1992).

Novelty of findings

While the results obtained in this research compare well with other studies, this study makes a substantial contribution to the field as to the authors' knowledge it is the first that reports on CIFLE in Australia. Additionally, the use of a national, population-based Australian sample from the AusDiab study allows for greater accuracy. Previous mental health expectancy calculations in Australia utilised data from the affluent Canberra region or extrapolated data from European countries with similar characteristics. Another strength of this study lies in the use of the Sullivan Health Expectancy. This method permits comparison with other countries and also allows us to observe trends within the same country. Additionally, an assessment of cognitive status was performed only on a subset of the sample. An analysis of those for whom no data on cognition was collected (either because of non-selection or drop out) shows that a greater proportion were female (56.8%). A greater proportion of those who did not do cognitive testing also belonged to the low education category (31.7%). As both gender and education level are associated with cognitive status it may be that CIm prevalence is underestimated and CIFLE overestimated in this present study.

5.7 Chapter Conclusion

Monitoring healthy life expectancy trends is key to maintaining quality of life in older age groups, proactive policy making and development of effective interventions. Although previously neglected, cognitive health is an important aspect of overall health. The results of this study highlight the growing need for greater investment in overall health in general and mental health in particular given the disease burden (direct, indirect and non-financial costs) to individuals and their families, communities, and society.

Chapter 6

Estimating the Burden of Cognitive Impairment in Latin America and the Caribbean

6.1 Chapter Summary

The rising prevalence of CIm is an increasing challenge with the ageing of our populations but little is known about the burden in low- and middle-income Latin American and Caribbean countries (LAC) that are ageing more rapidly than their developed counterparts. Life expectancies with CIm (CILE) and free of CIm (CIFLE) in seven developing LAC countries were examined.

Data from The Survey on Health, Well-being and Ageing in LAC (SABE) (N = 10,597) was utilised and cognitive status was assessed using the Mini-Mental State Examination (MMSE). The Sullivan Method was applied to estimate CILE and CIFLE. Logistic regression was used to determine the effect of age, gender, and education on cognitive outcome. Meta-regression models were fitted for all 7 countries together to investigate the relationship between CIFLE and education in men and women at age 60.

The prevalence of CIm increased with age in all countries except Uruguay and with a significant gender effect observed only in Mexico where men had lower odds of CIm compared to women [Odds Ratio (OR) 0.46, 95% Confidence Interval (CI): 0.27–0.81]. Low education was associated with increased prevalence of CIm in Brazil (OR 4.85, 95% CI: 1.17–20.04), Chile (OR 3.11, 95% CI: 1.10–8.79), Cuba (OR 2.30, 95% CI: 1.25–4.23) and Mexico (OR=3.84, 95% CI: 1.37–10.77). For males, total life expectancy (TLE) at age 60 was highest in Cuba (19.7 years) and lowest in Brazil and Uruguay (17.6 years). TLE for females at age 60 was highest for Chileans (22.8 years) and lowest for Brazilians (20.2 years). CIFLE for men was greatest in Cuba (19.0 years) and least in Brazil (16.7 years). These differences did not appear to be explained by educational level (men: p = 0.41, women: p = 0.70).

Increasing age, female sex and low education were associated with higher CIm in LAC reflecting patterns found in other countries.

6.2 Background

Cognitive impairment (CIm) is a condition where a person has trouble remembering, learning new things, concentrating or making decisions that affect their everyday life (U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011). CIm can be mild or can be severe enough to affect an individual's ability to live independently (U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011). The rising prevalence of CIm is an increasing challenge with the ageing of our populations but little is known about the burden in low- and middle-income countries. This is a particular concern since low-and middle-income countries, including LAC, are ageing more rapidly. At present, over 60% of the world's population 60 years and older live in these countries and this projection is expected to rise to a high of 80% by 2050 (U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011).

Age is currently the strongest known predictor of cognitive decline (Barnes & Yaffe, 2009; Dangour & Uauy, 2006). As such, because of the rapid increase in demographic ageing in all world regions, global prevalence of dementia is predicted to double every 20 years to over 80 million people by 2040 (Morris, 2009). Since CIm has been shown to negatively affect quality of life including functional status (Matthews et al., 2009) countries that are ageing most rapidly will face considerable challenges.

Education level has been associated with reduced risk of dementia (Matthews et al., 2013; Meng & D'Arcy, 2012) but education influences health in varied ways (Anstey & Christensen, 2000; Mirowsky & Ross, 2003) including by encouraging health-seeking behaviours and healthy lifestyles (Mirowsky & Ross, 2003). The role of education in screening and detection tests has however been controversial since it may influence the ease with which a respondent is able to answer questions asked and display the necessary skills to be measured (Mungas et al., 1996).

As the older population grows in both size and proportion, it is important to find out whether the additional years lived are spent with more disease and disability (U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011). Health expectancies, which combine information on mortality and morbidity are useful population indicators to assess whether the extra years of life expectancy are in good or poor health (Robine & Ritchie, 1991). The most widely reported health expectancy is disability-free life expectancy and, while there have been some published studies on mental health expectancies in a number of developed countries (Cloos et al., 2010; Dubois & Hébert, 2006; Jagger & Matthews, 2002; Nepal et al., 2008; Ritchie, Robine, Letenneur, & Dartigues, 1994b; Roelands, van Oyen, & Baro, 1994), data on the older population, particularly on cognitive status, is not routinely collected in Latin America and the Caribbean. This paper is the first to report life expectancy with and without CIm in LAC, utilising data from a survey conducted in seven LAC countries (Argentina, Barbados, Brazil, Chile, Cuba, Mexico and Uruguay) between the period 1999–2000. In addition, cross-national comparisons to investigate burden of CIm at various ages and an examination of the role of education in determining cognitive status was undertaken.

6.3 Aim

- To conduct a cross-national comparison of CIm prevalence and estimate disease burden using Sullivan's Method in seven LAC countries (Argentina, Barbados, Brazil, Chile, Cuba, Mexico, and Uruguay).

6.4 Methodology

6.4.1 Study Design and Sample (SABE)

The study draws on existing data derived from the Survey on Health, Well-being and Ageing in Latin America and the Caribbean (SABE). The SABE, conducted during the period 1999–2000, represents the most comprehensive study undertaken in the region on the elderly population. As a multi-centre project it involved the collection of baseline data in the capital cities of seven countries: Buenos Aires (Argentina), Bridgetown (Barbados), Sao Paolo (Brazil), Santiago (Chile), Havana (Cuba), Mexico City (Mexico) and Montevideo (Uruguay). The project aimed to examine health conditions and functional limitations of persons aged 60 and older in the countries under study and placed special emphasis on those over 80 years old (n=10,597). The total sample size of the SABE was 10,597 participants. Response rates varied from 85% in Bridgetown, Sao Paulo, and Mexico City to 60% in Buenos Aires, 84% in Santiago, 95% in Havana, and 66% in Montevideo. Sampling was based on censuses conducted in 1998 in Buenos Aires, 1996 in Sao Paulo, 1992 in Santiago, 1999 in Havana, 1999 in Mexico City, and 1997 in Montevideo (Barceló, Peláez, Rodriguez-Wong, & Pastor-Valero, 2006).

A multistage, clustered sampling with stratification of the units at the highest levels of aggregation was used (Palaez et al., 2004). The primary sampling unit was a cluster of independent households within predetermined geographic areas grouped into socioeconomic strata and then divided into secondary sampling units, each containing a smaller number of households (Palaez et al., 2004).

Households and target individuals (persons age 60 and older) were randomly selected and target individuals contacted to schedule an interview at home. The interviews were conducted in English, Portuguese or Spanish depending on the official language of the country in which the survey was administered. If a person who agreed to be interviewed failed the cognitive test, a proxy was selected to respond to some parts of the questionnaire (Palaez et al., 2004).

Definition of CIm

The MMSE (Folstein et al., 1975) was used to establish cognitive status in all study samples. The MMSE is a sum-score evaluating various dimensions of cognition (memory, attention, and language) and is an index of global cognitive performance (Folstein et al., 1975). In the SABE, a regression analysis had been carried out prior to identify the MMSE questions that would be best to determine CIm. The Modified MMSE was developed with nine variables instead of the 19 original MMSE variables in a bid to lessen the low literacy bias (Icaza, 1999). Each respondent's score was then computed, with a score of <12 (out of a maximum of 30) indicating CIm (Palaez et al., 2004).

The Pfeffer Scale measures functional capacity, taking into consideration ability to perform daily tasks as well as instrumental activities such as conduct of simple fiscal transactions, doing laundry, and comprehension of current events and it is used to assess and compare normal and demented adults (Pfeffer, Kurosaki, Harrah, Chance, & Filos, 1982). The modified MMSE was used in conjunction with the Pfeffer Scale for those persons who obtained a score of 12 or less in the modified MMSE and was administered to an informant or carer accompanying the participant with cognitive deterioration in order to confirm that their level of cognitive decline affected functional capacity (Palaez et al., 2004). A participant scoring 12 or less on the Modified MMSE and 6 or more on the Pfeffer Scale was considered unable to be interviewed and a proxy of the participant was asked to respond instead (Palaez et al., 2004).

Level of education

In this study, a high education level was defined as any learning that occurred after completion of secondary school while a low education level was defined as having either primary and/or secondary school education only.

6.4.2 Statistical Analysis

Logistic regression analysis using Stata version 12 was carried out to assess the relationship of gender, age and education on cognitive status. The Sullivan Method was used to calculate life expectancies with and without CIm (CILE and CIFLE) for each country (and gender) by applying country and age-specific CIm prevalence from the study outlined above to country-specific life tables. CIFLE reflects the number of remaining years, at a particular age, which an individual can expect to live on average in the absence of CIm (Jagger et al., 2006). Life tables were calculated from mortality rates and population figures obtained from the World Health Organisation. Five year age intervals were used during analysis except for the final age-grouping which was recorded as 85+ years (Jagger et al., 2006). The curvature of the true survival curve over each age interval (a_x) was estimated as 0.5 since this is generally a reasonable assumption (Chiang, 1984; Jagger et al., 2006). The standard error of the estimates of CIFLE was calculated for all age and sex groupings in each country (Jagger et al., 2006). Men and women were analysed separately. Meta-regression models were fitted to all 7 countries together (Jagger et al., 2009) to investigate the relationship between education level and CIFLE at age 60 for men and women separately. The analyses conducted and results presented are unadjusted.

6.5 Results

The mean age of all persons in the study was 70.8 years (SD = 8.2). Overall 58.7% of study participants were female and there were proportionately more females than males in all countries. Around 80% of men and women overall had a low education level though this ranged from around 93% in Barbados (men: 94.4%; women: 92.5%) to 15% in Cuba (men: 14.9%; women: 16.8%).

Table 6.1 shows descriptive statistics for the populations under study in the seven countries.

Table 6.1: Mean Age and Proportion of Males and Females in Study Samples by Country

Country	*Mean Age (Years)*	*Males (%)*	*Females (%)*	*Low Education Level* Males (%)*	*Low Education Level Females (%)*
Argentina	70.74	37.0	63.0	92.5	85.6
Barbados	72.59	60.7	39.3	94.4	92.5
Brazil	73.28	40.8	59.2	86.1	91.5
Chile	71.57	34.3	65.7	87.6	92.0
Cuba	71.97	38.4	61.6	14.9	16.8
Mexico	64.71	41.2	58.8	81.5	82.7
Uruguay	70.94	36.6	63.4	77.3	84.2
TOTAL	70.8	41.3	58.7	80.0	78.5

**Low education level defined as primary and/or secondary school education.*

The prevalence of CIm ranged from a low of 8.5% (Argentina) to 23.4% (Chile). A greater proportion of females were recorded as having CIm in all countries. Figure 6.1 below highlights the prevalence of CIm by gender across the study sites.

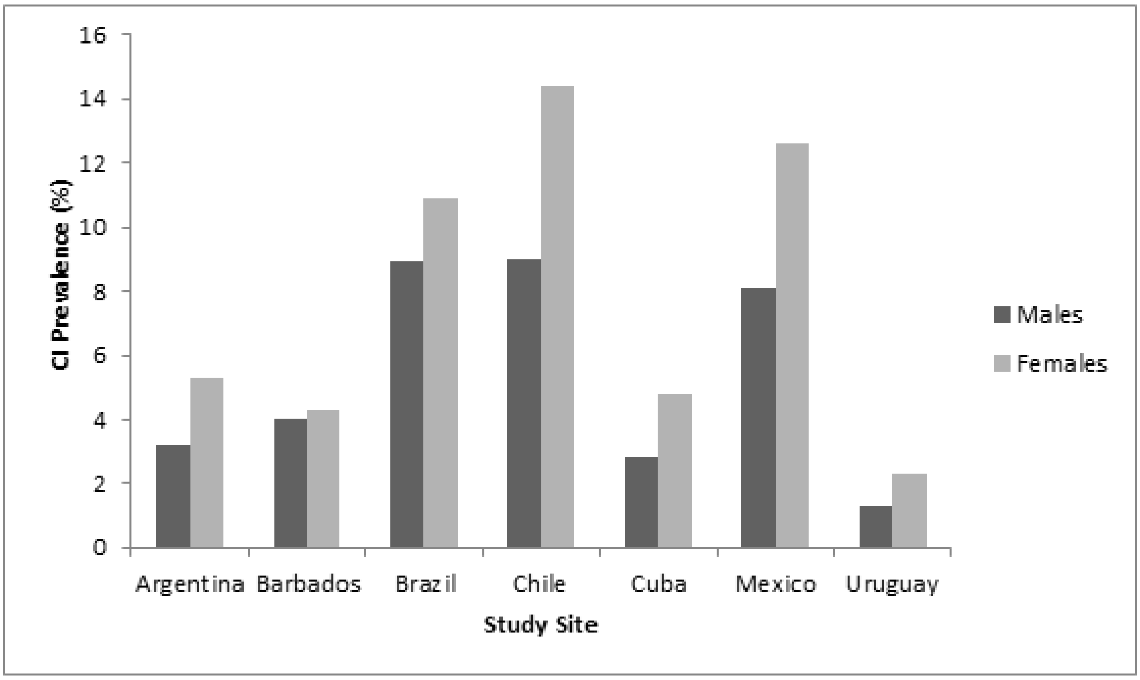


Figure 6.1: CIm Prevalence by Country and Gender

Logit models fitted to all study sites with the inclusion of a country effect indicated that age, education, gender, and country all had a significant impact on cognitive status. For every 1 year increase in age, the odds of CIm are increased (OR 1.11; 95% CI: 1.10–1.13). The odds of CIm were lower in males when compared to females (OR 0.74; 95% CI: 0.60–0.91). Compared to those with a high education level, the odds of CIm are increased for those with a low education level (OR 2.93; 95% CI: 1.97–4.34). There was a significant difference in the odds of CIm between the countries. Compared to Argentina (which was randomly selected as a reference) the odds of CIm were significantly higher in Brazil (OR 1.50; 95% CI: 1.01–2.24), Chile (OR 2.40; 95% CI: 1.62–3.56), Mexico (OR 2.95; 95% CI: 1.94–4.49), and Cuba (OR 2.61; 95% CI: 1.57–4.35) and significantly lower in Uruguay (OR 0.37; 95% CI: 0.21–0.65). The odds of CIm were not significantly different between Barbados and Argentina (reference) (OR 0.87; 95% CI: 0.56–1.35).

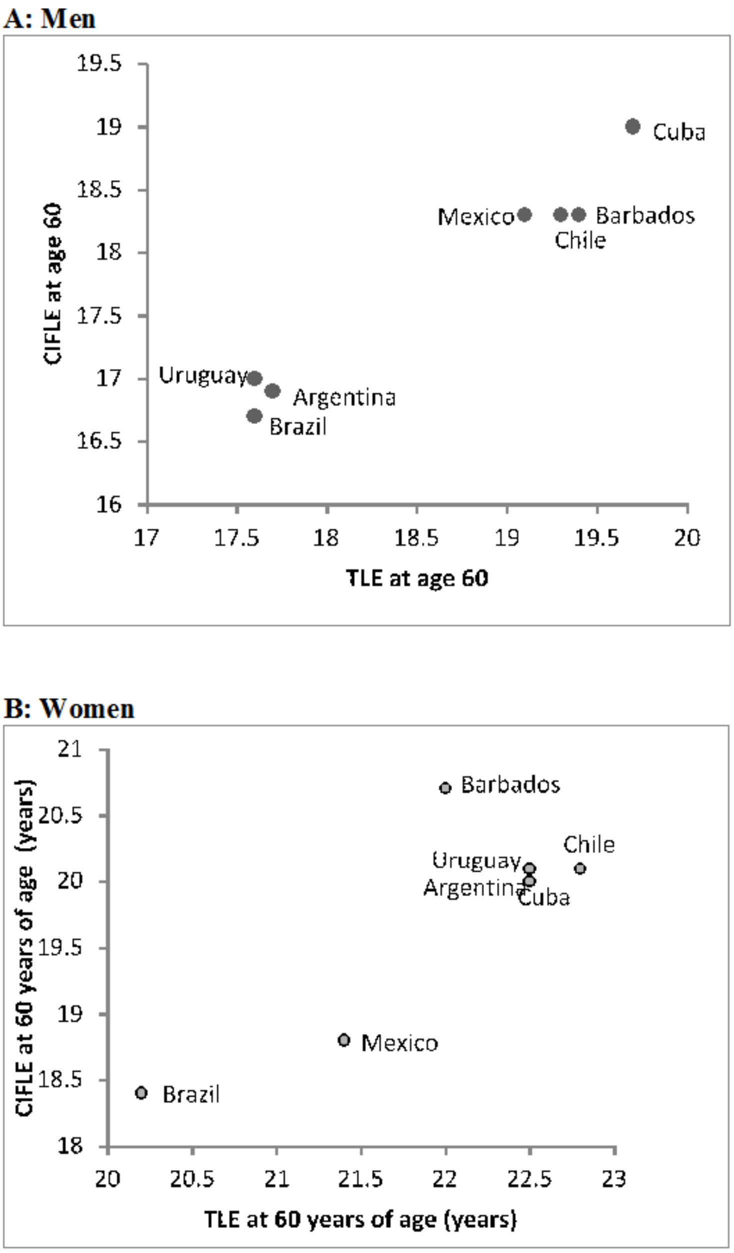
Logistic regression analysis was subsequently performed to assess the impact of age, gender and education levels on cognitive status in each country separately. In Argentina, Barbados, Brazil, Chile, Cuba and Mexico the log odds of CIm increase linearly as age increases. Thus a one year increase in age increases the odds of CIm by 1.12 (95% CI: 1.08–1.17) in Argentina, 1.17 (95% CI: 1.13–1.21) in Barbados, 1.11 (95% CI: 1.08–1.14) in Chile and 1.10 (95% CI: 1.06–1.13) in Cuba. A quadratic age term significantly improved the models for Brazil (p=0.04) and Mexico (p=0.01). In Brazil for example, holding gender and education level constant, increasing age from 60 to 61 increases the odds of CIm by 1.02 (95% CI: 0.94–1.11) while increasing age from 70 to 71 increases the odds of CIm by 1.08 (95% CI: 1.03–1.12) and increasing age from 80 to 81 increases the odds of CIm by 1.14 (95% CI: 1.10–1.17). In Mexico, holding gender and education level constant, increasing age from 60 to 61, 70 to 71 and 80 to 81 increases the odds of CIm by 0.96 (95% CI: 0.88–1.05), 1.05 (95% CI: 1.01–1.09) and 1.14 (95% CI: 1.08–1.21) respectively. Conversely, the odds of CIm decreased with age in Uruguay. The statistically significant quadratic age term (p=0.04) included in the final regression model for Uruguay showed that an increase in age from 60 to 61, 70 to 71 and 80 to 81 decreased the odds of CIm by 1.72 (95% CI: 1.15–2.59), 1.36 (95% CI: 1.12–1.65) and 1.08 (95% CI: 0.98–1.18) respectively.

A significant gender effect was observed in Mexico (p=0.01) with males having lower odds of CIm compared to females after adjusting for age and education level (OR 0.46; 95% CI: 0.27–0.81).

In Brazil (OR 4.85; 95% CI: 1.17–20.04), Chile (3.11; 95% CI: 1.10–8.79), Cuba (2.30; 95% CI: 1.25–4.23) and Mexico (3.84; 95% CI: 1.37–10.77), the odds of CIm are increased for persons with a low education level when compared to persons with a high education level.

Table 6.2 presents TLE, CILE, CIFLE and %CIFLE/TLE for males and females by country and at ages 60 and 80 years. In Figure 6.2, it can be observed that at age 60 years, TLE for males varies from a low of 17.6 years (Brazil and Uruguay) to a high of 19.7 years (Cuba). For females, TLE is generally longer than males and at age 60 varied from a high of 22.8 years (Chile) to a low of 20.2 years (Brazil). By the age of 80, the longest TLE and CIFLE for males were observed in Mexico (TLE: 7.2 years, CIFLE: 6.9 years) while the shortest TLE and CIFLE were observed in Barbados (TLE: 6.0 years, CIFLE: 4.8 years). For females at age 80, Chileans and Cubans recorded the longest TLE (8.2 years) while Mexicans recorded the longest CIFLE (7.1 years).

At age 60, males in Uruguay (97.0%) and Cuba (96.6%) spend the greatest proportion of their remaining lives free of CIm when compared to those at other study sites despite males in Uruguay having the shortest TLE at age 60. Among females aged 60, the greatest proportion of life is spent free of CIm in Barbados (94.1%) and Brazil (91.2%). At age 80, males in Argentina (98.4%) and Chile (97.0%) and females in Mexico (91.3%) and Barbados (89.4%) spend the greatest proportion of their lives free of CIm.



C	Men		Women	
	TLE	CIFLE	TLE	CIFLE
Argentina	17.7	16.9	22.5	20.0
Barbados	19.4	18.3	22.0	20.7
Brazil	17.6	16.7	20.2	18.4
Chile	19.1	18.3	22.8	20.1
Cuba	19.7	19.0	22.5	20.0
Mexico	19.3	18.3	21.4	18.8
Uruguay	17.6	17.0	22.5	20.1

Figure 6.2: Total Life Expectancy (TLE) and CIm-Free Life Expectancy (CIFLE) at 60 years of age for countries under study. (A) and (B) shows scatter graphs for men and women, respectively. (C) shows data for scatter graphs.

Table 6.2: TLE, CILE and CIFLE according to age based on MMSE results from SABE countries (Upper and Lower 95% Confidence Intervals in Brackets)

Males Aged 60							
	Argentina	**Barbados**	**Brazil**	**Chile**	**Cuba**	**Mexico**	**Uruguay**
TLE	17.7	19.4	17.6	19.1	19.7	19.3	17.6
CILE	0.8	1.1	0.9	0.8	0.7	1.0	0.8
CIFLE	16.9(16.5 – 17.3)	18.3(18.1 – 18.6)	16.7(16.4 – 17.0)	18.3 (17.9 – 18.6)	19.0 (18.7 – 19.3)	18.3(17.9 – 18.7)	17.0(16.8 – 17.3)
%CIFLE/TLE	95.2	94.5	95.0	95.8	96.6	94.8	97.0
Females Aged 60							
TLE	22.5	22.0	20.2	22.8	22.5	21.4	22.5
CILE	2.5	1.3	1.8	3.1	2.1	2.1	2.0
CIFLE	20.0 (19.4 – 20.6)	20.7 (20.2 – 21.1)	18.4(18.1 – 18.7)	20.1(19.7 – 20.6)	20.0(19.6 – 20.4)	18.8(18.2 – 19.3)	20.1(19.6 – 20.5)
%CIFLE/TLE	88.8	94.1	91.2	88.5	89.0	87.8	89.1
Males Aged 80							
TLE	6.3	6.0	6.8	6.8	6.8	7.2	6.5
CILE	0.1	1.2	0.8	0.2	0.5	0.3	0.5
CIFLE	6.2(5.8 – 6.5)	4.8(4.5 – 5.2)	6.2(6.0 – 6.5)	6.6(6.3 – 6.9)	6.3(6.0 – 6.6)	6.9(6.4 – 7.3)	6.0(5.6 – 6.4)
Females Aged 80							
TLE	7.8	7.5	7.2	8.2	8.2	7.8	7.9
CILE	0.7	1.2	1.2	1.5	1.5	0.7	1.0
CIFLE	6.4(5.8 – 7.1)	6.7(6.3 – 7.2)	6.0(5.6 – 6.3)	6.7 (6.2 – 7.2)	6.7(6.2 – 7.1)	7.1(6.6 – 7.7)	6.9(6.4 – 7.3)
%CIFLE	82.4	89.4	82.8	82.1	81.2	91.3	87.0

To see the extent to which educational level in a country explained the observed differences in CIFLE, meta-regression models were fitted to CIFLE at age 60 separately for males and females but no association was found (males: $p = 0.408$; females: $p = 0.695$). This conclusion remained when the analysis was repeated excluding Cuba which had by far the largest percentage with high education levels (see Figure 6.3 and Figure 6.4 below).

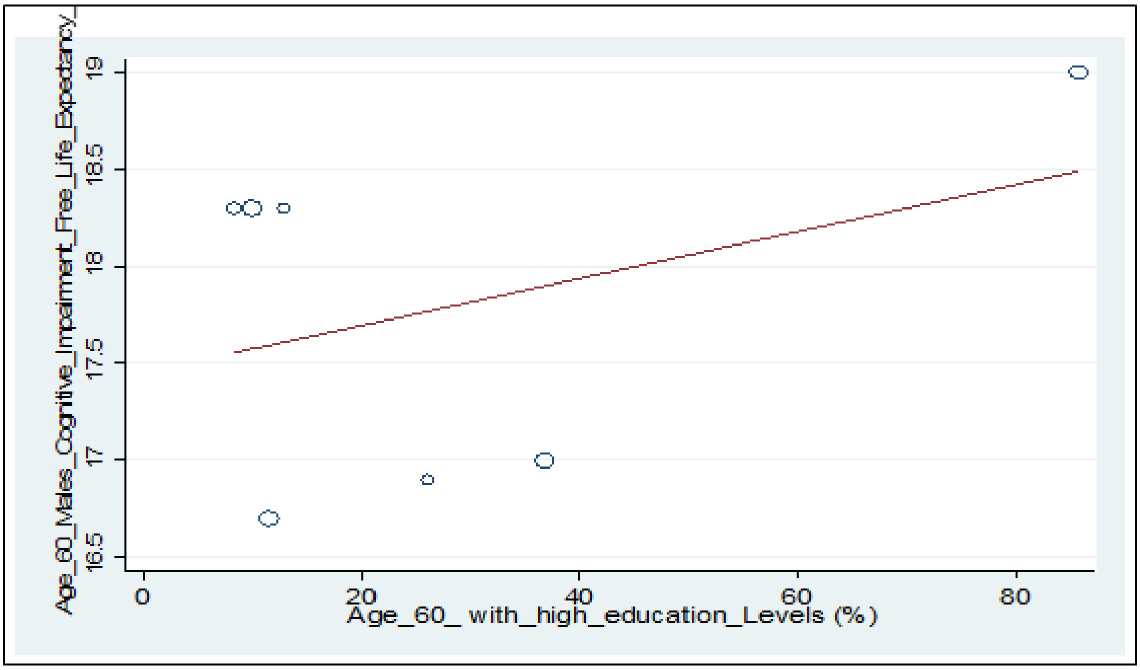


Figure 6.3: Meta-regression Results – Relationship between Education Level and CIFLE at Age 60 Males

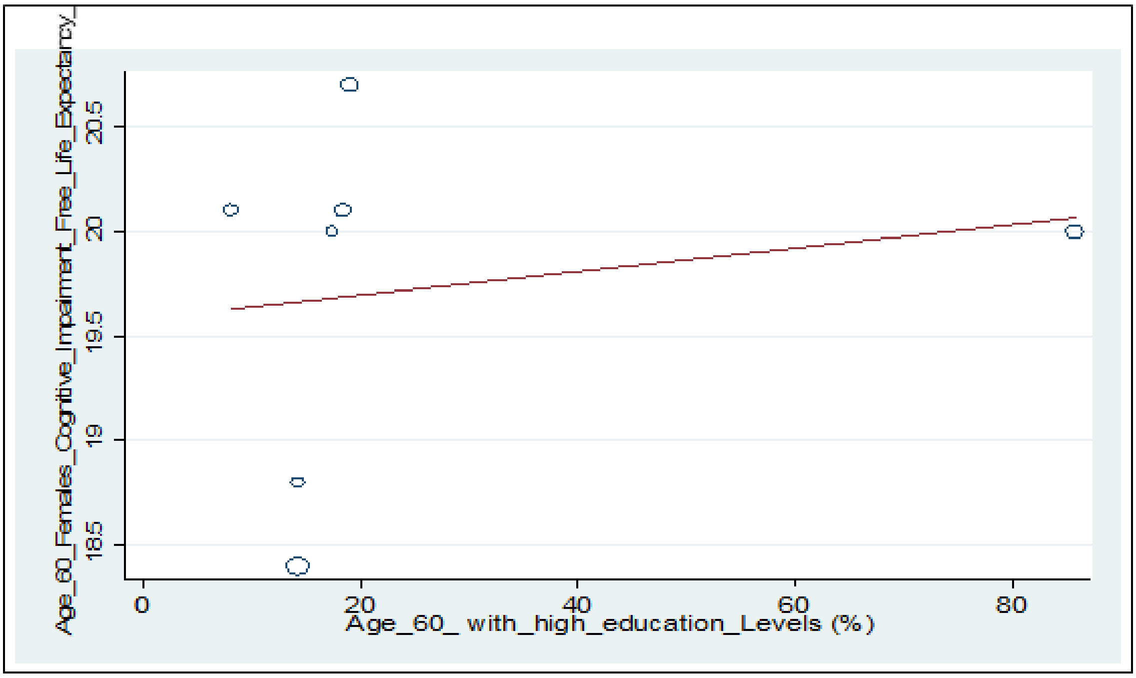


Figure 6.4: Meta-regression Results – Relationship between Education Level and CIFLE at Age 60 Females

6.6 Discussion

In the LAC countries under study, the odds of CIm increased with age in all countries except Uruguay. A significant gender effect was observed only in Mexico with males having lower odds of CIm compared to females. For males, TLE at age 60 years was highest in Cuba and lowest in Brazil and Uruguay. CIFLE at age 60 for males was highest in Barbados, Chile and Mexico and lowest in Brazil. However, although Uruguay had the lowest TLE and did not have the highest CIFLE at age 60, Uruguayan men experienced the greatest proportion of their remaining life free of CIm (97.0%). For females at age 60 years, TLE was highest in Chile and lowest in Brazil. CIFLE for females at age 60 was highest in Barbados and lowest in Brazil. Although higher odds of CIm were observed in those with low education in Brazil, Chile, Cuba and Mexico, level of education did not appear to explain the differences in CIFLE at age 60 in LAC countries.

The differences observed among countries in our study are noteworthy and future research is necessary to determine the exact cause. Possible explanations include the effect of confounding factors not controlled for such as race/ethnicity, or differences in the application of the survey instrument at each study site. In addition, research indicates that among the study countries there is great variation in the structure of the healthcare systems and the role played by the public health sector in protecting the health of the older population and these could account for the differences observed between countries (Wong, Peláez, Palloni, & Markides, 2006).

While the Uruguay sample had a higher mean age than Mexico (70.94 and 64.71 respectively), TLE at age 60 in Mexico is much higher. This may be explained by the oversampling of the target population in Mexico where all eligible individuals found in a target home were interviewed compared to Uruguay where only one individual was selected per household (Palaez et al., 2004). It is also possible that in Uruguay, stratification and subsequent sampling was defined by socioeconomic as well as geographic and global indicators while in Mexico stratification may have been based solely on geography (Wong et al., 2006). Reports on CIm of older people in low- and low- and middle- countries are rare. However, the Mexican Health and Ageing Study has produced data estimating prevalence of CIm (no dementia) that can be used for comparison with results obtained in the present study. Published data from the Mexican study estimates CIm prevalence at 28.7% (Mejia-Arango & Gutierrez, 2011). These estimates are higher than those obtained in the present study for the Mexican population (approximately 10.8%) and may reflect the fact that SABE data were collected from city dwellers only, who may have greater access to health care, belong to higher socio-economic groupings, and have a healthier diet. Additionally, differing methodologies used for diagnosis of CIm may have led to variations in results.

Studies on dementia-free life expectancy (DFLE) for some Latin American countries (Uruguay, Chile and Brazil) have been published and estimates range from 3.4% to 7.1% (Mejia-Arango & Gutierrez, 2011). The results of the present study provide CIm prevalence estimates in these countries between 1.9% and 12.5%.

Comparisons with developed countries such as Australia, Canada and England and Wales provide much needed perspective. An analysis of DFLE in Australia during the period 2004–2006 revealed that males and females aged 65 were expected to live a further 18.3 and 21.5 years respectively (Nepal et al., 2008). Of these years, males could expect to have a DFLE of 17.1 years and females 19.5 years (Nepal et al., 2008). Figures for the Canadian population are similar, Canadian males and females aged 65 are expected to live a further 16.4 years and 19.4 years respectively. Of these years, 13.8 years for males and 17.2 years for females are expected to be lived free from CIm (Dubois & Hébert, 2006). When compared to Australian and Canadian males, TLE and CIFLE are lower in all LAC countries. For example in Cuba, the country with the highest TLE and CIFLE at age 65, a male is expected to live a further 15.9 years of which 15.3 would be spent CIm-free. When comparisons are made among females, the TLE and CIFLE for Australian females are higher than those in Canada but LAC countries record the lowest estimates. In Australia, a female aged 65 is expected to live a further 21.5 years of which 19.5 would be spent free of CIm while in Chile, the LAC country with the highest TLE at age 65, a female is expected to live a further 18.7 years of which 16.2 years would be spent CIm-free.

The Medical Research Council Cognitive Function and Ageing Study (MRC CFAS) allows for comparisons between LAC countries and the older population in England and Wales in 1991 (Brayne, Matthews, McGee, & Jagger, 2001). In both settings, men live shorter lives than women. Among both sexes, TLE is higher across all age-groups in LAC countries when compared to that observed in England and Wales. For instance, males in Cuba and Barbados at age 65 can expect to live a further 15.9 and 15.7 years respectively while those in England and Wales can expect to live a further 14.1 years. In the case of females at 65 years of age those in England and Wales have a TLE of 17.8 years and a CILE of 1.2 years. This is lower than the CILE for the same age in all LAC study countries. It must be noted though that these comparisons are based on estimates over a decade apart (CFAS:1991, LAC 1999–2000) (Brayne et al., 2001).

The effect of education on health outcomes including CIm has been published in relation to previous studies (Anstey & Christensen, 2000; Matthews et al., 2009). The results of this study, which show that the odds of CIm are greater in persons with low education levels, support previous research from the United Kingdom which concluded that there is a substantial burden of life expectancy with CIm for groups with low education (Anstey & Christensen, 2000; Matthews et al., 2009).

Among the limitations of this current study is the inability to disaggregate CIm by type of dementia. However, SABE represents the only comprehensive cross-national study on the health of elders in the LAC region and while likely to have underestimated prevalence estimates due to its focus on city dwellers, its results are useful. Secondly, no data were collected from adults living in institutions in any of the study countries and so may not be representative of that population. Research indicates though that the percentage of the population in institutions in LAC countries is quite small and so this bias is also likely to be small. Thirdly, the MMSE may lack the sensitivity required to detect early signs of dementia and may result in incorrect false-diagnoses. (Andrade, 2009).

The main strength of this study is the fact that CIm and CIm-free life expectancies have not been published for such a wide range of LAC countries prior to this and provide useful data for policymakers to assess healthy ageing trends.

6.7 Chapter Conclusion

The results from this study are consistent with other published findings which have indicated that age, sex, and education level are significant predictors of CIm. Novel though is the comparison of healthy life expectancies among LAC countries and these show substantial differences in the absolute years lived and the proportion of remaining life spent free of CIm. These results provide a greater understanding of the burden of CIm in LAC and highlight the need for follow-up surveys to be conducted as their populations continue to age.

Chapter 7

Analysis of Dietary Patterns in relation to Cognitive Impairment in Australia using a Data-driven Method

7.1 Chapter Summary

Principal Component Analysis (PCA) was used to determine the association between dietary patterns and cognitive function and to examine how classification systems based on food groups and food items affect levels of association between diet and CIm.

Three Waves of dietary data from the Australia Diabetes Obesity and Lifestyle Study (AusDiab) were utilised. At Wave 3 the Mini Mental State Examination (MMSE) assessed cognitive status, the Symbol Digit Modalities Test (SDMT) assessed processing speed, and a list recall task measured memory.

Dietary patterns were obtained using PCA and three methods of food use classification – 101 individual food items, 32 food groups, and 20 food groups. Variable reduction using 20 food groups, as opposed to 101 individual food items or 32 food groups, explained a greater proportion of food use variance in the sample. The only significant results obtained in logistic regression analysis were observed when PCA-derived dietary patterns had utilised 101 individual food items. At Wave 1, for every one unit increase in the following pattern scores, the odds of CIm decreased [(Fruit and Vegetable Pattern: p = 0.03, OR 1.06, CI: 1.01 – 1.12); (Fish, Legumes and Vegetable Pattern: p = 0.04, OR 1.03, CI: 1.00 – 1.06); (Dairy, Cereal and Eggs Pattern: p = 0.00, OR 1.02, CI: 1.01 – 1.03)]. At Wave 2, also using 101 food items, for every one unit increase in the 'Variety' pattern score, the odds of CIm increased (Variety Pattern: p = 0.05, OR 1.02, CI: 1.00 – 1.04).

GLM using 101 individual food items showed that at Wave 2 the 'Variety' dietary pattern was a predictor of poorer processing speed (β= -0.03, SE = 0.02, p = 0.02) while at Wave 3 the 'Plant-based, Processed Fish and Yoghurt' dietary pattern was predictive of better memory, processing speed and verbal knowledge (β = 0.01, SE = 0.01, p = 0.01; β = 0.05, SE = 0.02, p = 0.02; β = 0.04, SE = 0.01, p = 0.01). At Wave 3, the 'Plant-based and Snacks' dietary pattern was shown to be a predictor of better processing speed (β = 0.11, SE = 0.05, p = 0.02).

GLM using 32 food groups also produced some significant findings. At Wave 1, the 'Western' dietary pattern was predictive of poorer memory and processing

speed (β = -0.01, SE = 0.00, p = 0.00 and β = -0.02, SE = 0.01, p = 0.04 respectively), the 'Vegetable, Grains and Wine' pattern was a predictor of better processing speed (β = 0.02, SE = 0.01, p = 0.03) while the 'Prudent' pattern was predictive of poorer processing speed (β = 0.04, SE = 0.01, p = 0.00). At Wave 2, the 'Prudent' and 'Eggs and Alcohol' patterns were predictive of poorer processing speed (β = -0.03, SE = 0.01, p = 0.01 and β = -0.01, SE = 0.00, p = 0.02 respectively) while the 'Vegetable' pattern was predictive of better processing speed (β = 0.04, SE = 0.02, p = 0.01).

Finally using 20 food groups, at Wave 1 the 'Variety' dietary pattern was a predictor of poorer processing speed (β = -0.03, SE = 0.01, p = 0.02) and the 'Dairy, Grains and Alcohol' pattern predictive of poorer memory (β = -0.00, SE = 0.00, p= 0.01). At Wave 2, the 'Plant-based' dietary pattern was predictive of poorer processing speed (β = -0.02, SE = 0.01) while the 'Western' pattern was predictive of poorer memory and processing speed (β = -0.01, SE = 0.00, p = 0.01 and β = -0.04, SE = 0.02, p = 0.02 respectively).

Complex patterns of associations between dietary factors and cognition were evident, with the most consistent finding being the protective effects of high vegetable and plant-based food item consumption and negative effects of 'Western' patterns on cognition. Further long-term studies and investigation of the best methods for dietary measurement are needed to better understand diet-disease relationships in this age group.

7.2 Background

Diet is among several modifiable factors that have been found to influence cognitive function (Gillette-Guyonnet et al., 2013; McNeill, Winter, & Jia, 2009; Shatenstein et al., 2012). Age is presently the strongest known predictor for cognitive decline and CIm has been shown to adversely affect quality of life and functional ability (Barnes & Yaffe, 2009; Matthews et al., 2009). Risk reduction is especially important because there is still no effective treatment for dementia (Andrade & Radhakrishnan, 2009).

Studies aimed at elucidating the association between diet and cognitive function have utilised both the single nutrient and dietary pattern approaches (Jacobs & Steffen, 2003; Waijers, Feskens, & Ocké, 2007). While the single-nutrient approach has addressed various public health problems, many researchers theorise that due to high correlations between individual food constituents there should be a shift toward analysis using a dietary pattern approach (Jacobs & Steffen, 2003; Scarmeas, Stern, Mayeux, Manly, et al., 2009).

Few studies have examined the effect of dietary patterns on cognitive function using a data-driven method and even fewer of these studies have utilised

Australian data. Only two studies were identified that utilised a data-driven approach to dietary analysis that have examined links with cognition in an Australian sample. The first used data from the Melbourne Collaborative Cohort Study in conducting factor analysis to determine the effect of dietary intake on psychological distress in older Australians (Hodge, Almeida, English, Giles, & Flicker, 2013) and the second utilised data from the Personality and Total Health (PATH) Through Life Study to examine the diet-depression relationship in three cohorts (Jacka, Cherbuin, Anstey, & Butterworth, 2014).

PCA is a data-driven approach that reduces a large number of food variables into a smaller set that captures the major dietary traits in the population (Reedy et al., 2010). In nutritional epidemiology, PCA can be used to investigate exposure-disease associations. As it relates to older age groups, such information can serve to develop age-specific guidelines and policies. One of the major criticisms of PCA however is that results can differ based on the methods employed during variable reduction and classification (Fabrigar, Wegener, MacCallum, & Strahan, 1999; McCann, Marshall, Brasure, Graham, & Freudenheim, 2001) and there is presently no accepted gold standard for dietary analysis to guide researchers.

7.3 Aim

- To determine how classification systems used to reduce food variables before application of PCA affect the observed association between diet and cognitive function.
- To examine the association between dietary patterns and cognitive function in a population-based cohort of Australian adults at three different time points.
- To determine the percentage of the variance in food use explained by the different variable reduction methods employed i.e. using 101 individual food items, 32 food groups, and 20 food groups.

7.4 Methodology

7.4.1 Study Design and Sample

The study utilised existing data derived from the AusDiab study, a population-based national survey of the general (non-institutionalised) Australian population aged 25 years and older (Dunstan et al., 2001). The baseline examination was undertaken in 1999–2000 (n=11,247), with follow-ups conducted in 2004-05 (n=8,798) and 2011–12 (n= 6,186) (Dunstan et al., 2001). Dietary data were obtained from a sub-group of the sample using a questionnaire at all Waves (Wave 1: n = 3298; Wave 2: n = 2475; Wave 3: n = 2435) (Dunstan et al., 2001). Measurement of cognitive function was conducted on those who attended survey sites in the third Wave of data collection (n = 4,764) (Tanamas et al., 2013b). The present study focusses on the older segment of the sample (age 60+) that completed the MMSE and tests of memory, verbal ability, and processing speed.

Cognitive Outcome Measurement

The MMSE was used in data collection 2011–12 (AusDiab Wave 3) to determine CIm status. Participants were classed based on their MMSE score as being either cognitively impaired (score of 0–23) or not cognitively impaired (score of 24–30) (Anstey et al., 2006).

The California Verbal Learning Test (CVLT) was used to assess memory using a 16-point scoring system. For this test, participants were asked to recall and repeat a list of 16 common shopping items that had been read to them by an interviewer. During a short delay of 20 minutes, during which participants were given other tasks to perform, the interviewer then asked the participant to recall the 16 common shopping list items again (delayed recall). The Spot-the-Word test (STW) was used in this study to test participants' vocabulary and verbal knowledge with scores ranging from 0 to 60. STW testing involved presenting participants with pairs of items – one of which was a real word and the other a non-word; participants were then required to identify the word. Performance of the STW has not been shown to decline with age and is highly correlated with verbal acumen (Baddeley, Emslie, & Nimmo-Smith, 1993). Finally, processing speed was tested using the Symbol-Digit Modalities Test (SDMT). Participants were provided with a reference key and asked to pair geometric figures with specific numbers. Using the SDMT, participants were scored from 0–60 on the number of correct answers provided in 90 seconds.

Food Consumption Data and Classification

The AusDiab semi-quantitative food frequency questionnaire consisted of 121-items that asked participants about their consumption of 101 food items (Grantham et al., 2013). This questionnaire assessed usual intake and recorded the amount and types of specific food items consumed by participants. In some cases, for example casseroles and potatoes, pictures of serving sizes were provided so that persons could indicate whether they had more or less of a given food item each day and each week, using the past 12 months as a reference. Participants were asked to specify the number of times they had specific food items in the past year by checking 1 of 10 frequency categories ranging from 'never' to 'three or more times per day'. The average daily intake of food weight in grams was subsequently computed and used in the present analysis.

Three methods were used in order to classify these foods before applying PCA. In the first instance, the 101 individual food items asked about in the questionnaire were used (no categorisation). In the second and third instances, foods were combined and reduced to 32 and 20 food groups respectively based on nutrient content and culinary usage – a method employed in several other published studies (McCann et al., 2001; van Dam, Rimm, Willett, Stampfer, & Hu, 2002) (see Appendix A.5).

Some foods were not categorised and were kept separate since they did not comfortably fit into any of the categories for example, pizza and meat pies (Khani, Ye, Terry, & Wolk, 2004; McCann et al., 2001). More specifically, for the reduction of 101 items to 32 food groups individual items were classed into groups for example, the item 'Processed Meats' was a tally of a participant's bacon, ham, salami, and sausage consumption in g/day while the item 'Red Meats' was a tally of beef, pork, lamb, veal, and hamburgers in g/day. In the final classification system, the 32 food groups were further categorised into broader groups which resulted in 20 food groups for example, the item 'Meats' was a tally of a participant's 'Processed Meats' and 'Red Meats' consumption in g/day.

7.4.2 Statistical Analysis

PCA using SPSS version 22 was conducted to identify underlying dietary patterns. In determining the number of components to retain for further analysis, consideration was given to component eigenvalues greater than 1 along with examination of scree plots. Components were rotated by an orthogonal (varimax) rotation to improve interpretability. Overall though, the comprehensibility and interpretability of the rotated factors were considered along with the aforementioned criteria. Similar to other studies, derived components were labelled based on our description of the observed patterns (Hu et al., 1999).

Dietary pattern scores were calculated for each individual at each Wave using all three classification methods (101 individual food items, 32 food groups, and 20 food groups). Scores for an observed pattern were computed using the following equation: $i = \sum_j [(b_{ij}/\lambda_i)X_j]$ (Hu et al., 1999). Variables with factor loadings of ≥ 0.30 were included in the weighted average (Hosking & Danthiir, 2013; Northstone, Ness, Emmett, & Rogers, 2007).

Logistic regression analysis was performed to determine the association between dietary pattern scores at each Wave and cognitive status at Wave 3 using all three food item categorisation methods i.e. 101 individual food items, 32 food groups, and 20 food groups.

Generalised linear models (GLM) were used to estimate the associations between dietary pattern scores at each Wave and memory, verbal ability and processing speed using all three food variable reduction methods – 101 individual food items, 32 food groups, and 20 food groups.

In this study, 2721, 1550, and 934 participants were excluded from the current analysis at Waves 1, 2 and 3 respectively since these participants had no dietary and/or cognitive data recorded. The final samples included at each Wave were as follows: Wave 1: 577 participants, Wave 2: 1550 participants, and Wave 3: 934 participants.

7.5 Results

Descriptive statistics for the AusDiab sample are presented in Table 7.1. A total of 577 participants (49.22% female) had both diet and cognitive data recorded at Wave 1. At Waves 2 and 3, 925 (53.73% female) and 1501 (53.76% female) participants had both diet and cognitive data recorded respectively.

Table 7.1: Descriptive Statistics at Waves 1, 2 and 3 for the AusDiab sample who had both Dietary and CIm data (Age 60+)

Variables	*Wave 1 (N=3298; n=577)*	*Wave 2 (N=2475; n=925)*	*Wave 3 (N=2435; n=1501)*
Age Range (years)	60–83	60–88	60–85
Mean Age – years (SD)	66.07 (4.85)	67.39 (5.82)	67.69 (5.36)
Female (%)	284 (49.22)	497 (53.73)	807 (53.76)
BMI – kg/m^2 (SD)	26.89 (4.09)	27.70 (4.75)	28.00 (5.05)
Secondary School (%)	242 (24.4)	206 (22.3)	466 (31.0)
Tertiary Level (%)	229 (401)	280 (30.4)	473 (31.5)
Other – Trade, Technician, Primary (%)	100 (17.4)	439 (47.3)	579 (38.5)
Current Smoker (%)	29 (5.1)	37 (4.2)	53 (3.7)
Ex-Smoker (%)	182 (32.0)	295 (33.2)	522 (36.4)
Non-smoker	357 (62.9)	556 (62.6)	859 (59.9)
Exercise Mean (SD), mins./week	292.45 (324.21)	290.50 (309.75)	358.66 (371.36)
Mean MMSE Score (SD)			28.28 (1.91)
Mean CVLT Score (SD)			6.08 (2.30)
Mean STW Score (SD)			50.47 (5.89)
Mean SDMT Score (SD)			46.20 (9.96)
Impaired (%) (SD)			47 (3.1)

Dietary Pattern Analysis

At all Waves, classification method affected the number and components of the patterns identified. Variable reduction using 20 food groups explained a greater proportion of variance in the sample than variable reduction using 32 food groups and 101 individual food items. Use of 20 food groups explained 30.74%, 37.13%, and 38.49% of total variance in food use in the sample at Waves 1, 2, and 3 respectively. Comparatively, use of 101 individual foods explained 23.22%, 18.43%, and 14.01% of total variance in food use in the sample at Waves 1, 2 and 3 respectively and use of 32 food groups explained 29.74%, 34.04%, and 20.52% of total variance in food use at Waves 1, 2 and 3 respectively.

Wave 1 Dietary Patterns using 101 individual food items

Seven dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.2.

Table 7.2: Factor-loading matrix for 7 major dietary patterns identified at Wave 1 using 101 individual food items

Food Item	Pattern 1 (Fruit and Vegetable)	Pattern 2 (Snack & Processed Food)	Pattern 3 (Veg-etable)	Pattern 4 (Meat)	Pattern 5 (Fish, Legumes & Vegetable)	Pattern 6 (Veg, Pasta, Alcohol)	Pattern 7 (Dairy, Cereals & Eggs)
Carrots	.705						
Onion	.563						
Beetroot	.533						
Pumpkin	.507					-.373	
Mango	.465						
Zucchini	.452						
Avocado	.435		.348				
Peaches	.430						
Apricots	.404						
Crackers	.376						.331
Potatoes	.371	.313					
Multigrain bread	.337						
Cakes		.595					
Jam		.524					
Ice cream		.522					
Sweet Biscuits		.462					
Salami		.447					
Sausages		.394					

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Table 7.2 – Continued

Food Item	Pattern 1 (Fruit and Vegetable)	Pattern 2 (Snack & Processed Food)	Pattern 3 (Vegetable)	Pattern 4 (Meat)	Pattern 5 (Fish & Plant-based)	Pattern 6 (Veg, Pasta, Alcohol)	Pattern 7 (Dairy, Cereals & Fruit)
Chocolate		.387					
Sugar		.370	-.319				
Meat pies		.356					
Vegemite		.317					
Lettuce			.580				
Cucumber			.566				
Capsicum			.434				
Peas	.310		-.426				
Celery			.415				
Tomatoes			.398				
Chips			-.361				
Yoghurt			.357				
White bread			-.327				
Pork				.782			
Veal				.757			
Lamb				.705			
Beef				.628			
Chicken				.426			
Peanut butter				.331			
Soft cheese				.306			
Fish					.520		
Other beans					.505		

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Table 7.2 – Continued

Food Item	Pattern 1 (Fruit and Vegetable)	Pattern 2 (Snack & Processed Food)	Pattern 3 (Vegetable)	Pattern 4 (Meat)	Pattern 5 (Fish & Plant-based)	Pattern 6 (Veg, Pasta, Alcohol)	Pattern 7 (Dairy, Cereals & Fruit)
Tofu					.505		
Spinach					.463		
Baked beans					.408		
Tinned fish					.390		
Ricotta or cottage cheese					.384		
Mushrooms	.312				.380		
Bean sprouts					.363		
Strawberries					.354		
Fried fish					.319		
Soya milk					.301		
Cauliflower						-.519	
Broccoli	.304					-.415	
Cabbage	.366					-.372	
Red wine						.363	
Pasta						.347	
Spirits						.301	
Full cream milk							-.478
Low-fat cheese							.448
Tinned fruit							.440
Cornflakes						.331	.369
Fruit juice							.368

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Table 7.2 – Continued

Food Item	Pattern 1 (Fruit and Vegetable)	Pattern 2 (Snack & Processed Food)	Pattern 3 (Vegetable)	Pattern 4 (Meat)	Pattern 5 (Fish & Plant-based)	Pattern 6 (Veg, Pasta, Alcohol)	Pattern 7 (Dairy, Cereals & Fruit)
Eggs							-.356
All bran							.323
Butter and margarine blends							-.317

Notes
Eigenvalues: Pattern 1 = 5.86; Pattern 2 = 4.55; Pattern 3 = 3.20; Pattern 4 = 2.75; Pattern 5 = 2.52; Pattern 6 = 2.40; Pattern 7 = 2.18

The first dietary pattern identified was labelled 'Fruit and Vegetable' because of the high loadings of unprocessed fruit and vegetables observed. The second dietary pattern identified was labelled 'Snack and Processed Food' due to the high factor loadings observed for foods that could be qualified as such for example, cakes, jam, ice cream, sausages, salami. Dietary pattern labels for the other observed dietary structures can be viewed in Table 7.2. Together, the dietary patterns identified accounted for 23.0% of total variance in the sample.

Wave 1 Dietary Patterns using 32 food groups

After applying PCA, four dietary patterns were extracted. The rotated component matrix with factor loadings is shown in Table 7.3.

Table 7.3: Factor-loading matrix for 4 major dietary patterns identified at Wave 1 using 32 Food Groups

Food Group	Pattern 1 (Western)	Pattern 2 (Prudent)	Pattern 3 (Veg., Grains & Wine)	Pattern 4 (High fat)
Processed Meats	.640			
Red Meats	.554			
Snacks	.507		.375	
Refined Grains	.432			
Poultry	.404			
Condiments	.392		.377	
Meat Pies	.377			
Chips/French Fries	.367			
Beer	.356			
Pizza	.315			
Other Vegetables		.704		
Green Leafy Vegetables		.544		
Fruit		.540		
Garlic and Onions		.518		
Fish		.429		
Nuts		.343		
Tomatoes		.335		
Dark Yellow Vegetables			.732	
Potatoes			.660	
Cruciferous Vegetables			.519	
Whole Grains			.395	
Wine			-.336	
High Fat Dairy Products				.689
Low Fat Dairy Products				-.641
Margarine				-.593
Butter				.510
Butter and Margarine Blends				.441

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Table 7.3 – Continued

Food Group	Pattern 1 (Western)	Pattern 2 (Prudent)	Pattern 3 (Veg., Grains & Wine)	Pattern 4 (High fat)
Eggs				.349

Notes
Eigenvalues: Pattern 1 = 3.52; Pattern 2 = 2.39; Pattern 3 = 1.90; Pattern 4 = 1.72

The first pattern identified was labelled 'Western' because of the predominantly high loadings of processed meats, refined grains, and convenience foods. The second dietary pattern identified was labelled 'Prudent' and had characteristically high factor loadings of fish, vegetables, and fruit. Dietary pattern labels for the other observed dietary structures can be viewed in Table 7.3. Together, the dietary patterns identified accounted for 30.0% of total variance in the sample.

Wave 1 Dietary Patterns using 20 food groups

Three dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.4.

Table 7.4: Factor-loading matrix for 3 major dietary patterns identified at Wave 1 using 20 Food Groups

Food Group	Pattern 1 (Variety)	Pattern 2 (Western)	Pattern 3 (Dairy, grains & alcohol)
Vegetables	.566		
Fish	.549		
Fruit	.544		
Poultry	.543		
Nuts	.497		
Condiments	.459	.371	
Meat	.418		.393
Fruit Juice	.392		
Sugar	.580		
Snacks		.545	
Fats and Oils		.530	
Meat Pies		.474	
Chips/French Fries		.448	
Legumes		-.378	
Dairy			-.611
Whole Grains	.420		-.564
Alcohol			.516
Refined Grains			.393

Notes
Pattern 1 = 5.86; Pattern 2 = 4.55; Pattern 3 = 3.20

The first pattern identified was labelled 'Variety' because of the high loadings of a wide variety of foods – vegetables, fruit, fish, meat, and nuts. The second dietary pattern was labelled 'Western' because of the high factor loadings of high fat and high sugar foods. The final dietary pattern was labelled 'Dairy, grains and alcohol' due to the high factor loadings of these foods recorded. Together, the dietary patterns identified accounted for 31.0% of total variance in the sample.

Wave 2 Dietary Patterns using 101 individual food items

Four dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.5 below.

Table 7.5: Factor-loading matrix for 5 major dietary patterns identified at Wave 2 using 101 individual food items

Food Item	Pattern 1 (Fish & plant-based)	Pattern 2 (Meat, poultry & sweet Snacks)	Pattern 3 (vegetable, legume & snacks)	Pattern 4 (Plant-based)	Pattern 5 (Variety)
Capsicum	.573				
Cucumber	.501				
Mushrooms	.482				
Lettuce	.478				
Avocado	.478				
Onion	.442			.307	.305
Garlic	.429				
Celery	.425				
Zucchini	.377				
Mango	.372				
Tinned fish	.340	.309			
Strawberries	.339				
White bread	-.327				.322
Nuts	.315				
Sausages		.693			
Pork		.643			
Lamb		.633			
Veal		.630			
Chicken		.578			
Beef		.558			
Ham		.515			
Salami		.390			

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Table 7.5 – Continued

Food Item	Pattern 1 (Fish & plant-based)	Pattern 2 (Meat, poultry & sweet Snacks)	Pattern 3 (vegetable, legume & snacks)	Pattern 4 (Plant-based)	Pattern 5 (Variety)
Sweet Biscuits		.345			
Tinned fruit		.328			
Cakes			.637		
Peanut butter			.632		
Ice cream			.568		
Other beans			.484		
Spinach			.460		
Melon			.448		
Beetroot			.427		
Peas			.380	.352	
Tomato sauce			.342		
Jam			.339		
Carrots				.668	
Pumpkin				.636	
Cauliflower				.596	
Cabbage				.571	
Broccoli				.535	
Potatoes				.494	
Green beans				.445	
Chips				.357	
Porridge				.323	
Eggs					.400
Pasta					.385

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Table 7.5 – Continued

Food Item	Pattern 1 (Fish & plant-based)	Pattern 2 (Meat, poultry & sweet Snacks)	Pattern 3 (vegetable, legume & snacks)	Pattern 4 (Plant-based)	Pattern 5 (Variety)
Bacon					.372
Full-cream milk					.352
Spirits					.341
Crisps					.332
Yoghurt	.314				-.319
Low-fat cheese					-.312
Fried fish					.309

Notes
Eigenvalues: Pattern 1 = 6.04; Pattern 2 = 4.43; Pattern 3 = 3.02; Pattern 4 = 2.67; Pattern 5 = 2.47

The first pattern identified was labelled 'Fish and plant-based' because of the high loadings of fish, vegetables, fruit and nuts. The second dietary pattern identified was labelled 'Meat, Poultry and Sweet snacks' due to high loadings of these food items. Dietary pattern labels for the other observed dietary structures can be viewed in Table 7.5. These dietary patterns together accounted for 18.0% of total variance in the sample.

Wave 2 Dietary Patterns using 32 food groups

Five dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.6 below.

Table 7.6: Factor-loading matrix for 5 major dietary patterns identified at Wave 2 using 32 Food Groups

Food Group	Pattern 1 (Western)	Pattern 2 (Prudent)	Pattern 3 (Vegetable)	Pattern 4 (Dairy, fat & sugar)	Pattern 5 (Alcohol & eggs)
Red Meats	.656		.322		.313
Processed Meats	.638				
Snacks	.549				
Poultry	.518				
Refined Grains	.471				
Condiments	.424				
Meat Pies	.403				
Fruit Juice	.332				
Pizza	.322				
Other Vegetables		.739			
Onions and Garlic		.594			
Green Leafy Vegetables		.559			
Nuts		.476			
Fruit		.464			
Whole Grains		.398			-.368
Tomatoes		.372			
Fish	.335	.341			
Dark Yellow Vegetables		.311	.743		
Cruciferous Vegetables			.639		
Potatoes			.549		
Chips/French Fries			.535		
High-fat Dairy Products				.670	
Butter				.516	

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Table 7.6 – Continued

Food Group	Pattern 1 (Western)	Pattern 2 (Prudent)	Pattern 3 (Vegetable)	Pattern 4 (Dairy, fat & sugar)	Pattern 5 (Alcohol & eggs)
Low-fat Dairy Products				-.499	-.473
Sugar				.443	
Margarine				-.330	
Butter and Margarine Blends					
Other Spirits					.479
Beer					.448
Eggs					.358
Wine					.341

Notes
Eigenvalues: Pattern 1 = 3.59; Pattern 2 = 2.38; Pattern 3 = 1.81; Pattern 4 = 1.67; Pattern 5 = 1.44

The first pattern identified was labelled 'Western' and had high loadings of red and processed meats, snacks, refined grains and convenience foods. The second pattern identified was called 'Prudent' as a result of the high loadings of vegetables, fish, nuts and whole grains. Pattern 3 was labelled 'Vegetable' and had high loadings of dark yellow vegetables, cruciferous vegetables and potatoes. Dietary pattern labels for the other observed dietary structures can be viewed in Table 7.7. These dietary patterns together accounted for 34% of total variance in the sample.

Wave 2 Dietary Patterns using 20 food groups

Four dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.7 below.

Table 7.7: Factor-loading matrix for 4 major dietary patterns identified at Wave 2 using 20 Food Groups

Food Groups	Pattern 1 (Plant-based)	Pattern 2 (Western)	Pattern 3 (Meat, poultry & fish)	Pattern 4 (Dairy, legumes & eggs)
Whole Grains	.666			
Vegetables	.609			
Condiments	.565	.367		
Nuts	.521			
Fruit	.511			
Fruit Juice	.377			
Refined Grains		.612		
Fats and Oils		.559		
Sugar		.416		
Pizza		.393		
Meat Pies		.384		
Snacks		.382	.358	
Chips/French Fries		.356		
Eggs		.318		
Poultry			.755	
Meat		.347	.698	
Fish			.591	
Dairy				.752
Legumes				-.657
Alcohol		.343		-.392

Notes
Eigenvalues: Pattern 1 = 2.90; Pattern 2 = 1.68; Pattern 3 = 1.52; Pattern 4 = 1.32

The first pattern identified was labelled 'Plant-based' and had high loadings of whole grains, vegetables, nuts and fruit. The second pattern was called 'Western' and had high loadings of refined grains, fats and oils and convenience foods. Dietary pattern labels for the other observed dietary patterns can be viewed in Table 7.7.

These dietary patterns together accounted for 37.0% of total variance in the sample.

Wave 3 Dietary Patterns using 101 individual food items

Three dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.8.

Table 7.8: Factor-loading matrix for 3 major dietary patterns identified at Wave 3 using 101 individual food items

Food Item	Pattern 1 (Plant-based & snacks)	Pattern 2 (Meat, poultry, fish, processed fruit)	Pattern 3 (Plant-based, processed fish and yoghurt)
Carrots	.670		
Potatoes	.641		
Pumpkin	.566		
Peas	.517		
Chips	.448		
Cabbage	.406		
Jam	.393		
Sweet biscuits	.368		
Cakes	.347		
Cauliflower	.343		
Ice cream	.325		
Chocolate	.322		
Tomato sauce	.321		
Apples	.321		
Beetroot	.320		
Weetbix	.303		
Pork		.613	
Fried fish		.570	
Lamb		.565	
Veal		.526	
Sausages		.519	
Chicken		.514	
Bacon		.512	
Beef	.348	.500	

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Table 7.8 – Continued

Food Item	Pattern 1 (Plant-based & snacks)	Pattern 2 (Meat, poultry, fish, processed fruit)	Pattern 3 (Plant-based, processed fish and yoghurt)
Salami		.432	
Fish		.409	
Tinned fruit		.382	
Ham		.371	
Avocado			.503
Garlic			.478
Lettuce			.466
Cucumber			.446
Capsicum			.441
Other beans			.417
Zucchini	.376		.408
Celery			.403
Nuts			.402
Spinach	.318		.395
Mushrooms	.328		.392
Yoghurt			.364
Onion	.341		.352
Tofu			.325
Strawberries			.321
Tinned fish			.308
Broccoli			.305

Notes
Eigenvalues: Pattern 1 = 6.82; Pattern 2 = 4.49; Pattern 3 = 2.85

The first pattern identified was labelled 'Plant-based and snacks' because of the high loadings of vegetables, legumes, cereals, sweet biscuits, and cake. The second dietary pattern identified was labelled 'Meat, poultry, fish and processed fruit' due to high loadings of these food items. The final dietary pattern was called 'Plant-based, processed fish and yoghurt' and had characteristically high factor loadings of vegetables such as avocado, lettuce, cucumber, beans, tinned fish, and yoghurt. These dietary patterns together accounted for 14.0% of total variance in the sample.

Wave 3 Dietary Patterns using 32 food groups

Two dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.9.

Table 7.9: Factor-loading matrix for 2 major dietary patterns identified at Wave 3 using 32 Food Groups

Food Group	Pattern 1 (Western)	Pattern 2 (Prudent)
Red Meats	.684	
Processed Meats	.617	
Chips/French Fries	.501	
Snacks	.482	
Refined Grains	.468	
High-fat Dairy Products	.465	
Poultry	.430	
Meat pies	.407	
Condiments	.396	
Sugar	.382	
Beer	.380	
Potatoes	.352	
Low-fat Dairy Products	-.336	
Pizza	.324	
Fruit Juice	.317	
Other Vegetables		.673
Green Leafy Vegetables		.587
Dark Yellow Vegetables		.569
Fruit		.569
Garlic and Onions		.488
Nuts		.468
Cruciferous Vegetables		.455
Whole Grains		.419
Fish		.392
Tomatoes		.333

Notes
Eigenvalues: Pattern 1 = 4.06; Pattern 2 = 2.51

The first pattern identified was labelled ‘Western’ and had high loadings of red and processed meats, refined grains, beer, and convenience foods. The second pattern identified was called ‘Prudent’ as a result of the high loadings of vegetables, fish, nuts, and whole grains. These dietary patterns together accounted for 21.0% of total variance in the sample.

Wave 3 Dietary Patterns using 20 food groups

Four dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Table 7.10 below.

Table 7.10: Factor-loading matrix for 4 major dietary patterns identified at Wave 3 using 20 Food Groups

Food Group	Pattern 1 (Western)	Pattern 2 (Plant-based)	Pattern 3 (Meat, poultry, fish & alcohol)	Pattern 4 (Legumes and dairy)
Fats and Oils	.555			
Snacks	.548	.423		
Meat pies	.545			
Chips/French Fries	.517			
Condiments	.457	.444		
Sugar	.436			
Refined Grains	.436		.301	
Pizza	.380			
Whole Grains		.611		
Fruit		.586	.307	
Nuts		.584		
Vegetables		.570		
Meats	.325		.734	
Poultry			.679	
Fish			.648	
Alcohol			.454	
Legumes				.714
Dairy				-.708

Notes
Eigenvalues: Pattern 1 = 3.35; Pattern 2 = 1.67; Pattern 3 = 1.37; Pattern 4 = 1.30

The first pattern identified was labelled 'Western' and had high loadings of convenience foods, snacks, refined grains and fats and oils. The second pattern was called 'Plant-based' and had high loadings of whole grains, fruit, nuts, and vegetables. The third pattern identified was labelled 'Meat, poultry, fish and alcohol' due to high factor loadings of these items. The final pattern identified was called 'Legumes and dairy' and had high loadings of these items. Together, these dietary patterns accounted for 38.0% of total variance in the sample.

Dietary Pattern as a Predictor of Cognitive Impairment (CIm) using the MMSE

Logistic regression analysis at each Wave using dietary pattern scores obtained from all three variable reduction techniques (i.e. 101 individual food items, 32 food groups and 20 food groups) were conducted to examine the relationship between dietary pattern and CIm (< 24 on MMSE). Covariates included the independent variables age, sex, energy, education, BMI, smoking status, exercise time, and STW (as a control for premorbid intelligence) (Crowell, Vanderploeg, Small, Graves, & Mortimer, 2002).

Wave 1

Age was a significant predictor of CIm at Wave 1 when dietary pattern scores were obtained using all three food reduction methods [(101 individual food items: p = 0.01, OR 1.14, 95% CI: 1.03 – 1.27); (32 food groups: p = 0.04, OR 1.10, 95% CI: 1.00 – 1.21) and (20 food groups: p = 0.04, OR 1.10, 95% CI: 1.00 – 1.21)]. These results indicated that as age increased, the odds of CIm also increased.

Sex, energy, smoking status, education level, and exercise time were not significantly associated with CIm at Wave 1.

BMI was a significant predictor of CIm when 101 individual food items were used to compute dietary pattern scores (p = 0.04, OR 1.15, 95% CI: 1.01 – 1.30).

Using all food reduction methods at Wave 1, premorbid intelligence was a significant predictor of CIm. For every one point increase in STW score, the odds of CIm decreased [(101 individual food items: p = 0.01, OR 0.93, 95% CI: 0.89 – 0.98); (32 food groups: p = 0.00, OR 0.93, 95% CI: 0.89 – 0.97); (20 food groups: p = 0.00, OR 0.94, 95% CI: 0.90 – 0.98)].

The only significant dietary predictors of CIm at Wave 1 were obtained using 101 individual food items. Three of the seven dietary patterns identified were observed to be significant predictors of CIm. For every one unit increase in these pattern scores, the odds of CIm decreased [(Fruit and Vegetable Pattern: p = 0.03, OR 1.06, 95% CI: 1.01 – 1.12); (Fish, Legumes and Vegetable Pattern: p = 0.04, OR 1.03, 95% CI: 1.00 – 1.06); (Dairy, Cereal and Eggs Pattern: p = 0.00, OR 1.02, 95% CI: 1.01 – 1.03)].

In another model where the interaction term ($dietarypatternscore \times exercisetime$) was included, no significant results were obtained at Wave 1.

Wave 2

Age was a significant predictor of CIm using all three food reduction methods showing that as age increased, the odds of CIm also increased [101 individual food items: p = 0.00, OR 1.11, 95% CI: 1.05 – 1.18); (32 food groups: p = 0.00, OR

1.11, 95% CI: 1.04 – 1.18) and (20 food groups: p = 0.00, OR 1.11, 95% CI: 1.04 – 1.18)].

Sex was a significant predictor of CIm at Wave 2 when 101 individual food items was used to identify dietary patterns showing that males had greater odds of CIm when compared to females (p = 0.04, OR = 2.48, 95% CI: 1.02 – 5.98).

Similar to Wave 1, energy, smoking status, education level, and exercise time were not significantly associated with CIm at Wave 2. BMI was also not a significant predictor of CIm at Wave 2.

Premorbid intelligence was a significant predictor of CIm using all three food reduction methods at Wave 2. For every one unit increase in STW score, the odds of CIm decreased [(101 individual food items: p = 0.00, OR 0.92, 95% CI: 0.89 – 0.95); (32 food groups: p = 0.00, OR 0.92, 95% CI: 0.89 – 0.95); (20 food groups: p = 0.00, OR 0.92, 95% CI: 0.89 – 0.95)].

Similar to Wave 1, the only significant dietary predictor of CIm at Wave 2 was obtained using 101 individual food items. One of the five dietary patterns identified in PCA was observed to be a significant predictor of CIm. For every one unit increase in the 'Variety' pattern score, the odds of CIm increased (Variety Pattern: p = 0.05, OR 1.02, 95% CI: 1.00 – 1.04).

In another model where the interaction term ($dietarypatternscore \times exercisetime$) was included, there were no significant associations between the predictor interaction term and CIm.

Wave 3

Age was a significant predictor of CIm using all three food reduction methods showing that as age increased, the odds of CIm also increased [(101 individual food items: p = 0.04, OR 1.10, 95% CI: 1.01 – 1.20); (32 food groups: p = 0.03, OR 1.10, 95% CI: 1.01 – 1.21) and (20 food groups: p = 0.02, OR 1.11, 95% CI: 1.01 – 1.21)].

Sex, energy, smoking status, education level, and exercise time were not significantly associated with CIm at Wave 2.

BMI was a significant predictor of CIm at Wave 3 when 101 individual food items were used to compute dietary pattern scores (101 individual food items: p = 0.01, OR 1.12, 95% CI: 1.03 – 1.22).

Premorbid intelligence was a significant predictor of CIm using all three food reduction methods at Wave 3. For every one unit increase in STW score, the odds of CIm decreased [(101 individual food items: p = 0.00, OR 0.90, 95% CI: 0.86 – 0.94); (32 food groups: p = 0.00, OR 0.90, 95% CI: 0.86 – 0.94); (20 food groups: p = 0.00, OR 0.90, 95% CI: 0.86 – 0.94)].

None of the dietary patterns identified at Wave 3 were found to be significantly associated with CIm. In another model where the interaction term

($dietarypatternscore \times exercisetime$) was included, there were no significant associations between the predictor interaction term and CIm.

Results of logistic regression analyses are shown in Table 7.11, Table 7.12 and Table 7.13.

Table 7.11: Results of Logistic Regression Analyses showing associations between CIm at Wave 3 and dietary patterns obtained using 101 food items at Waves 1, 2 and 3 (Odds ratios with 95% Confidence Intervals shown in brackets)

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4	Dietary Pattern 5	Dietary Pattern 6	Dietary Pattern 7
Wave 1	Fruit & Vegetable	Snack & Processed Foods	Vegetable	Meat	Fish, Legumes & Vegetable	Vegetable, Pasta & Alcohol	Dairy, Cereal & Eggs
OR (95% CI)	**1.061 (1.006 – 1.118) p = 0.030***	1.051 (0.967 – 1.143)p = 0.239	0.986 (0.916 – 1.061)p = 0.701	1.005 (0.964 – 1.048)p = 0.806	**1.032 (1.001 – 1.064) p = 0.040***	1.000 (0.965 – 1.037) p = 0.994	**1.020 (1.007 – 1.033) p = 0.003****
Wave 2	Fish & Plant-based	Meat, Poultry & Sweet Snacks	Vegetable, Legume & Snacks	Plant-based	Variety		
OR (95% CI)	1.035 (0.924 – 1.160) p = 0.550	0.976 (0.924 – 1.030) p = 0.368	1.005 (0.960 – 1.052) p = 0.830	1.009 (0.988 – 1.031) p = 0.387	**1.018 (1.000 – 1.036) p = 0.045***		

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Table 7.11 – Continued

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4	Dietary Pattern 5	Dietary Pattern 6	Dietary Pattern 7
Wave 3	Plant-based & Snacks	Meat, Poultry, Fish & Processed Fruit	Plant-based, Processed Fish & Yoghurt				
OR (95% CI)	0.930 (0.824 – 1.049) p = 0.239	0.989 (0.925 – 1.058) p = 0.752	1.001 (0.955 – 1.049) p = 0.973				

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time; *p <0.05 **p<0.01.

Table 7.12: Results of Logistic Regression Analyses showing associations between CIm at Wave 3 and dietary patterns obtained using 32 food groups at Waves 1, 2 and 3 (Odds ratios with 95% Confidence Intervals shown in brackets)

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4	Dietary Pattern 5
Wave 1	Western	Prudent	Vegetable, Grains & Wine	High-fat	
OR (95% CI)	1.005 (0.994 – 1.016) p = 0.409	0.997 (0.984 – 1.010)p = 0.643	1.008 (0.995 – 1.020)p = 0.229	0.999 (0.992 – 1.007)p = 0.826	
Wave 2	Western	Prudent	Vegetable	Dairy, Fat & Sugar	Eggs & Alcohol
OR (95% CI)	0.991 (0.962 – 1.021)p = 0.550	1.001 (0.988 – 1.014)p = 0.896	0.990 (0.969 – 1.012)p = 0.381	0.999 (0.992 – 1.007)p = 0.847	1.002 (0.999 – 1.005)P = 0.242
Wave 3	Western	Prudent			
OR (95% CI)	1.007 (0.996 – 1.018)p = 0.191	0.997 (0.983 – 1.011)P = 0.654			

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time.

Table 7.13: Results of Logistic Regression Analyses showing associations between CIm at Wave 3 and dietary patterns obtained using 20 food groups at Waves 1, 2 and 3 (Odds ratios with 95% Confidence Intervals shown in brackets)

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4
Wave 1	Variety	Western	Dairy, Grains & Alcohol	
OR (95% CI)	1.006 (0.994 – 1.018)p = 0.333	1.008 (0.986 – 1.031)p = 0.497	1.001 (0.998 – 1.005)p = 0.383	
Wave 2	Plant-based	Western	Meat, Poultry & Fish	Dairy, Legume & Alcohol
OR (95% CI)	1.003 (0.992 – 1.013)p = 0.642	1.007 (0.990 – 1.024)p = 0.442	0.996 (0.982 – 1.010)p = 0.558	1.001 (0.998 – 1.004)p = 0.612
Wave 3	Western	Plant-based	Meat, Poultry, Fish & Alcohol	Legumes & Dairy

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Table 7.13 – Continued

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4
OR (95% CI)	0.875 (0.918 – 1.035)p = 0.400	0.997 (0.988 – 1.006)p = 0.472	1.002 (0.999 – 1.005)p = 0.254	1.001 (0.995 – 1.007)p = 0.744

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time.

Dietary Pattern as a Predictor of Memory, Vocabulary and Verbal Knowledge and Processing Speed

*W*ave 1

Using dietary pattern scores calculated from 101 individual food items, there were no dietary patterns observed to be significantly predictive of memory, processing speed or verbal knowledge.

Using 32 food groups however, the ‘Western’ dietary pattern was a predictor of poorer memory and processing speed (β = -0.008, SE = 0.003, p = 0.001 and β = -0.024, SE = 0.011, p = 0.035). In addition, the ‘Prudent’ dietary pattern was also a predictor of poorer processing speed (β = -0.035, SE = 0.011, p = 0.002).

When 20 food groups were used to calculate dietary pattern scores, the ‘Dairy, grains and alcohol’ dietary pattern was predictive of poorer memory while the ‘Variety’ dietary pattern was associated with poorer processing speed (β = -0.002, SE = 0.001, p = 0.005 and β = -0.026, SE = 0.011, p = 0.018 respectively).

*W*ave 2

Dietary pattern scores calculated from 101 individual food items were not predictive of memory, processing speed or verbal knowledge.

Using 32 food groups the ‘Vegetable’ dietary pattern was significantly predictive of better processing speed (β = 0.041, SE = 0.016, p = 0.011) while the ‘Prudent’ and ‘Eggs and Alcohol’ dietary patterns were predictive of poorer processing speed (β = -0.025, SE = 0.010, p = 0.010 and β = -0.009, SE = 0.004, p = 0.020 respectively).

When 20 food groups were used to calculate dietary pattern scores at Wave 2, the ‘Western’ dietary pattern was found to be predictive of poorer memory and processing speed (β = -0.008, SE = 0.004, p = 0.014 and β = -0.036, SE = 0.015, p = 0.018 respectively). In addition, the plant-based dietary pattern was found to be predictive of poorer processing speed (β = -0.018, SE = 0.009, p = 0.042).

*W*ave 3

Using dietary pattern scores calculated from 101 individual food items, the ‘Plant-based, Processed Fish and Yoghurt’ dietary pattern was predictive of better memory, processing speed and verbal knowledge (β = 0.013, SE = 0.005, p = 0.007; β = 0.048, SE = 0.020, p = 0.018 and β = 0.037, SE = 0.013, p = 0.005 respectively). The ‘Plant-based and Snacks’ dietary pattern was predictive of better processing speed (β = 0.106, SE = 0.047, p = 0.024).

Using 32 food groups the ‘Western’ dietary pattern was significantly predictive of poorer processing speed (β = -0.020, SE = 0.008, p = 0.018).

When 20 food groups were used, none of the identified dietary patterns were predictive of memory, processing speed or verbal knowledge.

Results of GLM analyses are shown in Table 7.14, Table 7.15 and Table 7.16 below.

Table 7.14: Results of GLM showing associations between CIm at Wave 3 and dietary patterns obtained using 101 individual food items at Waves 1, 2 and 3 (β values with Standard Errors shown in brackets)

	Dietary Pattern 1	**Dietary Pattern 2**	**Dietary Pattern 3**	**Dietary Pattern 4**	**Dietary Pattern 5**	**Dietary Pattern 6**	**Dietary Pattern 7**
Wave 1	Fruit & Vegetable	Snack & Processed Foods	Vegetable	Meat	Fish, Legumes & Vegetable	Vegetable, Pasta & Alcohol	Dairy, Cereal & Eggs
CVLT	0.012 (0.013)p = 0.336	0.020 (0.015)p = 0.186	-0.001 (0.012)p = 0.930	0.000 (0.005)p = 0.984	-0.002 (0.007)p = 0.793	0.004 (0.006)p = 0.551	-4.474 (0.002)p = 0.986
SDMT	0.097 (0.057)p = 0.091	0.060 (0.067)p = 0.365	0.013 (0.054)p = 0.801	0.014 (0.023)p = 0.536	-0.062 (0.032)p = 0.054	-0.003 (0.028)p = 0.916	-0.016 (0.011)p = 0.149
STW	0.077 (0.039)p = 0.051	0.080 (0.046)p = 0.086	0.046 (0.037)p = 0.224	0.007 (0.020)p = 0.722	0.000 (0.022)p = 0.994	0.000 (0.021)p = 0.982	0.002 (0.008)p = 0.799
Wave 2	Fish & Plant-based	Meat, Poultry & Sweet Snacks	Vegetable, Legume & Snacks	Plant-based	Variety		

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Table 7.14 – Continued

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4	Dietary Pattern 5	Dietary Pattern 6	Dietary Pattern 7
CVLT	-0.011 (0.022)p = 0.610	0.000 (0.007)p = 0.943	-0.006 (0.006)p = 0.294	0.006 (0.004)p = 0.179	-0.002 (0.004)p = 0.504		
Wave 2 *continued*	Fish & Plant-based	Meat, Poultry & Sweet Snacks	Vegetable, Legume & Snacks	Plant-based	Variety		
SDMT	-0.012 (0.096)p = 0.902	0.007 (0.030)p = 0.829	-0.022 (0.027)p = 0.408	0.013 (0.019)p = 0.471	**-0.027 (0.016)p = 0.016***		
STW	-0.066 (0.069)p = 0.341	-0.012 (0.022)p = 0.593	-0.001 (0.019)p = 0.965	0.014 (0.014)p = 0.305	0.022 (0.012)p = 0.064		
Wave 3	Plant-based & Snacks	Meat, Poultry, Fish & Processed Fruit	Plant-based, Processed Fish & Yoghurt				

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Table 7.14 – Continued

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4	Dietary Pattern 5	Dietary Pattern 6	Dietary Pattern 7
CVLT	-0.007 (0.011)p = 0.542	-0.007 (0.005)p = 0.219	**0.013 (0.005)p = 0.007****				
SDMT	**0.106 (0.047) p = 0.024***	-0.039 (0.022)p = 0.081	**0.048 (0.020)p = 0.018****				
STW	0.055 (0.030) p = 0.066	- 0.028 (0.015)p = 0.054	**0.037 (0.013)p = 0.005****				

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time; *p <0.05 **p<0.01.

Table 7.15: Results of GLM showing associations between CIm at Wave 3 and dietary patterns obtained using 32 food groups at Waves 1, 2 and 3 (β values with Standard Errors shown in brackets)

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4	Dietary Pattern 5
Wave 1	Western	Prudent	Vegetable, Grains & Wine	High-fat	
CVLT	**-0.008 (0.003)p = 0.001****	-0.005 (0.003)p = 0.067	0.001 (0.003)p = 0.764	-0.001 (0.001)p = 0.711	
SDMT	**-0.024 (0.011)p = 0.035***	**-0.035 (0.011)p = 0.002****	**0.024 (0.012)p = 0.034***	0.005 (0.006)p = 0.403	
STW	- 0.006 (0.008)p = 0.467	-0.006 (0.008)p = 0.425	0.013 (0.008)p = 0.119	0.001 (0.005)p = 0.774	
Wave 2	Western	Prudent	Vegetable	Dairy, Fat & Sugar	Eggs & Alcohol
CVLT	-0.002 (0.005)p = 0.666	-0.001 (0.002)p = 0.766	0.007 (0.004)p = 0.055	-0.001 (0.001)p = 0.363	-0.001 (0.001)p = 0.238

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Table 7.15 – Continued

	Dietary Pattern 1	Dietary Pattern 2	Dietary Pattern 3	Dietary Pattern 4	Dietary Pattern 5
SDMT	-0.026 (0.023)p = 0.247	**-0.025 (0.010)p = 0.010***	**0.041 (0.016)p = 0.011***	-0.003 (0.006)p = 0.652	**-0.009 (0.004)p = 0.020***
STW	-0.013 (0.017)p = 0.448	-0.005 (0.007)p = 0.508	0.020 (0.012)p = 0.100	0.005 (0.004)p = 0.209	0.005 (0.003)p = 0.096
Wave 3	Western	Prudent			
CVLT	0.000 (0.002) p = 0.890	0.000 (0.002)p = 0.822			
Wave 3 *continued*	Western	Prudent			
SDMT	**-0.020 (0.008)p = 0.018***	-0.006 (0.006)p = 0.994			
STW	-0.009 (0.005)p = 0.090	0.004 (0.004)p = 0.342			

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time; *p <0.05 **p<0.01.

Table 7.16: Results of GLM showing associations between CIm at Wave 3 and dietary patterns obtained using 20 food groups at Waves 1, 2 and 3 (β values with Standard Errors shown in brackets)

	Dietary Pattern 1	**Dietary Pattern 2**	**Dietary Pattern 3**	**Dietary Pattern 4**
Wave 1	Variety	Western	Dairy, Grains & Alcohol	
CVLT	-0.003 (0.003)p = 0.272	-0.004 (0.005)p = 0.376	**-0.002 (0.001)p = 0.005****	
SDMT	**-0.026 (0.011)p = 0.018***	-0.007 (0.021)p = 0.740	-0.005 (0.003)P = 0.149	
STW	-0.008 (0.008)p = 0.291	0.002 (0.015)p = 0.901	-0.001 (0.002)p = 0.618	
WAVE 2	Plant-based	Western	Meat, Poultry & Fish	Dairy, Legume & Alcohol
CVLT	-0.001 (0.002)p = 0.703	**-0.008 (0.004)p = 0.014***	-0.002 (0.002)p = 0.329	0.000 (0.001)p = 0.803

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Table 7.16 – Continued

	Dietary Pattern 1	**Dietary Pattern 2**	**Dietary Pattern 3**	**Dietary Pattern 4**
SDMT	**-0.018 (0.009)p = 0.042***	**-0.036 (0.015)p = 0.018***	-0.012 (0.009)p = 0.169	-0.005 (0.003)p = 0.076
STW	-0.001 (0.007)p = 0.890	-0.013 (0.011)p = 0.263	-0.009 (0.007)p = 0.185	0.003 (0.002)p = 0.182
Wave 3	Western	Plant-based	Meat, Poultry, Fish & Alcohol	Legumes & Dairy
CVLT	-0.008 (0.006)p = 0.190	-0.001 (0.001)p = 0.565	0.000 (0.001)p = 0.443	0.001 (0.001)p = 0.419
Wave 3 *continued*	Western	Plant-based	Meat, Poultry, Fish & Alcohol	Legumes & Dairy
SDMT	-0.023 (0.026)p = 0.376	-0.001 (0.004)p = 0.802	-0.004 (0.002)p = 0.098	0.000 (0.003)p = 0.911

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Table 7.16 – Continued

	Dietary Pattern 1	**Dietary Pattern 2**	**Dietary Pattern 3**	**Dietary Pattern 4**
STW	-0.010 (0.016)p = 0.537	0.004 (0.003)p = 0.093	-0.001 (0.001)p = 0.526	0.002 (0.002)p = 0.289

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time; *p <0.05 **p<0.01.

7.6 Discussion

This is one of the few studies that use a data-driven method of dietary analysis to assess the relationship between diet and cognitive function in older Australian adults. A number of findings from this study are noteworthy. First, the broader the categories used in grouping foods, the greater the variability in food use that was explained. It was observed however that the results of logistic regression were more sensitive when dietary analysis was based on individual food items than food groups. At Wave 1, for every one unit increase in 'Fruit and Vegetable', 'Fish, Legumes and Vegetable' and 'Dairy, Cereal and Eggs' dietary pattern scores, the odds of CIm decreased. In addition, at Wave 2, for every one unit increase in 'Fish, Legume and Vegetable' dietary pattern score, the odds of CIm increased. GLM using individual food items showed that at Wave 2 the 'Variety' dietary pattern was a predictor of poorer processing speed while at Wave 3 the 'Plant-based, Processed Fish and Yoghurt' dietary pattern was predictive of better memory, processing speed, and verbal knowledge. At Wave 3, the 'Plant-based and Snacks' dietary pattern was shown to be a predictor of better processing speed. GLM using 32 food groups also produced some significant findings. At Wave 1, the 'Western' dietary pattern was predictive of poorer memory and processing speed, the 'Vegetable, Grains and Wine' pattern was a predictor of better processing speed while the 'Prudent' pattern was predictive of poorer processing speed. At Wave 2, the 'Prudent' and 'Eggs and Alcohol' patterns were predictive of poorer processing speed while the 'Vegetable' pattern was predictive of better processing speed. Finally at Wave 1 using 20 food groups, the 'Variety' dietary pattern was a predictor of poorer processing speed and the 'Dairy, Grains and Alcohol' pattern predictive of poorer memory. At Wave 2, the 'Plant-based' dietary pattern was predictive of poorer processing speed while the 'Western' pattern was predictive of poorer memory and processing speed. A summary of these results is presented in Table 7.17 below.

Table 7.17: Summary of main findings of data-driven dietary analyses

	Food Group Classification Method		
	101 Individual Items	32 Groups	20 Groups
Dietary Patterns Wave 1	Fruit & Vegetable*	Western$^{\pm\diamond}$	Variety$^{\pm}$
	Snack & Processed Food	Prudent$^{\pm}$	Western
	Vegetable	Veg, Grains & Wine$^{\pm}$	Dairy, Grains & Alcohol$^{\diamond}$

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Table 7.17 – Continued

	101 Individual Items	32 Groups	20 Groups
	Meat	High-fat	
	Fish, Legumes & Vegetable*		
	Veg, Pasta & Alcohol		
	Dairy, Cereal & Eggs*		
Dietary Patterns Wave 2	Fish & Plant-based	Western	Plant-based±
	Meat, Poultry & Sweet snacks	Prudent±	Western±⋄
	Vegetable, Legume & Snacks	Vegetable±	Meat, Poultry & Fish
	Plant-based‡	Dairy, Fat & Sugar	Dairy, Legumes & Eggs
	Variety±*	Alcohol & Eggs±	
Dietary Patterns Wave 3	Plant-based & Snacks∓	Western	Western
	Meat, Poultry, Fish & Processed Fruit	Prudent	Plant-based
	Plant-based, Processed fish and Yoghurt∓⋆†		Meat, Poultry, Fish & Alcohol
			Legumes & Dairy

*Increased consumption predictive of decreased odds of CIm ($p < 0.05$).

‡ Increased consumption predictive of increased odds of CIm ($p < 0.05$).

± Predictive of poorer processing speed.

⋄ Predictive of poorer memory.

∓ Predictive of better processing speed.

⋆ Predictive of better memory.

† Predictive of better verbal knowledge.

It was found that the method of reducing food variables affected the amount of variance in food use that was explained. Similar to other published findings, the broader the categories used the greater the variability in food use explained (McCann et al., 2001). This it is suggested may be due to the inclusion of foods that are both weakly and strongly correlated with a specific pattern in the broader categorisations which leads to an increase in the information captured (McCann et al., 2001). Interestingly though, for logistic regression analyses it was only when the level of detail in the items included in PCA-derived dietary patterns increased that significant associations between diet and disease were observed i.e. it was variable reduction that utilised dietary pattern scores from individual foods that produced the only significant results. This may be because analysis using individual foods captures more meaningful results as it is able to show whether consumption or non-consumption of specific food items is associated with disease.

Prior studies suggest that dietary patterns change over time and that these changes are largely driven by individual socio-demographic shifts (Hosking & Danthiir, 2013; Mishra, McNaughton, Bramwell, & Wadsworth, 2006). In the present study, despite different populations and different periods being examined at each Wave, there were some similarities apparent in the patterns of consumption observed. Using 32 food groups, both a 'Western' and 'Prudent' dietary pattern were identified at all 3 Waves. The 'Western' pattern had high loadings of high-fat, high-salt foods, meat and refined grains while the 'Prudent' pattern had high loadings of fish, fruit, vegetables, and whole-grains. Using 20 food groups, a 'Western' pattern was also identified at all 3 Waves and a 'Plant-based' dietary pattern was identified at Waves 2 and 3. This plant-based pattern was characterised by high loadings of fruit, vegetable, and grain items.

Despite the variation in findings between Waves, our results are consistent with previous studies in showing that diets with high loadings of vegetables and other plant-based food items (fruit, grains and legumes) resulted in reduced odds of disease and improved cognitive function (McCann et al., 2001; van Dam et al., 2002). In a study of 6,911 Chinese subjects aged 65 and older who formed part of the Chinese Longitudinal Health Longevity Study, lower intakes of vegetables and legumes were associated with cognitive decline when using MMSE as a measure of cognitive function (Chen et al., 2012). Multivariate logistic regression showed that always eating vegetables and always consuming legumes were inversely associated with cognitive decline (Chen et al., 2012). Additionally, in a study of 2,148 community-based elderly subjects without dementia in New York, higher intakes of cruciferous and dark and green leafy vegetables were found to be associated with a decreased risk of developing AD (Gu et al., 2010). This seemingly protective association between plant-based foods and CIm may be the result of the high concentration of antioxidant nutrients present in vegetables and fruits and their role in suppressing inflammation. There is evidence that oxidative stress and inflammation can lead to impaired cognitive function because of an increase in free radicals and the damage they cause to neuronal cells (Wärnberg et al., 2009).

The Mediterranean Diet (MeDi), one of the most studied dietary patterns, describes a diet rich in cereals, olive oil, fish, fruits and vegetables and low in dairy and meat with a moderate consumption of red wine. This diet has been linked to increased survival, reduced risk of cancers, cardiovascular disease and CIm, and increased longevity. (Scarmeas, Stern, Mayeux, Manly, et al., 2009; Scarmeas et al., 2006; Sofi et al., 2010; Solfrizzi, Panza, et al., 2011; Trichopoulou et al., 2003). In the present study, diets rich in vegetables, grain and wine were found to be predictive of better processing speed and diets high in vegetables and plant-based food items were generally associated with better cognitive outcomes.

The unexpected finding that the 'Prudent' dietary pattern was predictive of poorer processing speed at Waves 2 and 3 is of interest. This dietary pattern was so labelled because of its high loadings of fish, fruit and vegetables, nuts and whole-grains. Perhaps an explanation of this lies in the method in which food items are prepared or whether or not foods included in this pattern really have a protective effect. For instance, while many studies have examined the effect of fish consumption on cognition, some clarification is still needed on the purported link between the two. In a study of 6,150 Chicago residents, aged 65 and older, aimed to examine whether intakes of fish and the omega-3 fatty acids protect against age-related cognitive decline, it was reported that fish consumption may be associated with slower cognitive decline with age (Morris, 2009). Similar findings were also reported by Kalmijn et al., 1997 who found statistically significant decreased risks of AD with higher fish consumption (Kalmijn et al., 1997). In two more recent Australian studies one reported that higher fish consumption was associated with an increased risk of cognitive disorder (Cherbuin & Anstey, 2012) while the other found no evidence to support the hypothesis that higher proportions of fish intake benefits cognitive performance in normal older adults (Danthiir et al., 2014).

In the present study, the 'Western' dietary pattern was predictive of poorer memory and processing speed. This is supported by other research which has reported that the 'Western' dietary pattern is associated with cognitive decline and reduced executive function (Gardener et al., 2014).

The main limitation of this study lies in its cross-sectional treatment of dietary data. It is acknowledged that a sample of participants had dietary data for all three Waves but these were not analysed longitudinally in the present study. Another limitation of the study is that disease incidence was not able to be reported as cognitive data were only collected at one time point (Wave 3).

Despite its limitations, this study adds to the sparse body of literature in Australia examining the relationship between dietary patterns and CIm among older adults. Further, the study's focus on older age groups whose dietary patterns have not been widely studied and reported is noteworthy. Finally, the study's ability to answer a methodological question that has been one of the main critiques of PCA makes it noteworthy – How do variable reduction methods before the application of PCA affect the results obtained? This question is particularly important when examining the relationship between dietary patterns and cognition since there is a level of subjectivity involved in reducing food variables and these can affect the associations with cognitive function observed (van Dam et al., 2002).

Future studies examining the association between dietary intake and cognitive status will be useful to identify other patterns associated with CIm and to examine more nuanced issues as it relates to diet and cognitive function.

7.7 Chapter Conclusion

The findings of this study showed that diets with high factor loadings of fruit, vegetables, and plant-based food items conferred cognitive benefit while those with high factor loadings of high-fat and convenience foods are linked to poorer cognitive outcomes. These results are similar to those of other studies which show that diets with high loadings of vegetables, fruit, and grain reduce the odds of a myriad of diseases (Chan, Chan, & Woo, 2013; McCann et al., 2001; van Dam et al., 2002). In addition it was demonstrated that the method of variable reduction in dietary studies may influence results. Further work is required to establish robust and replicable methods of dietary analysis for use in research into cognitive ageing. Additional studies that focus on the dietary habits of those over age 60 would be useful in order to further elucidate more specific details between dietary patterns, types and amount of fat, protein and carbohydrates, number of calories, and micro and macronutrients that are linked with optimal cognitive function and reduced risk of CIm in older adults. Such information is required for the development of dietary guidelines and policies that promote optimal cognitive health in ageing.

Chapter 8

The Effect of Diet and Physical Activity on Cognitive Impairment using an *A Priori* Method

8.1 Chapter Summary

Both diet and physical activity have been associated with cognitive function and risk of CIm. Investigating whether lifestyle factors significantly reduce the risk of CIm is a key focus in the fight against dementia and other conditions that affect brain function.

Three Waves of dietary data collected from adults aged 60 and older participating in the Australia Diabetes Obesity and Lifestyle Study (AusDiab) were included in this analysis. The Mini Mental State Examination (MMSE) was used to assess CIm status at the most recent Wave only (Wave 3). At each Wave, self-reported leisure-time physical activity and television viewing time were obtained and participants were assigned a Mediterranean Diet (MeDi) score using a published protocol.

Logistic regression analysis was performed to determine the association of adherence to the MeDi, physical activity and television viewing time (as markers of energy expenditure) on CIm at each Wave.

MeDi adherence, weekly physical activity time and weekly television viewing time were not predictive of CIm in fully adjusted models. At Wave 1 greater daily legume intake was associated with increased odds of CIm β = 0.01 [OR 1.01; 95% Confidence Interval (CI): 1.00 – 1.01; p = 0.04]. At Wave 2, greater daily meat intake was associated with decreased odds of CIm β = -0.01 (OR 0.99; 95% CI: 0.98 – 1.00; p = 0.03) while greater daily saturated fat intake was associated with increased odds of CIm β = 0.09 (OR 1.09; 95% CI: 1.00 – 1.19; p = 0.05). MeDi adherence was not a predictor of memory, verbal knowledge, and processing speed at any of the three Waves. Greater weekly physical activity time was predictive of poorer processing speed, memory, and verbal ability at Wave 3 β = -0.12; SE = 0.06; p = 0.03, β = -0.08; SE = 0.04; p = 0.05 and β = -0.04; SE = 0.01; p = 0.00 respectively.

Greater adherence to the MeDi, engagement in physical activity, and television viewing time did not significantly influence the odds of CIm among older adults in the AusDiab study. However, some individual constituents of the MeDi were significantly associated. Greater physical activity was predictive of processing speed, memory, and verbal ability at some time points.

8.2 Background

Previous research has shown that both diet and physical activity exert mixed effects on cognitive status (Gu & Scarmeas, 2011); some have shown protective effects while others have shown deleterious effects (Scarmeas et al., 2006).

Studies examining diet-disease relationships have utilised both the single nutrient and dietary pattern approaches (Jacobs & Steffen, 2003; Scarmeas et al., 2006). Historically, the single nutrient approach has been instrumental in solving nutrient deficiency diseases such as scurvy and beri beri (Jacobs & Steffen, 2003). Recently though, there has been a shift toward examining the diet as a whole as it relates to disease since the complex interplay of dietary constituents makes it difficult to implicate a single nutrient as being causal (Gu & Scarmeas, 2011).

One dietary pattern that has been singled out as having possible protective qualities is the Mediterranean Diet (MeDi) (Babio et al., 2009; Kouris-Blazos et al., 1999; Trichopoulou et al., 2003). The MeDi describes the traditional dietary pattern of populations bordering the Mediterranean Sea (Solfrizzi, Frisardi, et al., 2011). It is characterised by high consumption of fruits and vegetables, legumes, cereals, fish, olive oil; low consumption of meat and saturated fats and a moderate intake of alcohol (mostly in the form of wine). The MeDi has been widely reported to be associated with a number of favourable health outcomes including reduced risk of cancers, cardiovascular disease and CIm, and increased longevity (Scarmeas et al., 2006; Solfrizzi, Frisardi, et al., 2011; Trichopoulou et al., 2003). There has however been a lack of consistency among studies as it relates to the MeDi and cognition which makes it difficult for population-based policies to be developed. For example, while in some studies higher adherence to the MeDi has been associated with a reduction in risk for Alzheimer's Disease (AD), reduced risk of developing mild cognitive impairment (MCI) and reduced risk of MCI conversion to AD (Scarmeas, Stern, Mayeux, Manly, et al., 2009; Scarmeas et al., 2006); in other studies adherence to the MeDi was not protective against CIm, not associated with MCI, and not linked to better global cognitive function (Cherbuin & Anstey, 2012; Psaltopoulou et al., 2008; Roberts et al., 2010; Vercambre, Grodstein, Berr, & Kang, 2012). In addition, fundamental questions have arisen about the applicability of the MeDi in other countries and socio-cultural settings (Cherbuin & Anstey, 2012). Few of the studies conducted to date have examined the impact of the MeDi in older age groups.

The evaluation of nutrition in relation to mental health requires a holistic approach that takes into account other lifestyle factors such as physical activity

(Dangour & Uauy, 2006). The World Health Organisation reports that levels of physical inactivity are rising in many countries and contributes substantially to disease burden (World Health Organisation, 2010). Increases in time spent being active and decreased engagement in sedentary behaviour have been associated with reduced risk of CIm and slower rates of cognitive decline (Forbes et al., 2008; Larson et al., 2006). High levels of television viewing time have been found to be associated with negative health outcomes (metabolic syndrome and premature mortality) and to be a proxy measure of overall time spent engaged in sedentary behaviour (Clark et al., 2011). Few studies though have examined the association between television viewing and CIm.

8.3 Aim

To determine the influence of diet, time engaged in physical activity and television viewing time on CIm among a cohort of adults over age 60 at three time points in the AusDiab.

8.4 Methodology

8.4.1 Study Design and Sample

This study utilised existing data derived from the AusDiab, a population-based national survey of the general (non-institutionalised) Australian population aged 25 years and older (Dunstan et al., 2001). The sample selection was based on a stratified cluster method and sample size selection based on estimates of national diabetes prevalence obtained from previous surveys (Dunstan et al., 2001). Baseline examination was undertaken in 1999–2000 (n=11,247), with follow-ups conducted in 2004–05 (n=8,798) and 2011–12 (n= 6,186) (Dunstan et al., 2001).

The older cohort (age 60+) was the focus of this study. Dietary data were obtained using a questionnaire at all Waves (Wave 1: n = 3298; Wave 2: n = 2424; Wave 3: n = 2063) (Dunstan et al., 2001). Similarly, self-reported leisure-time physical activity and television viewing time data were collected at all Waves using a questionnaire – Physical activity: (Wave 1: n = 3266; Wave 2: n = 2450; Wave 3: n = 2368) and Television viewing Time: (Wave 1: n = 3267; Wave 2: n = 2447; Wave 3: n = 2359. Measurement of cognitive function was conducted on those who attended survey sites in the third Wave of data collection (n = 1,725) (Tanamas et al., 2013a).

Statistical tests were carried out using those who had diet, physical activity time, and television viewing time recorded at any of the three Waves and cognitive status data recorded at Wave 3 along with data on all other covariates (Wave 1: n

= 522; Wave 2: n = 509; Wave 3: n = 709).

Ethics Approval

The research protocol was approved by the human research ethics review boards of the International Diabetes Institute, the Monash University and the Alfred Hospital, Melbourne. All participants in the study provided written informed consent.

Cognitive Outcome Measurement

The Mini Mental State Examination (MMSE) was used in data collection 2011–12 (AusDiab Wave 3) to determine CIm status. Participants were categorised based on their MMSE score as being either cognitively impaired (score of 0–23) or not cognitively impaired (score of 24–30) (Anstey et al., 2006). The MMSE evaluates various dimensions of cognition including memory, attention, and language (Féart et al., 2009).

In addition, participants' memory, verbal and processing abilities were also assessed during the 2011–12 Wave. The California Verbal Learning Test (CVLT) was used to assess memory using a 16-point scoring system. For this test, participants were asked to recall and repeat a list of 16 common shopping items that had been read to them by an interviewer. During a short delay of 20 minutes, during which participants were given other tasks to perform, the interviewer then asked the participant to recall the 16 common shopping list items again (delayed recall). The Spot-the-Word test (STW) was used in this study to test participants' vocabulary and verbal knowledge with scores ranging from 0 to 60. STW testing involved presenting participants with pairs of items – one of which was a real word and the other a non-word; participants were then required to identify the word. Performance on the STW has not been shown to decline with age and is highly correlated with verbal acumen (Baddeley et al., 1993). Finally, processing speed was tested using the Symbol-Digit Modalities Test (SDMT). Participants were provided with a reference key and asked to pair geometric figures with specific numbers. Using the SDMT, participants were scored from 0–60 on the number of correct answers provided in 90 seconds.

Food Consumption Data and Mediterranean Diet Scoring

Dietary data were collected using a self-administered semi-quantitative food frequency questionnaire (Reeves et al., 2013). This questionnaire assessed usual intake and recorded the amount and types of specific food items consumed by participants. Participants were asked to indicate the number of times they had specific food items in the past year by checking 1 of 10 frequency categories ranging from 'never' to 'three or more times per day'. The average daily intake of food weight in grams was subsequently computed and used in the present analysis.

Similar to previous studies, participants' adherence to the MeDi was assessed by assigning a MeDi score ranging from 0 to 9 (Scarmeas, Stern, Mayeux, Manly, et al., 2009). The higher the MeDi score, the closer a participant had adhered to the MeDi (Gu & Scarmeas, 2011; Sofi et al., 2008). For foods perceived as beneficial (fruits, vegetables, legumes, cereals, fish) as well as ratio of monounsaturated fatty acids (MUFA) to saturated fatty acids (SFA) a score of 1 was assigned to individuals who consumed more than the sex-specific median of the population (Scarmeas, Stern, Mayeux, Manly, et al., 2009). For participants who consumed less than the sex-specific median, a score of 0 was assigned (Gu & Scarmeas, 2011; Scarmeas, Stern, Mayeux, Manly, et al., 2009). For meat and dairy products (components presumed to be detrimental), individuals whose consumption was below the sex-specific median were assigned a value of 1, and individuals whose consumption was at or above the sex-specific median were assigned a value of 0 (Gu & Scarmeas, 2011; Scarmeas et al., 2006). For alcohol, a score of 0 was assigned to those who consumed no alcohol and also to those with high levels of consumption ($\geq 30g/d$). A score of 1 was assigned to those with mild to moderate alcohol consumption ($> 0to < 30g/d$) (Gu & Scarmeas, 2011; Scarmeas, Stern, Mayeux, Manly, et al., 2009). The final MeDi score, calculated at each Wave, was a tally of all these individual scores (Gu & Scarmeas, 2011; Scarmeas, Stern, Mayeux, Manly, et al., 2009).

Physical Activity Measurement

Use of the Active Australia Survey allowed participants to self-report frequency and duration of leisure-time physical activity during the previous week (Dunstan et al., 2004). This survey asks participants about walking for recreation or transport, "other" moderate activity, and vigorous physical activity (Dunstan et al., 2004).

Total physical activity time for the previous week was calculated as the sum of the time spent walking (if continuous and $\geq$ 10min) or performing moderate physical activity plus double the time spent in vigorous physical activity (Hansen et al., 2012). Participants were asked the following questions:

- In the last week, how many times have you walked continuously, for at least 10 minutes, for recreation, exercise or to get to or from places?
- In the last week, how many times did you do vigorous household chores that made you breathe harder or puff and pant?

- In the last week, how many times did you do any vigorous gardening or heavy work around the yard which made you breathe harder or puff and pant?

- In the last week, how many times did you do any other more moderate physical activities that you have not already mentioned (for example, lawn bowls, golf, gentle swimming etc.)?

Total television viewing time was calculated as the sum of weekday TV viewing time and weekend TV viewing time (Dunstan et al., 2004). More specifically, participants were asked to estimate the total time during the last week spent watching TV or videos – when it was the main activity they were doing. As such, time when the TV was switched on and a meal was being prepared was not included.

8.4.2 Statistical Analysis

Logistic regression analysis was performed at each Wave to determine the influence of diet, physical activity time, and television viewing time on CIm using SPSS version 22. More specifically, adherence to the MeDi, total physical activity time per week, and television viewing time per week were used as predictor variables to determine the influence of diet and physical activity on CIm among the cohort under study.

Generalised linear models (GLM) were used to estimate the associations between MeDi scores, physical activity time, television viewing time and memory, verbal ability and processing speed at each Wave with casewise exclusion for missing data. Prospective analyses using data at Waves 1 and 2 along with cross-sectional analyses using data at Wave 3 were conducted to determine the association between MeDi adherence and leisure time physical activity and CIm at each Wave.

Figure 8.1 below shows how samples were selected for analysis.

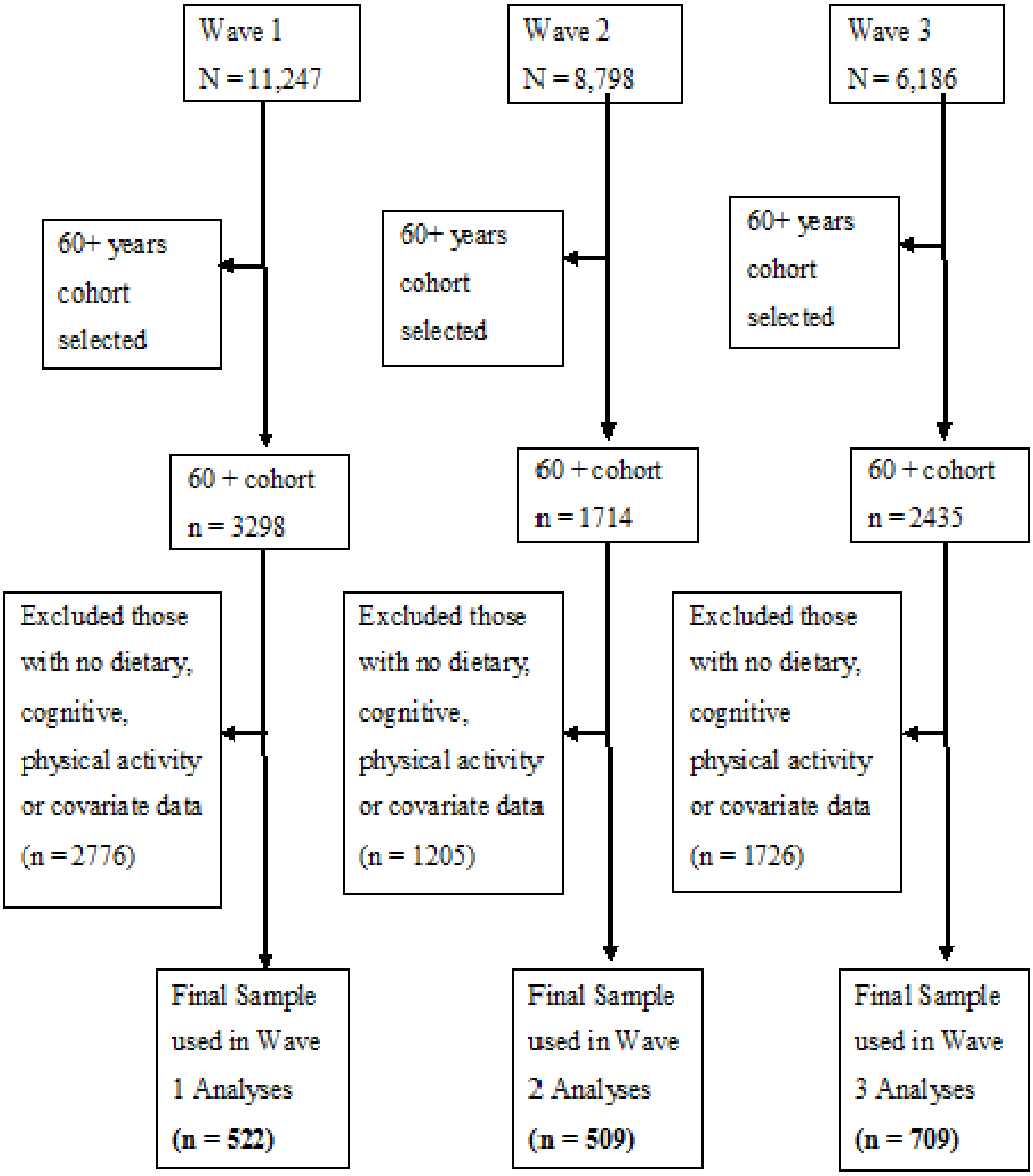

Figure 8.1: Selection of Sample for Analysis from AusDiab

8.5 Results

Demographics

Descriptive statistics for the sample at each Wave are presented in Table 8.1 below:

Table 8.1: Descriptive Statistics for the AusDiab Sample included in Analyses

Variables	Wave 1 (n = 522)	Wave 2 (n = 509)	Wave 3 (n = 709)
Age Range – years	60 – 83	60 – 80	60 – 81
Mean Age – years (SD)	66.0 (4.8)	65.8 (4.7)	67.2 (5.3)
Female (%)	266 (51.0)	265 (52.1)	384 (54.2)
BMI – kg/m^2 (SD)	26.8 (4.0)	27.4 (4.4)	27.8 (4.9)
Sec. School (%)	216 (41.4)	110 (21.6)	221 (31.2)
Tertiary Level (%)	136 (26.1)	139 (27.3)	241 (34.0)
Other (%)	170 (32.6)	260 (51.1)	247 (34.8)
Current smoker (%)	27 (5.2)	18 (3.5)	26 (3.7)
Ex-smoker (%)	167 (32.0)	161 (31.6)	229 (32.3)
Non-smoker (%)	328 (62.8)	330 (64.8)	454 (64.0)
PA time (SD), hours/week	5.0 (5.5)	4.9 (5.1)	6.0 (6.0)
TV. Time (SD), hours/week	14.8 (8.8)	16.1 (9.7)	15.0 (10.0)
MeDi score (SD)	4.4 (1.6)	4.4 (1.6)	4.6 (1.6)
MMSE score (SD)*			28.1 (2.1)
CVLT score (SD)*			6.1 (2.3)
STW score (SD)*			50.3 (6.2)
SDMT score (SD)*			46.2 (9.6)
Impaired (%)*			14.0 (2.0)

**Cognitive measures were collected at Wave 3 only. All other measures were taken at each Wave.*

MeDi Score as a Predictor of Cognitive Status

Logistic regression analysis was performed to determine the influence of MeDi score, weekly physical activity time and weekly television viewing time at Waves 1, 2 and 3 on CIm at Wave 3. At each Wave, two models were used to examine the relationship.

In Model 1 (the basic model) covariates included were age (years), highest education level (categorised as completed secondary, university/further and other), and gender. In Model 2, covariates included were age (years), highest education level (categorised as completed secondary, university/further and other), caloric intake (KJ/day), BMI, gender, and smoking status (categorised as current smoker, ex-smoker and non-smoker).

In the basic model, weekly physical activity time was significantly associated with CIm. For every one hour increment in physical activity time, the odds of CIm decreased β = -0.09 (OR 0.91; 95% CI: 0.84 – 0.99; p = 0.03). In Model 2, MeDi score, weekly physical activity time and weekly television viewing time were not found to be significantly associated with CIm. See results in Table 8.2 below.

Table 8.2: Results of Logistic Regression Analyses showing associations between CIm at Wave 3 and MeDi Score, physical activity time per week (hours) and television viewing time per week (hours) – Odds ratios with 95% Confidence Intervals shown in brackets

Model 1	Wave 1	Wave 2	Wave 3
MeDi Score	β = 0.081 [1.085 (0.885 – 1.328) p = 0.433]	β = -0.106 [0.900 (0.743 – 1.089) p = 0.278]	β = -0.098 [0.906 (0.682 – 1.205) p = 0.498]
Physical Activity Time	β = -0.046 [0.955 (0.885 – 1.031)p = 0.237]	β = **-0.094** [**0.911 (0.838 – 0.989)** **p = 0.026**]*	β = 0.000 [1.000 (0.925 - 1.081) p = 0.996]
Television Viewing Time	β = 0.012 [1.012 (0.979 – 1.047) p = 0.470]	β = -0.006 [0.994 (0.964 – 1.025) p = 0.718]	β = 0.089 [1.093 (0.614 – 1.946) p = 0.763]
Model 2	Wave 1	Wave 2	Wave 3
MeDi Score	β = 0.037 [1.038 (0.785 – 1.372) p = 0.793]	β = -0.073 [0.930 (0.721 – 1.199) p = 0.574]	β = -0.056 [0.946 (0.640 – 1.398) p = 0.780]
Physical Activity Time	β = -0.042 [0.959 (0.880 – 1.044) p = 0.332]	β = -0.068 [0.934 (0.860 – 1.015) p = 0.107]	β = 0.019 [1.019 (0.944 – 1.101) p = 0.628]
Television Viewing Time	β = 0.009 [1.009 (0.974 – 1.047) p = 0.610]	β = -0.004 [0.996 (0.965 – 1.028) p = 0.800]	β = 0.007 [1.007 (0.966 – 1.049) p = 0.755]

Model 1 – Dependent Variable: CIm. Model included the independent variables age, gender, education and MeDi score.

Model 2 – Dependent Variable: CIm. Model included the independent variables age, gender, education, energy, BMI, smoking status, MeDi score, physical activity time and television viewing time.

* p = <0.05

Sensitivity Analysis

It is possible that these findings were due to the effect of premorbid cognitive abilities. To further evaluate this, the influence of MeDi adherence, physical activity time, and television viewing time on CIm was re-examined adjusting for Spot-the-Word (STW) score. The STW test has been reported to be a useful method of estimating premorbid intelligence (Yuspeh & Vanderploeg, 2000). The association between MeDi adherence, physical activity time, and television viewing time on CIm remained non-significant at all 3 Waves (see results in Table 8.3 below).

Table 8.3: Results of sensitivity analysis adjusting for STW – Odds ratios with 95% Confidence Intervals shown in brackets

Model 1	Wave 1	Wave 2	Wave 3
MeDi Score	β = 0.143 [1.154 (0.782 – 1.703) p = 0.470]	β = -0.104 [0.901 (0.644 – 1.261) p = 0.545]	β = 0.123 [1.131 (0.667 – 1.917) p = 0.648]
Physical Activity Time	β = -0.018 [0.982 (0.889 – 1.085) p = 0.717]	β = -0.099 [0.905 (0.805 – 1.018) p = 0.098]	β = 0.013 [1.013 (0.912 – 1.125) p = 0.812]
Television Viewing Time	β = 0.008 [1.008 (0.956 – 1.064) p = 0.764]	β = 0.002 [1.002 (0.960 – 1.045) p = 0.941]	β = -0.018 [0.982 (0.920 – 1.048) p = 0.591]

Model – Dependent Variable: CIm. Model included the independent variables age, gender, education, energy, BMI, STW, smoking status, MeDi score, physical activity time and television viewing time.

Individual Constituents of the MeDi as a predictor of Cognitive Status

In basic models, at Wave 2 greater daily dairy intake was associated with decreased odds of CIm β = -0.00 (OR 1.00; 95% CI: 0.99 – 1.00; p = 0.02) while at Wave 3 greater daily meat intake was associated with increased odds of CIm β = 0.01 (OR 1.01; 95% CI: 1.00 – 1.02; p = 0.04).

In fully adjusted models, at Wave 1 daily legume intake was significantly associated with cognitive status. Greater daily legume intake was associated with increased odds of CIm β = 0.01 (OR 1.01; 95% CI: 1.00 – 1.01; p = 0.04). At Wave 2, greater daily meat intake was associated with decreased odds of CIm = β -0.01 (OR 0.99; 95% CI: 0.98 – 1.00; p = 0.03) while greater daily saturated fat intake was associated with increased odds of CIm β = 0.09 (OR 1.09; 95% CI: 1.00 – 1.19; p = 0.05). See results in Table 8.4 and Table 8.5 below.

Table 8.4: Results of Logistic Regression Analyses (Model 1) showing associations between CIm at Wave 3 and individual constituents of the MeDi, physical activity time per week (hours) and Television viewing time per week (hours) – Odds ratios with 95% Confidence Intervals shown in brackets

Model 1	Wave 1	Wave 2	Wave 3
Fish intake (mg/day)	β = -0.003 [0.997 (0.985 – 1.009) p = 0.586]	β = 0.002 [1.002 (0.993 – 1.011) p = 0.720]	β = -0.004 [0.996 (0.982 – 1.011) p = 0.629]
Dairy intake (mg/day)	β = -0.001 [0.999 (0.996 – 1.001) p = 0.209]	**β = -0.003 [0.997 (0.995 – 1.000) p = 0.016*]**	β = 0.000 [1.000 (0.997 – 1.003) p = 0.844]
Meat intake (mg/day)	β = 0.002 [1.002 (0.998 – 1.006) p = 0.283]	β = -0.002 [0.998 (0.993 - 1.004) p = 0.554]	**β = 0.009 [1.009 (1.001 – 1.018) p = 0.037*]**
Vegetable intake (mg/day)	β = 0.000 [1.000 (0.995 – 1.004) p = 0.903]	β = -0.003 [0.997 (0.992 – 1.002) p = 0.265]	β = -0.002 [0.998 (0.987 – 1.008) p = 0.648]
Legume intake (mg/day)	β = 0.001 [1.001 (0.996 – 1.005) p = 0.803]	β = -0.003 [0.997 (0.991 – 1.002) p = 0.225]	β = -0.005 [0.995 (0.988 – 1.001) p = 0.099]
Cereal intake (mg/day)	β = 0.001 [1.001 (0.998 - 1.004) p = 0.437]	β = 0.002 [1.002 (0.999 – 1.005) p = 0.124]	β = -0.001 [0.999 (0.994 – 1.003) p = 0.578]
Fruit intake (mg/day)	β = 0.001 [1.001 (0.999 – 1.002) p = 0.535]	β = 0.000 [1.000 (0.998 – 1.002) p = 0.728]	β = 0.002 [1.002 (1.000 – 1.004) p = 0.112
Monounsaturated fat intake (mg/day)	β = -0.036 [0.964 (0.895 – 1.039) p = 0.339]	β = -0.031 [0.969 (0.901 – 1.043) p = 0.402]	β = -0.111 [0.895 (0.770 – 1.040) p = 0.147]
Saturated fat intake (mg/day)	β = 0.026 [1.026 (0.976 – 1.079) p = 0.310]	β = 0.032 [1.032 (0.979 – 1.089) p = 0.243]	β = 0.017 [1.017 (0.920 – 1.124) p = 0.738]
Alcohol intake (grams/day)	β = -0.006 [0.994 (0.971 – 1.018) p = 0.647]	β = -0.004 [0.996 (0.974 – 1.019) p = 0.754]	β = 0.007 [1.007 (0.985 – 1.031) p = 0.532]

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Table 8.4 – Continued

Model 1	Wave 1	Wave 2	Wave 3
Physical activity time (hours/week)	β = -0.044 [0.957 (0.886 – 1.035) p = 0.272]	**β = -0.087** [**0.917 (0.843 – 0.997)** **p = 0.044***]	β = 0.014 [1.015 (0.937 – 1.099) p = 0.723]
Television viewing time (hours/week)	β = 0.015 [1.015 (0.981 – 1.050) p = 0.397]	β = -0.002 [0.998 (0.967 – 1.029) p = 0.885]	β = 0.016 [1.016 (0.970 – 1.063) p = 0.502]

Model 1 – Dependent Variable: CIm. Model included the independent variables age, gender, education and individual constituents of the MeDi, physical activity time and television viewing time.

* p = <0.05

Table 8.5: Results of Logistic Regression Analyses (Model 2) showing associations between CIm at Wave 3 and individual constituents of the MeDi, physical activity time per week (hours) and Television viewing time per week (hours) – Odds ratios with 95% Confidence Intervals shown in brackets

Model 1	Wave 1	Wave 2	Wave 3
Fish intake (mg/day)	β = -0.014 [0.986 (0.964 – 1.009) p = 0.236]	β = 0.006 [1.006 (0.995 – 1.017) p = 0.318]	β = -0.005 [0.995 (0.978 – 1.013) p = 0.574]
Dairy intake (mg/day)	β = 0.001 [1.001 (0.998 – 1.005) p = 0.472]	β = 0.000 [1.000 (0.996 – 1.003) p = 0.831]	β = 0.001 [1.001 (0.997 – 1.005) p = 0.558]
Meat intake (mg/day)	β = 0.000 [1.000 (0.991 – 1.008) p = 0.954]	**β = -0.011 [0.989 (0.980 – 0.999) p = 0.027***]	β = 0.008 [1.009 (0.996 – 1.021) p = 0.174]
Vegetable intake (mg/day)	β = 0.007 [1.007 (1.000 – 1.014) p = 0.067]	β = 0.000 [1.000 (0.993 – 1.006) p = 0.915]	β = -0.006 [0.994 (0.980 – 1.009) p = 0.444]
Legume intake (mg/day)	**β = 0.005 [1.005 (1.000 – 1.010) p = 0.035***	β = 0.001 [1.001 (0.995 – 1.007) p = 0.838]	β = -0.008 [0.992 (0.981 – 1.003) p = 0.156]
Cereal intake (mg/day)	β = 0.005 [1.005 (0.999 – 1.010)p = 0.089]	β = 0.004 [1.004 (1.000 – 1.008) p = 0.057]	β = 0.001 [0.999 (0.992 – 1.005) p = 0.679]
Fruit intake (mg/day)	β = 0.003 [1.003 (1.000 – 1.007) p = 0.072]	β = 0.001 [1.001 (0.998 – 1.004) p = 0.522]	β = -0.001 [0.999 (0.994 – 1.004) p = 0.606
Monounsaturated fat intake (mg/day)	β = 0.120 [1.127 (0.984 – 1.291) p = 0.084]	β = 0.088 [1.092 (0.971 – 1.228) p = 0.140]	β = -0.104 [0.901 (0.691 – 1.175) p = 0.441]
Saturated fat intake (mg/day)	β = 0.063 [1.065 (0.969 – 1.171) p = 0.191]	**β = 0.089 [1.093 (1.000 – 1.194) p = 0.049***]	β = -0.057 [0.945 (0.801 – 1.114) p = 0.499]
Alcohol intake (grams/day)	β = -0.016 [0.984 (0.943 – 1.026) p = 0.445]	β = 0.012 [1.012 (0.985 – 1.039) p = 0.393]	β = 0.001 [1.001 (0.964 – 1.039) p = 0.968]

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Table 8.5 – Continued

Model 1	Wave 1	Wave 2	Wave 3
Physical activity time (hours/week)	β = -0.026 [0.974 (0.865 – 1.096) p = 0.661]	β = -0.104 [0.901 (0.800 – 1.015) p = 0.087]	β = 0.013 [1.013 (0.909 – 1.130) p = 0.811]
Television viewing time (hours/week)	β = 0.012 [1.012 (0.953 – 1.074) p = 0.702]	β = 0.009 [1.009 (0.962 – 1.058) p = 0.722]	β = -0.008 [0.992 (0.924 – 1.064) p = 0.813]

Model 2 – Dependent Variable: CIm. Model included the independent variables age, gender, education, energy, BMI, STW, smoking status, individual constituents of the MeDi, physical activity time and television viewing time.

* p = <0.05

MeDi as a Predictor of Memory, Verbal Knowledge and Processing Speed

In fully adjusted models, diet was not a predictor of memory, verbal knowledge, and processing speed at any of the three Waves. At Wave 3, physical activity time per week was predictive of poorer processing speed, memory and verbal ability β = -0.12; SE = 0.06; p = 0.03, β = -0.08; SE = 0.04; p = 0.05 and β = -0.04; SE = 0.01; p = 0.00 respectively. At Wave 3, television viewing time trended toward being predictive of better processing speed β = 0.06; SE = 0.03; p = 0.06. See results in Table 8.6 below.

Table 8.6: Results of GLM showing associations between CIm at Wave 3 and MeDi Score, Physical Activity Time and TV Time at each Wave (β values with standard errors shown in brackets)

Model 2	Wave 1	Wave 2	Wave 3
Wave 1	**n = 710**	**n = 718**	**n = 690**
MeDi Score	-0.567 (0.230) p = 0.014*	-0.057 (0.050) p = 0.250	-0.265 (0.170) p = 0.120
Physical Activity Time	0.036 (0.068) p = 0.595	0.018 (0.014) p = 0.224	-0.011 (0.049) p = 0.827
TV Time	0.013 (0.041) p = 0.743	0.015 (0.009) p = 0.079	-0.017 (0.031) p = 0.573
Wave 2	**n = 718**	**n = 724**	**n = 690**
MeDi Score	0.249 (0.229) p = 0.276	0.018 (0.049) p = 0.722	0.058 (0.164) p = 0.725
Physical Activity Time	0.137 (0.071) p = 0.051*	0.018 (0.015) p = 0.232	0.041 (0.050) p = 0.416
TV Time	-0.005 (0.040) p = 0.906	0.014 (0.009) p = 0.110	-0.006 (0.029) p = 0.837
Wave 3	**n = 768**	**n = 768**	**n = 750**
MeDi Score	-0.024 (0.208) p = 0.909	-0.015 (0.050) p = 0.762	0.116 (0.141) p = 0.409
Physical Activity Time	-0.083 (0.054) p = 0.127	-0.040 (0.013) p = 0.002*	-0.065 (0.037) p = 0.076
TV Time	0.051 (0.033) p = 0.123	-0.006 (0.008) p = 0.458	-0.002 (0.022) p = 0.919
Model 2	**Speed**	**Memory**	**Verbal**
Wave 1	**n = 706**	**n = 714**	**n = 686**
MeDi Score	-0.397 (0.296) p = 0.180	-0.111 (0.220) p = 0.613	-0.055 (0.064) p = 0.396
Physical Activity Time	0.010 (0.069) p = 0.884	-0.037 (0.051) p = 0.465	0.012 (0.015) p = 0.435
TV Time	0.022 (0.041) p = 0.597	-0.027 (0.031) p = 0.396	0.015 (0.009) p = 0.087
Wave 2	n = 717	n = 723	n = 689
MeDi Score	0.534 (0.300) p = 0.075	0.064 (0.214) p = 0.763	-0.005 (0.065) p = 0.939

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Table 8.6 – Continued

Model 2	Wave 1	Wave 2	Wave 3
Physical Activity Time	0.127 (0.073) p = 0.082	0.029 (0.052) p = 0.578	0.019 (0.016) p = 0.238
TV Time	0.010 (0.040) p = 0.801	-0.005 (0.030) p = 0.878	0.014 (0.009) p = 0.122
Model 2	**Speed**	**Memory**	**Verbal**
Wave 3	**n = 747**	**n = 746**	**n = 729**
MeDi Score	0.067 (0.272) p = 0.805	0.325 (0.187) p = 0.082	-0.039 (0.066) p = 0.560
Physical Activity Time	-0.122 (0.055) p = 0.026*	-0.075 (0.038) p = 0.050*	-0.044 (0.013) p = 0.001*
TV Time	0.064 (0.033) p = 0.055	0.001 (0.023) p = 0.966	-0.003 (0.235) p = 0.691

Model 1 – Dependent Variable: CIm. Model included the independent variables age, gender, education and MeDi score.

Model 2 – Dependent Variable: CIm. Model included the independent variables age, gender, education, energy, BMI, STW, smoking status, MeDi score, physical activity time and television viewing time.

* p = <0.05

8.6 Discussion

In this study, MeDi adherence, weekly physical activity time, and weekly television viewing time were not predictive of CIm in fully adjusted models. MeDi adherence was also not a predictor of memory, verbal knowledge, and processing speed at any of the three Waves.

In the AusDiab study, adherence to the MeDi did not significantly influence the odds of CIm. This is consistent with other published work where adherence to the MeDi was not associated with better cognitive outcome (Psaltopoulou et al., 2008; Vercambre et al., 2012). For example, in studies conducted by Cherbuin and Anstey (2012), Psaltopoulou et al. (2008) and Vercambre et al. (2012), adherence to the MeDi was not protective against CIm, not associated with MCI and not linked to better global cognitive function. Findings such as these must however be examined in conjunction with others which have recorded reduction in MCI and AD risk with increased MeDi adherence (Scarmeas, Stern, Mayeux, Manly, et al., 2009; Scarmeas et al., 2006). This lack of consistency among findings as it relates to the MeDi and cognition make it difficult for population-based policies to be developed (Cherbuin & Anstey, 2012; Féart et al., 2009; Scarmeas et al., 2006). One of the key areas of interest in studying dietary patterns remains whether the MeDi can and should be applied across varying sociodemographic and cultural settings or whether there is a dietary pattern yet to be identified that may reap even more cognitive benefits. Results from this and other studies highlight that adherence to the MeDi may not translate to better health outcomes in Australian populations (Cherbuin & Anstey, 2012).

While adherence to the MeDi did not significantly influence the odds of CIm in AusDiab participants, individual constituents of the MeDi had a significant influence.

The unexpected legume finding at Wave 1 can be partially explained by the negative correlation observed between increasing age and daily legume consumption while the meat finding at Wave 2 may be explained by the positive correlation between meat and fish consumption. Fish consumption has been linked to improved cognitive function in the literature (Cherbuin & Anstey, 2012).

In the present study, greater physical activity time was not independently associated with lower odds of CIm. In addition, at Wave 3 increased engagement in weekly physical activity was predictive of poorer processing speed, memory, and verbal ability. These findings are difficult to explain and may stem from the types of activities that older adults at Wave 3 were able to engage in. Aerobic activities have been shown to improve cognitive function (Quaney et al., 2009) and our findings may be reflective of advancing age at Wave 3.

Although TV time has been reported in prior studies as being representative of sedentary behaviours and has been linked to kidney disease, obesity, and disease risk factors (Dunstan et al., 2004; White et al., 2011), it was not a significant predictor of CIm among older adults in the AusDiab. The results obtained though may be due to the fact that participants generally did not watch television for long periods. The average daily time spent watching television in the sample was approximately 2.2 hours (under 10% of the day).

Strengths of this study are centred on its utilisation of a holistic approach, inclusive of an *a priori* developed dietary pattern to assess factors that influence CIm in a non-Mediterranean population. To the authors' knowledge, this is the first Australian study that has examined the influence of both adherence to the MeDi and engagement in physical activity as predictors of CIm. Another strength of the study is that multiple Waves of dietary data were available for analysis. The ability to utilise AusDiab data is also noteworthy as this is one of the largest population-based studies of the over 25 population in Australia and involves collection of a wide range of data across multiple domains. Finally, by controlling for participants' STW score the influence of premorbid intelligence on lifestyle choices has been taken into account (Crowell et al., 2002).

In this study, the Active Australia Survey questionnaire was used to report participant engagement in physical activity. This questionnaire has been reported to have reasonable reliability and validity for reporting engagement in physical activity/inactivity in adults when validated against pedometer step counts as an objective measure of physical activity, self-reported physical function, and a step-test to assess cardiorespiratory fitness (Heesch, Hill, Van Uffelen, & Brown, 2011). Despite this, questionnaires may give rise to over-and-under reporting engagement in physical activity (Healy, Dunstan, Shaw, Zimmet, & Owen, 2006). Other limitations of the study include losses to follow up and small size of the sample when compared to the overall study population. Due to the unavailability of longitudinal cognitive data both prospective and cross-sectional methodologies were adopted. One area for future investigation is the determination of whether change in lifestyle factors at Waves 1 and 2 is predictive of CIm at Wave 3.

Further research is needed in order to gain clarification and consensus of the effect of both diet and physical activity on cognition since there is a need for effective preventative treatment approaches and even a modest protective outcome can result in significant public health impact.

8.7 Chapter Conclusion

The relationship between diet and physical activity is a complex one. In summary, greater adherence to the MeDi was not predictive of better cognitive outcome among older adults in the AusDiab study. Weekly physical activity time and television viewing time were also not predictive of CIm. Further studies are needed to examine whether the benefits of the MeDi can be widely applied to other socio-cultural and geographic groups and also to further examine the effects of diet and physical activity in older age groups.

Chapter 9

Analysis of Dietary Patterns in relation to Cognitive Impairment in Latin America and the Caribbean

9.1 Chapter Summary

Chi-square tests of independence and logistic regression analysis were used to determine the relationship between diet and regular physical activity on CIm among the seven LAC countries under study – Argentina, Barbados, Brazil, Chile, Cuba, Mexico and Uruguay. The Mini Mental State Examination (MMSE) was used to establish cognitive status in all study countries. Data on dietary and physical activity habits were obtained from Section C of the Survey on Health, Wellbeing and Ageing in LAC (SABE) study questionnaire which asked about participant health status (including disease, diet, functional status, and physical activity engagement).

Eating milk, cheese or similar products at least once a day was positively associated with CIm in Chile x^2(2, N = 1301) = 17.26, p < 0.00 while in both Chile and Cuba there was a positive association between eating eggs, peas and beans at least once a week and CIm: x^2(2, N = 1301) = 9.07, p = 0.01 and x^2(2, N = 1755) = 13.86, p = 0.00, respectively.

Eating meat, fish or poultry at least three times a week was positively associated with CIm in Brazil: x^2(1, N = 1969) = 8.69, p = 0.00, Chile: x^2(3, N = 1301) = 8.79, p = 0.03, and Mexico: x^2(1, N = 1129) = 6.37, p = 0.01. In Chile and Cuba there was a positive association between eating fruits or vegetables at least two times a day and CIm: x^2(2, N = 1301) = 8.160, p = 0.017 and x^2(2, N = 1755) = 13.13, p = 0.00, respectively.

Eating less in the past 12 months than before due to loss of appetite or digestive problems was found to be negatively associated with CIm in all study countries; Argentina: x^2(2, N = 1010) = 7.54, p = 0.02; Barbados: x^2(2, N = 1156) = 7.67, p = 0.02; Brazil: x^2 (2, N = 1969) = 8.64, p = 0.01; Chile: x^2(2, N = 1301) = 13.10, p = 0.00; Cuba: x^2(2, N = 1755) = 6.90, p = 0.03; Mexico: x^2(2, N = 1129) = 14.24, p = 0.00 and Uruguay: x^2(2, N = 1449) = 6.11, p = 0.05.

Number of days per week alcoholic drinks were consumed within the last three months was negatively associated with CIm in Chile only: x^2 (6, N = 1301) = 26.77, p <0.00. More specifically, number of glasses of wine per day over the last three months was found to be positively associated with CIm in Argentina [x^2(10, N = 431) = 42.38, p <0.00] while number of beers per day over the last three months was positively associated with CIm in Argentina and Mexico: x^2(9, N = 432) = 37.70, p < 0.00 and x^2(10, N = 232) = 40.07, p < 0.00, respectively. Number of drinks containing liquor consumed per day over the last three months was positively associated with CIm in Argentina x^2(4, N = 431) = 30.79, p < 0.00 and Mexico x^2(9, N = 232) = 28.65, p = 0.00.

Engagement in regular exercise or participation in vigorous activity such as playing a sport, dancing or heavy housework three or more times a week was positively associated with CIm in Chile, Mexico, and Uruguay: x^2(3, N = 1301) = 19.17, p < 0.00, x^2(2, N = 1129) = 18.32, p <0.00 and x^2(1, N = 1436) = 0.06, p = 0.02, respectively.

Results of logistic regression showed that while these variables were associated with CIm, this was not a predictive relationship. Questions that allow for a more detailed analysis of dietary and physical activity habits are essential to truly examine the nature of the relationship between diet, physical activity and CIm in the countries under study.

9.2 Background

At present, approximately 58% of all people with dementia live in low- and middle-income countries (ADI/BUPA, 2013). These estimates are predicted to increase to a high of 71% by 2050 (ADI/BUPA, 2013). The different pace of population ageing in LAC is of concern since very little is empirically known about the health and quality of life of the elderly in the region (United Nations Economic Commisssion for Latin America and the Caribbean, 2004). A recent publication by Alzheimer's Disease International and BUPA (ADI/BUPA, 2013) has highlighted that from 2010 to 2050, numbers of people with dementia will increase by 214% in Latin Caribbean countries, 237% in the non-Latin Caribbean, 414% in Mexico and by 422% in Brazil.

Preservation of cognitive abilities is central to the maintenance of independence and quality of life among older adults (Shatenstein et al., 2012). Diet and physical activity have been shown to be associated with cognitive function (Morris, 2009; Scarmeas, Luchsinger, et al., 2009). As with any other organ, the brain needs nutrients to build and maintain its structure, both to function harmoniously and to be protected from diseases or premature ageing (Wärnberg et al., 2009). Physical activity/exercise promotes functional neuro-protective changes in the hippocampus of the brain – a region central to learning and memory (Cotman & Berchtold, 2002). In addition, physical activity lowers cardiovascular disease risk, decreases blood pressure, and increases high density lipoprotein cholesterol levels and glucose tolerance, each of which may be related to neuronal integrity and cognitive function (Podewils et al., 2005).

As the proportion of older adults increases in the LAC region, devising intervention programs and policies that focus on modifiable lifestyle factors will become a priority. Both diet and physical activity have been shown to not only affect cognition but also to reduce the risk of other diseases such as cardiovascular disease, diabetes, hypertension, and certain cancers all of which are leading causes of death.

9.3 Aim

- To investigate the association between diet and cognitive outcome among older adults in the SABE.
- To investigate the association between regular physical activity and cognitive impairment among older adults in the SABE.

9.4 Methodology

9.4.1 Study Design and Sample

Existing data derived from the SABE was used in analyses. Conducted during the period 1999–2000, SABE represents the most comprehensive study on older adults in the LAC region and aimed to examine health conditions and functional limitations. Baseline data (n = 10,597) was collected in 7 capital cities: Buenos Aires (Argentina), Bridgetown (Barbados), Sao Paolo (Brazil), Santiago (Chile), Havana (Cuba), Mexico City (Mexico), and Montevideo (Uruguay).

Response rates were 85% in Bridgetown, Sao Paulo, and Mexico City to 60% in Buenos Aires, 84% in Santiago, 95% in Havana, and 66% in Montevideo. Sampling was based on censuses conducted in 1998 in Buenos Aires, 1996 in Sao Paulo, 1992 in Santiago, 1999 in Havana, 1999 in Mexico City, and 1997 in Montevideo (Barceló et al., 2006).

A multistage, clustered sampling with stratification of the units at the highest levels of aggregation was used (Palaez et al., 2004). The primary sampling unit was a cluster of independent households within predetermined geographic areas grouped into socioeconomic strata and then divided into secondary sampling units, each containing a smaller number of households (Palaez et al., 2004).

Households and target individuals (persons age 60 and older) were randomly selected and target individuals contacted to schedule an interview at home. The interviews were conducted in English, Portuguese or Spanish depending on the official language of the country in which the survey was administered. If a person who agreed to be interviewed failed the cognitive test, a proxy was selected to respond to some parts of the questionnaire (Palaez et al., 2004).

Definition of Cognitive Impairment (CIm)

The MMSE (Folstein et al., 1975) was used to establish cognitive status in all study samples. The MMSE is a sum-score evaluating various dimensions of cognition (memory, attention and language) and is an index of global cognitive performance (Folstein et al., 1975). In the SABE, a regression analysis had been carried out prior to identify the MMSE questions that would be best to determine CIm. The Modified MMSE was developed with nine variables instead of the 19 original MMSE variables in a bid to lessen the low literacy bias (Icaza, 1999). Each respondent's score was then computed, with a score of <12 (out of a maximum of 30) indicating CIm (Palaez et al., 2004).

The Pfeffer Scale measures functional capacity, taking into consideration ability to perform daily tasks as well as instrumental activities such as conduct of simple fiscal transactions, doing laundry, and comprehension of current events and it is used to assess and compare normal and demented adults (Pfeffer et al., 1982). The modified MMSE was used in conjunction with the Pfeffer Scale for those persons who obtained a score of 12 or less in the Modified MMSE and was administered to an informant or carer accompanying the participant with cognitive deterioration in order to confirm that their level of cognitive decline affected functional capacity (Palaez et al., 2004). A participant scoring 12 or less on the Modified MMSE and 6 or more on the Pfeffer Scale was considered unable to be interviewed and a proxy of the participant was asked to respond instead (Palaez et al., 2004).

Food Consumption Data

The SABE comprised few questions that asked about consumption of specific foods. In this study, questions from Section C of the Questionnaire were utilised which asked about participant health status (including disease, diet, functional status, and physical activity engagement). The specific dietary questions used in analyses are listed below:

- Do you eat milk, cheese or similar products at least once a day?
- Do you eat eggs, beans, peas or legumes at least once a week?
- Do you eat meat, fish or poultry at least three times a week?
- Do you eat fruit or vegetables at least 2 times a day?
- Have you been eating less in the last twelve months than you were before due to loss of appetite or digestive problems?

- In the last three months, on average, how many days per week have you had any alcohol to drink (for example, beer, wine, or another drink containing alcohol)?
- In the last three months, on the days you drank alcoholic beverages, how many glasses of wine, beers or drinks with liquor did you have on average?

Physical Activity Measurement

Very few questions were available on participant's physical activity type and duration. One question was identified from Section C on Health Status in order to give an indication of an individual's physical activity levels: 'In the last twelve months, have you exercised regularly or participated in vigorous physical activity such as playing a sport, dancing or heavy housework, 3 or more times a week?' This question required participants to self-report their engagement in physical activity.

9.4.2 Statistical Analysis

Chi-Square tests of association and logistic regression analysis using SPSS version 22 were carried out to assess the relationship of diet and physical activity on cognitive status. More specifically, participant weekly consumption of dairy products, legumes and eggs, meat, fish and poultry, fruits and vegetables and alcohol intake were used as predictor variables to determine the effect of diet on CIm among the cohort under study. In addition, participant engagement in regular exercise and vigorous physical activity was examined to determine association with CIm. Covariates included in the model were age, sex, years of education, ethnic background, smoking status, number of complete meals per day, and change in eating pattern in the last twelve months as a result of loss of appetite or digestive problems.

Participants with no dietary, cognitive or physical activity data recorded as well as data on the included covariates were excluded. Figure 9.1 shows how participants were selected for the study.

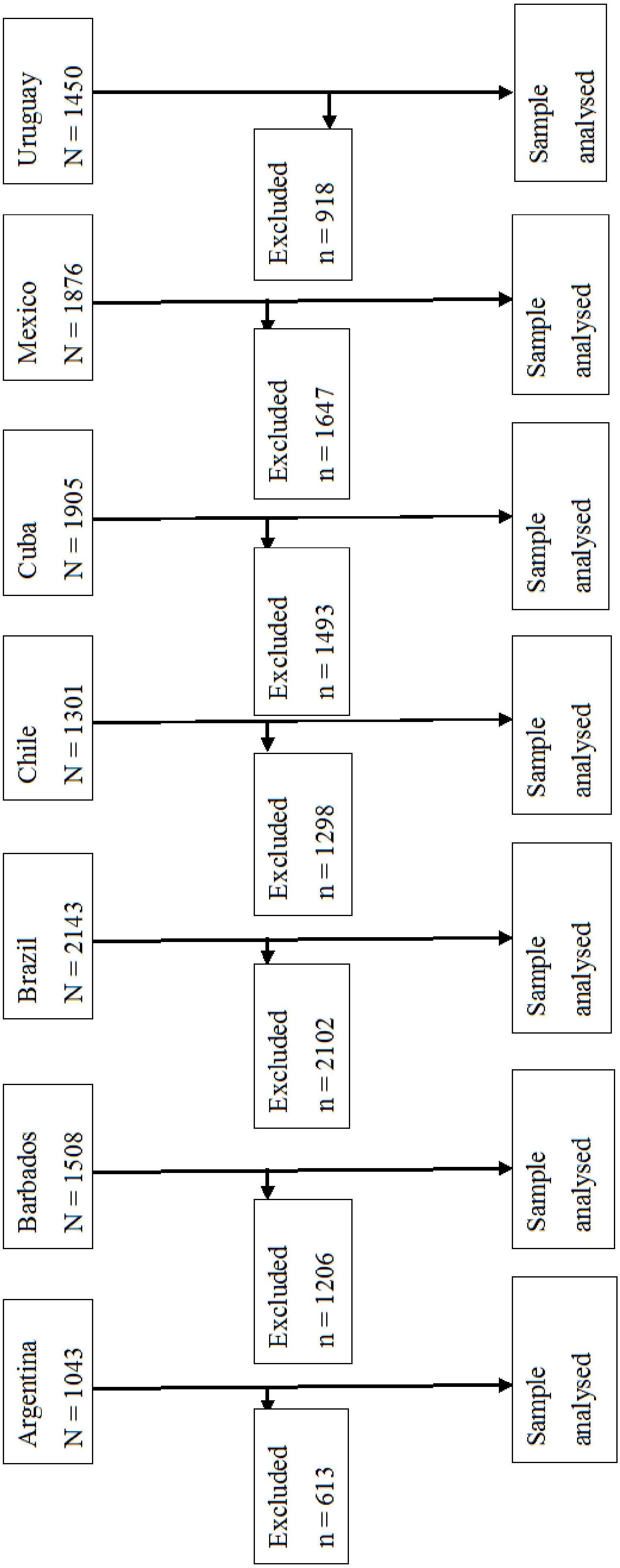

Figure 9.1: Selection of Sample for Analysis

9.5 Results

Association between Diet, Physical Activity and CIm

Chi-square tests of independence revealed that the number of complete meals eaten per day and CIm were not significantly associated in any of the countries under study.

Eating milk, cheese or similar products at least once a day was positively associated with CIm in Chile [$x^2(2, N = 1301) = 17.26, p < 0.00$] while in both Chile and Cuba there was a positive association between eating eggs, peas and beans at least once a week and CIm: $x^2(2, N = 1301) = 9.07, p = 0.01$ and x^2 (2, N = 1755) = 13.86, p = 0.00, respectively.

Eating meat, fish or poultry at least three times a week was positively associated with CIm in Brazil: $x^2(1, N = 1969) = 8.69, p = 0.00$, Chile: $x^2(3, N = 1301) = 8.79, p = 0.03$ and Mexico: $x^2(1, N = 1129) = 6.37, p = 0.01$.

In Chile and Cuba there was a positive association between eating fruits or vegetables at least two times a day and CIm: $x^2(2, N = 1301) = 8.16, p = 0.02$ and $x^2(2, N = 1755) = 13.13, p = 0.00$ respectively.

Eating less in the past 12 months than before due to loss of appetite or digestive problems was found to be negatively associated with CIm in all study countries; Argentina: $x^2(2, N = 1010) = 7.54, p = 0.02$; Barbados: $x^2(2, N = 1156) = 7.67, p = 0.02$; Brazil: x^2 (2, N = 1969) = 8.64, p = 0.01; Chile: $x^2(2, N = 1301) = 13.10, p = 0.00$; Cuba: $x^2(2, N = 1755) = 6.90, p = 0.03$; Mexico: $x^2(2, N = 1129) = 14.24, p = 0.00$ and Uruguay: $x^2(2, N = 1449) = 6.11, p = 0.05$.

Number of days per week alcoholic drinks were consumed within the last three months was negatively associated with CIm in Chile only [x^2 (6, N = 1301) = 26.77, p <0.00]. More specifically, the number of glasses of wine per day over the last three months was found to be positively associated with CIm in Argentina [$x^2(10, N = 431) = 42.38, p <0.001$] while number of beers per day over the last three months was positively associated with CIm in Argentina and Mexico: $x^2(9, N = 432) = 37.70, p < 0.00$ and $x^2(10, N = 232) = 40.07, p < 0.00$, respectively. Number of drinks containing liquor consumed per day over the last three months was positively associated with CIm in Argentina [$x^2(4, N = 431) = 30.79, p <0.00$] and Mexico [$x^2(9, N = 232) = 28.65, p = 0.00$].

Engagement in regular exercise or participation in vigorous activity such as playing a sport, dancing or heavy housework three or more times a week was positively associated with CIm in Chile, Mexico and Uruguay: $x^2(3, N = 1301) = 19.17, p < 0.00$, $x^2(2, N = 1129) = 18.32, p <0.00$ and $x^2(1, N = 1436) = 0.06, p = 0.02$, respectively. Further inferences can be made from Table 9.1.

Table 9.1: Chi-squared analyses showing association between diet, physical activity and CIm

	Argentina	**Barbados**	**Brazil**	**Chile**	**Cuba**	**Mexico**	**Uruguay**
Eat milk, cheese or similar at least once/day.	x^2(2, N = 1011) = p = 0.681	x^2(1, N = 1153) = 0.001, p = 0.970	x^2(1, N = 1969) = 1.753, p = 0.185	x^2(2, N = 1301) = 17.255, p = 0.000*	x^2(2, N = 1755) = 1.517, p = 0.468	x^2(1, N = 1131) = 0.538, p = 0.463	x^2(1, N = 1449) = 0.893, p = 0.345
Eat eggs, beans, peas, peas or legumes at least once/week.	x^2 (1, N = 1011) = 1.207, p = 0.272	x^2(1, N = 1156) = 0.031, p = 0.859	x^2(1, N = 1969) = 1.012, p = 0.314	x^2(2, N = 1301) = 9.069, p = 0.011*	x^2(2, N = 1755) = 13.859, p = 0.001*	x^2(1, N = 1130) = 0.079, p = 0.779	x^2(2, N = 1448) = 3.117, p = 0.210
Eat meat, fish or poultry at least three times/week.	x^2(1, N = 1011) = 1.489, p = 0.022	x^2(1, N = 1157) = 0.092, p = 0.761	x^2(1, N = 1969) = 8.693, p = 0.004*	x^2(3, N = 1301) = 8.794, p = 0.032*	x^2(2, N = 1755) = 0.570, p = 0.752	x^2(1, N = 1129) = 6.371, p = 0.012*	x^2(2, N = 1448) = 3.783, p = 0.151
Eat fruit or vegetables at least 2 times/day.	x^2(2, N = 1011) = 0.327, p = 0.849	x^2(1, N = 1157) = 0.062, p = 3.492	x^2(2, N = 1969) = 2.657, p = 0.265	x^2(2, N = 1301) = 8.160, p = 0.017*	x^2(2, N = 1755) = 13.127, p = 0.001*	x^2(1, N = 1131) = 0.088, p = 0.767	x^2(2, N = 1448) = 1.647, p = 0.439

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Table 9.1 – Continued

	Argentina	Barbados	Brazil	Chile	Cuba	Mexico	Uruguay
Eating less in the past 12 months due to loss of appetite or digestive problems.	x^2(2, N = 1010) = 7.542, p = 0.023‡	Barbados: x^2(2, N = 1156) = 7.674, p = 0.022‡	x^2(2, N = 1969) = 8.635, p = 0.013‡	x^2(2, N = 1301) = 13.100, p = 0.001‡	x^2(2, N = 1755) = 6.901, p = 0.032 ‡	x^2(2, N = 1129) = 14.241, p = 0.001‡	x^2(2, N = 1449) = 6.111, p = 0.047‡
Days per week alcohol consumed in last 3 months.	x^2(6, N = 1011) = 12.119, p = 0.059	x^2(6, N = 1156) = 4.464, p = 0.062	x^2(5, N = 1969) = 3.756, p = 0.585	x^2(6, N = 1301) = 26.765, p = 000‡	x^2(6, N = 1755) = 7.607, p = 0.268	x^2(5, N = 1131) = 7.106, p = 0.213	x^2(6, N= 1448) = 6.504, p = 0.369
Glasses wine/day.	x^2(10, N = 431) = 42.376, p = 0.000 *	x^2(7, N = 308) = 2.876, p = 0.896	x^2(6, N = 195) = 12.395, p = 0.054	x^2(12, N = 406) = 5.333, p = 0.946	x^2(9, N = 412) = 1.220, p = 0.999	x^2(11, N = 231) = 12.160, p = 0.352	x^2(12, N = 580) = 13.266, p = 0.350

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Table 9.1 – Continued

	Argentina	**Barbados**	**Brazil**	**Chile**	**Cuba**	**Mexico**	**Uruguay**
Beers/day.	x^2(9, N = 432) = 37.702, p = 0.000*	x^2(10, N = 310) = 7.230, p = 0.704	x^2(10, N = 370) = 5.782, p = 0.833	x^2(7, N = 76) = 2.479, p = 0.929	x^2(10, N = 412) = 4.441, p = 0.925	x^2(10, N = 232) = 40.067, p = 0.000*	x^2(8, N = 547) = 10.191, p = 0.252
Drinks with liquor/day.	x^2(4, N = 431) = 30.794, p = 0.000*	x^2(10, N = 308) = 3.569, p = 0.964	x^2(6, N = 174) = 10.136, p = 0.119	x^2(4, N = 36) = 4.261, p = 0.372	x^2 (16, N = 412) = 21.698, p = 0.153	x^2(9, N = 232) = 28.649	x^2(8, N = 567) = 2.401, p = 0.966
In the last 12 months exercised regularly/participated in vigorous physical activity.	x^2(1, N = 1008) = 2.051, p = 0.107	x^2(1, N = 1156) = 0.015, p = 0.903	x^2(2, N = 1968) = 0.624, p = 0.732	x^2(3, N = 1301) = 19.169, p = 0.000*	x^2(2, N = 1755) = 19.875, p = 0.106	x^2(2, N = 1129) = 18.316, p = 0.000*	x^2(1, N = 1436) = 0.062, p = 0.020*

*positive association with CIm
‡negative association with CIm

Diet and Physical Activity as Predictors of CIm

Logistic regression analysis was conducted for each country separately to determine the effect of diet and physical activity on CIm. The final model used in analyses included the covariates age, sex, years of education, ethnic background, smoking status, number of complete meals per day, and change in eating pattern in the last twelve months as a result of loss of appetite or digestive problems.

Results showed that none of the diet and physical activity questions from the questionnaire were significant predictors of CIm.

9.6 Discussion

Diet and physical activity data were limited in this cross-national survey of older adults. Approximately eight questions addressed participant dietary habits while only one question sought to obtain information about regular physical activity. In addition, no data were collected on quantities of specific food items consumed or methods of preparation which significantly affected the quality of the analyses able to be performed.

In the food frequency questionnaire, food items that are known to be predictors of CIm were included in the same question making it impossible to determine the exact nature of the relationship of each item on CIm. For example, in one question, participants were asked 'Do you eat meat, fish or poultry at least three times a week?' This meant that independent relationships between these food items and CIm could not be examined and introduced the issue of misclassification of exposure.

While chi-square tests revealed significant associations between dietary variables and CIm, GLM analysis showed that these variables were not predictive of CIm. In addition, the unusual finding that physical activity was associated with CIm in Chile, Mexico and Uruguay may be reflective of the structure of the physical activity question included in the survey which did not make it possible to make a distinction between those who 'exercised regularly' and those who 'engaged in more vigorous activities'. It is highly plausible that most respondents in this survey of older adults engaged primarily in light activities as opposed to moderate/vigorous ones which have been shown to confer cognitive benefit.

One of the main limitations of this study is the small sample size compared to overall study population as a result of participant non-response to some independent variables included in the model. It is highly likely that some biases were introduced into analyses as a result of such sizeable exclusions due to missing outcome and covariate data. Secondly, it was not possible to conduct dietary pattern analyses and examine their association with CIm as data related to quantity and frequency of consumption of individual food items were not available. This lead to the consideration of survey questions which were presumed to measure variables that have been reported to be associated with cognition. It is possible that the findings of this study may be the result of multiple testing where as more survey questions relating to food or physical activity are considered, the more likely it becomes to obtain an association between one of these variables and CIm. Strengths of the study include its ability to provide useful baseline information on the association between particular groups of food and health and also its focus on the eating habits of older adults in LAC. The results of this study highlight the need for more in-depth data to be collected at regular intervals so that the dietary habits of this age group in LAC can be better examined in relation to various health outcomes.

9.7 Chapter Conclusion

Weekly consumption of milk and cheese, eggs, peas and beans, meat, fish or poultry and fruits or vegetables were positively associated with CIm. Digestive problems that affected appetite over the last 12 months were negatively associated with CIm in all study countries. Number of alcoholic beverages consumed per day over the last 3 months was positively associated with CIm in Argentina, Chile, and Mexico. Regular exercise or participation in vigorous physical activity such as playing a sport, dancing or heavy housework three or more times a week was positively associated with CIm in Chile, Mexico, and Uruguay. Results of logistic regression showed that while these variables were associated with CIm, they were not significant predictors. Questions that allow for a more detailed analysis of dietary and physical activity habits are essential to truly examine the nature of the relationship between diet, physical activity, and CIm in the countries under study.

Chapter 10

Population Attributable Risk for Dementia in Australia Explained by Common Modifiable Risk Factors

10.1 Chapter Summary

Interventions to delay onset and reduce prevalence of dementia have focused on risk factor reduction. It is proposed that even a modest effect can have a significant public health impact.

Population attributable risk (PAR) for dementia in Australia was calculated accounting for both independence and non-independence of five lifestyle factors (excess alcohol consumption, midlife obesity, physical inactivity, smoking, and low educational attainment). The Australia Diabetes Obesity and Lifestyle Study (AusDiab) was used to generate a matrix of tetrachoric correlations and conduct exploratory factor analysis using the matrix as input to estimate the shared variance for all five risk factors using STATA version 22. The potential effect of a 5%, 10%, 15% and 20% risk factor reduction on future dementia prevalence was estimated.

Assuming risk factors operate independently, 44.6% of dementia cases (108,241 of 242,500 cases) could potentially be explained by the 5 factors under study in Australia. Physical inactivity was found to be related to the greatest proportion of dementia cases (17.9% or 43,468 cases). Taking into consideration that risk factors do not operate independently, a more conservative estimate of 39.0% of dementia cases (94,498 of 242,500 cases) were found to be attributable to the five modifiable lifestyle factors under study. If each risk factor were to be reduced by 5%, 10%, 15% and 20% per decade dementia prevalence would be reduced by between 1.4% – 6.2% in 2020, 2.8% – 12.5% in 2030, 4.3% – 18.7% in 2040 and 5.7% – 24.7% in 2050.

Taking into consideration non-independence of risk factors, 39.0% of dementia cases in Australia may be attributable to excess alcohol consumption, midlife obesity, physical inactivity, smoking, and low educational attainment. Our findings present a case for greater investment in risk factor reduction programs that target modifiable lifestyle factors, particularly increased engagement in physical activity.

10.2 Background

Dementia is a syndrome characterised by declines in memory, thinking ability, and behaviour that has no known cure (World Health Organisation, 2015b). As dementia progresses, so too does the ability to perform tasks of daily living. At present, over 40 million people worldwide are estimated to have the condition with over US$600 billion spent on treatment and management (Alzheimer's Disease International, 2013; World Health Organisation, 2015b). This figure is projected to increase to well over 70 million people by 2030 (Alzheimer's Disease International, 2013). Such worrying future prevalence estimates highlight the need for urgent intervention focused on risk reduction as even a modest delay in onset can result in significant public health gains (World Health Organisation, 2015b).

Cognitive decline and dementia is multicausal. Research has shown that lifestyle factors for example, smoking habits, alcohol consumption, education level, diet, and physical activity increase the risk of late-life dementia (Anstey et al., 2009; Morris, 2009; Scarmeas, Stern, Mayeux, Manly, et al., 2009).

The potential impact of possible interventions to delay the onset of dementia on future prevalence of the condition has been reported for the world and specific regions, but not Australia (Vickland, Morris, Draper, Low, & Brodaty, 2012; Norton, Matthews, Barnes, Yaffe, & Brayne, 2014). It is estimated that any intervention that could delay the onset of dementia by 1 year could reduce worldwide cases by 11% (Brookmeyer, Johnson, Ziegler-Graham, & Arrighi, 2007) while a 2- and 5-year delay in onset could reduce the cumulative number of people developing dementia by 13% and 30%, respectively (Vickland et al., 2012). However, it is possible that these figures overestimate the potential gain of risk reduction because they do not take into account that risk reduction leads to increased longevity which itself is a risk factor for dementia (Anstey et al., 2014). Delaying dementia onset not only lessens the average number of years spent living with the disease but also has significant public health resource allocation implications (Access Economics, 2004).

Using a method previously published by Norton et al. (2014) the proportion of dementia in the Australian setting attributable to five modifiable risk factors shown to be associated with the disease in the literature and for which data were readily available from the most recent ABS Health Survey 2012 – 2013 (excess alcohol consumption, midlife obesity, physical inactivity, smoking, and low educational attainment) was estimated. Second, the proportion of dementia attributable to these risk factors when combined was calculated. In addition, the number of dementia cases attributable to each risk factor was estimated and the effect of reducing the relative prevalence of each risk factor by 5%, 10%, 15%, and 20% per decade on the future prevalence of dementia in Australia examined.

To the author's knowledge, this is the only Australian study to provide estimates of population attributable risks (PARs) and future dementia prevalence taking into consideration non-independence of risk factors.

10.3 Aim

- To estimate the proportion of dementia in the Australian setting attributable to five modifiable risk factors shown to be associated with the disease in the literature (excess alcohol consumption, midlife obesity, physical inactivity, smoking, and low educational attainment).
- To calculate the proportion of dementia attributable to these five risk factors when combined.
- To calculate the number of dementia cases attributable to each risk factor and examine the effect of reducing the relative prevalence of each risk factor by 5%, 10%, 15%, and 20% per decade on the future prevalence of dementia in Australia.

10.4 Methodology

Risk factor prevalence was obtained from the Australian Bureau of Statistics (Australian Bureau of Statistics, 2013b).

Table 10.1 below provides the definitions for each of the five risk factors included in the study (Australian Bureau of Statistics, 2013b; Norton et al., 2014).

Table 10.1: Risk Factor Definitions

Risk Factor	Definition
Excess alcohol consumption	The proportion of adults who consumed more than 2 standard drinks/day
Mid-life obesity	The proportion of adults (45–54 years) with BMI ≥ 30
Physical inactivity	The proportion of adults not meeting physical activity guidelines
Smoking	The proportion of smokers
Low educational attainment	The proportion of adults who have not completed Year 12

Meta-analyses examining the association between dementia and the five risk factors of interest were used to obtain relative risk data (Anstey et al., 2011; Anstey et al., 2009; Hamer & Chida, 2009; Peters et al., 2008).

Table 10.2: Prevalence and Relative Risk data sources

Risk Factor	Prevalence [a]	Relative Risk	Communality [d]
Excess alcohol consumption	19.5	1.02 (0.36 – 1.67)[b]	15.2%
Midlife obesity	32.0	1.64 (1.34 – 2.00)[c]	13.2%
Physical inactivity	56.0	1.39 (1.16 – 1.67)[b]	18.7%
Smoking	16.1	1.28 (0.99 – 1.60)[b]	15.9%
Low educational attainment	24.0	1.72 (1.52 –1.96)[b]	9.5

Notes: [a] *Obtained from ABS Health Survey 2012–13 (Australian Bureau of Statistics, 2015a).* [b] *Obtained from World Alzheimer's Report 2014 (Prince, Albanese, & Guerchet, 2014).* [c] *Obtained from Anstey, Cherbuin, Budge, and Young (2011).* [d] *Communality estimated using the Australia Diabetes, Obesity and Lifestyle Study (Tanamas et al., 2013a).*

Table 10.2 shows the relative risk and prevalence data utilised in this study.

10.4.1 Statistical Analysis

The proportion of dementia cases attributable to each of the five risk factors was calculated using Levin's Population Attributable Risk formula (Levin, 1952):

$$PAR = [P \times (RR - 1)/(1 + P \times (RR - 1])]$$

where P = population prevalence and RR = relative risk.

The combined effect of the five PAR estimates calculated for each risk factor was estimated using the following formula (Barnes & Yaffe, 2011):

$$\text{Combined } PAR = 1 - (1 - PAR_{\text{excess alcohol consumption}}) \times (1 - PAR_{\text{midlife obesity}}) \\ \times (1 - PAR_{\text{physical inactivity}}) \times (1 - PAR_{\text{smoking}}) \times (1 - PAR_{\text{low education attainment}})$$

This formula assumes independence of risk factors.

Using a previously published modified formula, PAR was calculated accounting for non-independence of the five risk factors (Norton et al., 2014):

$$PAR_{\text{Adjusted Combined}} = 1 - \Pi 1 - (w \times PAR)$$

where w = weight, representing the uniqueness (1 – communality) of each risk factor (Norton et al., 2014).

Factor analysis was used to estimate communality for each risk factor using data for adults aged 25 years and older from the AusDiab.

Total number of dementia cases related to each of the five risk factors was calculated as the product of their individual PARs and dementia prevalence.

The effect of reducing the relative prevalence of each risk factor by 5%, 10%, 15% or 20% per decade on the future prevalence of dementia in Australia was calculated using published dementia prevalence estimates for Australia (Access Economics, 2009).

10.5 Results

Assuming Independence of Risk Factors

The proportion of dementia cases attributable to each of the five risk factors and the number of attributable dementia cases in 2010 are presented in Table 10.3. The total number of dementia cases attributable to each risk factor was calculated as the product of the individual PAR estimates and the present number of cases of dementia obtained from Access Economics (2007). Confidence limits for PAR and the number of attributable cases were calculated using a published substitution method (Daly, 1998). Results are shown in Table 10.3 below.

Table 10.3: PAR of dementia for each risk factor and number of cases attributable in 2010 in Australia

Risk Factor	Prevalence of Risk Factor	PAR % (95% CI)	Number of attributable cases in 2010 (95% CI)
Excess alcohol consumption	19.5	0.3 (-14.3 – 11.6)	942 (-34580 – 28022)
Midlife obesity	32.0	17.0 (9.8 – 24.2)	41,222 (23795 – 58788)
Physical inactivity	56.0	17.9 (8.2 – 27.3)	43,468 (19941 – 66162)
Smoking	16.1	4.3 (-0.2 – 8.8)	10,460 (-391 – 21362)
Low educational attainment	24.0	14.7 (11.1 – 18.7)	35,730 (26906 – 45410)
Combined	-	44.6 (15.8 – 63.9)	108,241 (38275 – 154931)
Adjusted combined	-	39.0 (13.0 – 57.2)	94,498 (31498 - 138673)

Note: Dementia cases 2010 = 242,500 (Access Economics, 2007)

Combined estimate of PAR assuming independence of risk factors

The five risk factors examined contribute up to 44.6% of dementia cases in Australia using the formula:

$$\text{Combined } PAR = 1-(1-PAR_{\text{excess alcohol consumption}})\times(1-PAR_{\text{midlife obesity}})$$
$$\times(1-PAR_{\text{physical inactivity}})\times(1-PAR_{\text{smoking}})\times(1-PAR_{\text{low education attainment}})$$

Accounting for non-independence of risk factors

To account for non-independence of risk factors, a previously published formula was used (Norton et al., 2014):

$$PAR_{\text{Adjusted Combined}} = 1-\Pi 1-(w\times PAR)$$

where w = weight, calculated as 1 minus the proportion of shared risk factor variance.

Data for those aged 25 years and older from the AusDiab was used to estimate the shared variance for all five risk factors (shown in Table 10.2). More specifically, to obtain communality, STATA version 22 was used to generate a matrix of tetrachoric correlations and subsequently exploratory factor analysis using the correlation matrix as input was performed. Similar to other studies, the Kaiser criterion for selecting the number of factors to retain was used (Norton et al., 2014). Accounting for non-independence of risk factors the five risk factors were estimated to contribute to 39.0% of dementia cases in Australia.

Effect of risk factor reduction

Table 10.4 and Figure 10.1 show the effect of a 5%, 10%, 15% and 20% per decade reduction in each risk factor on future dementia prevalence estimates.

Table 10.4: Effect of a 5%, 10%, 15% and 20% per decade reduction in each risk factor on future dementia prevalence in Australia (2010 – 2050)

	2010	2020	2030	2040	2050
Dementia	242,500	384,396	553,285	760,131	942,624
Estimates					
5%	242,500	379,062	538,084	729,132	891,923
	(0.0%)	(1.4%)	(2.8)	(4.3%)	(5.7)
10%	242,500	373,556	522,757	698,680	843,508
	(0.0%)	(2.9%)	(5.8%)	(8.8%)	(11.8%)
15%	242,500	367,870	507,383	669,149	798,311
	(0.0%)	(4.5%)	(9.0%)	(13.6%)	(18.1%)
20%	242,500	361,887	491,733	640,265	756,059
	(0.0%)	(6.2%)	(12.5%)	(18.7%)	(24.7%)

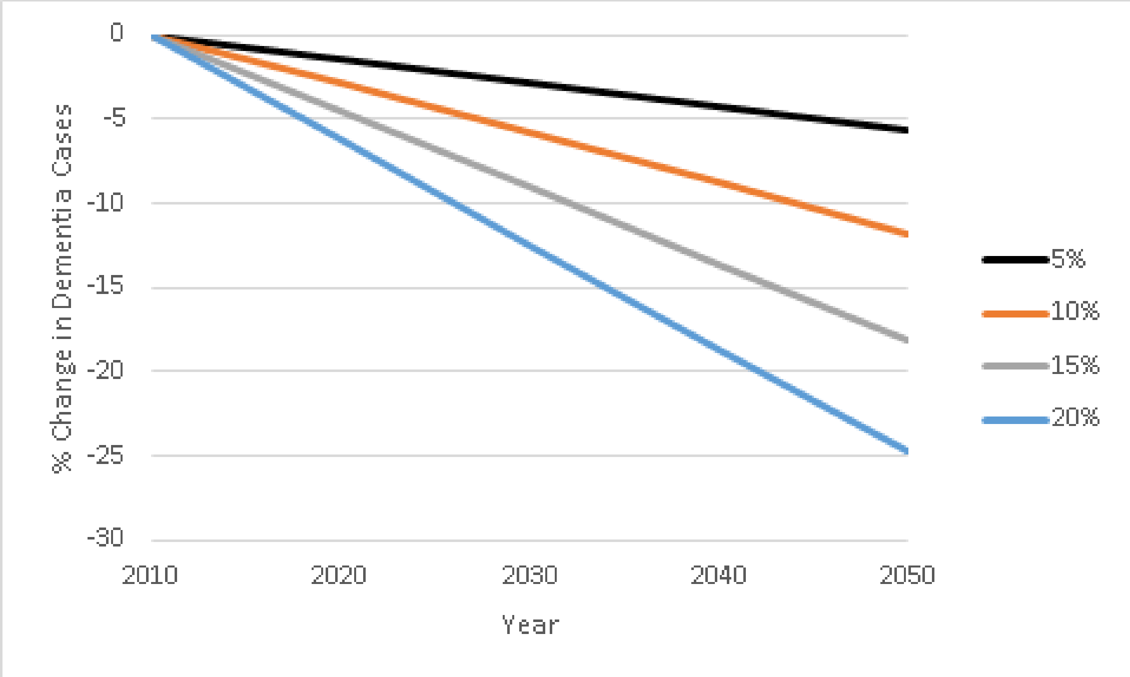

Figure 10.1: Percentage change in dementia cases as a result of a 5%, 10%, 15% and 20% reduction in each risk factor per decade in Australia

10.6 Discussion

Assuming that risk factors operate independently, an estimated 44.6% of dementia cases in Australia (108,241 of 242,500 cases) could be related to the five modifiable risk factors under study (excess alcohol consumption, midlife obesity, physical inactivity, smoking, and low educational attainment). Taking into consideration the non-independence of these risk factors, it was estimated that approximately 39.0% of dementia cases in 2010 (94,498 of 242,500 cases) were attributable to these five factors. Results show that a 5%, 10%, 15%, and 20% risk reduction of each risk factor per decade would have the effect of reducing future dementia prevalence by between 1.4% – 6.2% in 2020, 2.8% – 12.5% in 2030, 4.3% – 18.7% in 2040 and 5.7% – 24.7% in 2050.

Similar to other studies, it was found that physical inactivity was related to the largest proportion of dementia cases (17.9%) (Norton et al., 2014). Midlife obesity was related to the second highest proportion of dementia cases (17.0%) while excess alcohol consumption was related to the lowest proportion of cases (0.3%).

PAR estimates in this study for midlife obesity, physical inactivity, smoking and low educational attainment can be compared to PAR estimates reported for the USA, Europe and UK in a previous study that examined these risk factors in relation to Alzheimer's disease (AD) (Norton et al., 2014). Though reported for AD cases, the authors suggest that these PAR estimates can be applied to the most common forms of dementia (Norton et al., 2014). Overall, midlife obesity is related to a greater proportion of dementia cases in Australia (17.0%) than in the USA (7.3%), Europe (4.1%), and UK (6.6%) while physical inactivity is related to a relatively smaller proportion of cases in Australia (17.9%) than in the USA (21.0%), Europe (20.3%), and UK (21.8%). Notably, a smaller proportion of dementia cases are attributable to smoking in Australia (8.7%) when compared to the USA (10.8%), Europe (13.6%), and UK (10.6%). The proportion of dementia cases attributable to low educational attainment in the USA (7.3%), UK (12.2%), and Europe (13.6%) are lower than that of Australia (14.7%). These differences may be predominantly due to the prevalence of these individual risk factors in each country and also in variations in risk factor definitions used between studies.

The effect size estimates used in this study differ from those in a previous paper (Norton et al., 2014). Relative risk estimates used here are taken from the World Alzheimer's Report 2014 which included more recently published data (Prince et al., 2014). The estimates used were slightly lower for midlife obesity and physical inactivity in our study but higher for smoking and low educational attainment.

It is suggested that dementia may be delayed or prevented by targeting modifiable lifestyle factors (Scarmeas, Luchsinger, et al., 2009). In a study commissioned by Alzheimer's Australia, it was reported that a 2-year delay in dementia onset has the potential to reduce the number of people developing dementia by 13.0% (Vickland et al., 2012). By extension, a delay in dementia onset by 5 years could reduce future prevalence of the disease by up to 35.0% (Vickland et al., 2012). These projections are comparable to other Australian estimates. For example, Access Economics (2004) estimated that a 5-year delay in AD onset from 2005 would decrease prevalence by 48.5% in 2040. Other studies have calculated that any intervention that could delay onset by 5 years could decrease prevalence by between 37.0% – 44.0% (Jorm & Jolley, 1998; Vickland et al., 2011). These projection estimates are quite high and notably do not take into account the dynamic interplay between risk factors which have been considered in our study. Though imprecise, the estimates reported in the present study are more realistic and conservative.

The modifiable lifestyle factors considered in this study have also been recognised as risk factors for developing other conditions such as cardiovascular disease, diabetes, hypertensive diseases, and certain cancers all of which are leading causes of death in Australia (Australian Bureau of Statistics, 2014b). These findings present a case for greater investment in lifestyle interventions in preventing dementia as these have the potential to reap other health and wellbeing benefits as well. Reducing the prevalence or delaying the onset of dementia has the potential to lessen the impact of the disease, both financially and on individuals

(Alzheimer's Australia, 2005). Delaying dementia onset lessens the average number of years spent living with the disease (Access Economics, 2004). Those living with dementia for longer periods tend to require considerably more health services per annum than newly diagnosed individuals and this has substantial public health resource allocation implications(Access Economics, 2004).

Physical inactivity was shown to contribute to the greatest proportion of dementia cases. Physical activity promotes functional neuro-protective changes in the hippocampus of the brain (a region central to learning and memory) and also lowers cardiovascular disease risk which has an effect on neuronal integrity (Cotman & Berchtold, 2002; Podewils et al., 2005). This suggests that targeted interventions aimed at those who are not meeting recommendations may have the effect of reducing dementia prevalence. Policymakers however must be cognizant of the fact that no singular government intervention/policy, operating on its own, can directly reduce dementia onset/prevalence and change lifestyle habits (Ashby-Mitchell, Jagger, Fouweather, & Anstey, 2015). Further research is needed to examine the monetary investment and time needed to reduce risk factor prevalence (especially physical inactivity prevalence) to a level that will result in significant improvement in the overall prevalence of dementia and other chronic diseases. However, while dementia risk reduction has the effect of increasing longevity and delaying onset of disease, it may not necessarily prevent it. Previous research has pointed to the longevity paradox – that age is the strongest predictor of diseases that affect cognition and risk reduction has the potential to increase life expectancy (Anstey et al., 2014).

To the author's knowledge, this is the only Australian study to provide estimates of PAR and future dementia prevalence taking into consideration non-independence of risk factors. The methodology utilised in this paper has only been reported on once in the literature and represents a notable addition to the traditional Levin's formula used to calculate PAR in order to account for non-independence of risk factors (Norton et al., 2014). This study therefore makes a valuable contribution to the research.

While the use of incidence data are ideal in the calculation of PAR, such data are often difficult to obtain. Similar to another study, prevalence data was utlised and this could have affected the results obtained (Norton et al., 2014; Barnes & Yaffe, 2011). Prevalence and incidence are closely related and in the case of chronic diseases such as CIm where incidence may be low, survival which is a direct result of long duration of the disease can exert a confounding effect resulting in an overestimation of PAR. Other limitations of using this method have been presented in a previous study (Norton et al., 2014). These include use of biased adjusted relative risk estimates obtained from meta-analyses and the integrity of the method being untested (Norton et al., 2014). However, despite these limitations, it is thought to provide a more realistic estimate of PAR. As further studies are conducted using this adjusted PAR calculation, there will be the opportunity to compare results across various geographic locations and test robustness. While a substantial proportion of dementia cases were found to be attributable to the risk factors under study, the contribution of other known risk factors for dementia such as Type 2 diabetes, hypertension and depression were not examined. Further studies that take these into consideration can prove useful to policymakers.

10.7 Chapter Conclusion

Assuming that risk factors do not operate independently, approximately 39.0% of dementia cases in Australia can be potentially attributed to excess alcohol consumption, midlife obesity, physical inactivity, smoking, and low educational attainment. Any intervention that reduces the prevalence of these by 5%, 10%, 15% or 20% per decade can have a significant public health impact.

Chapter 11

Population Attributable Risk for Dementia in Selected LAC Countries Explained by Common Modifiable Risk Factors

11.1 Chapter Summary

Dementia is a progressive condition with no known cure. Developing countries like those of Latin America and the Caribbean (LAC) are known to be ageing more rapidly than their developed counterparts. Any intervention able to delay or prevent dementia onset by targeting modifiable lifestyle factors has the potential to significantly reduce future dementia prevalence in the LAC region.

Levin's Attributable Risk formula which assumes independence of risk factors was used to calculate the proportion of dementia attributed to diabetes mellitus, physical inactivity, and smoking in three countries in the LAC region – Barbados, Mexico and Cuba. Using a recently published modified formula, non-independence of risk factors was accounted for by using data from the Survey on Health, Well-Being, and Ageing in Latin America and the Caribbean (SABE). Finally the number of dementia cases attributable to each risk factor was computed and the effect on future dementia prevalence of a 5%, 10%, 15%, and 20% reduction in risk factor prevalence was estimated.

Assuming independence of risk factors, physical inactivity was related to the greatest proportion of dementia cases when compared to the other risk factors under study (16.7% of dementia cases in Barbados, 7.0% in Mexico, and 17.1% in Cuba). When combined, all three risk factors account for an estimated 24.2% of dementia cases in Barbados (727 cases), 16.0% (98,907 cases) in Mexico, and 27.9% (41,848 cases) in Cuba.

Accounting for non-independence of risk factors, the adjusted combined PAR was estimated to be 21.9% in Barbados (accounting for 658 cases), 14.7% in Mexico and 26.2% in Cuba accounting for 91,470 and 39,366 dementia cases respectively. If each risk factor were to be reduced by between 5% and 20% every 10 years to 2050, dementia prevalence would be reduced by between 1.3% and 16.3% in the countries under study. As these risk factors have much in common, any intervention that targets even one of them can significantly reduce future

dementia prevalence.

11.2 Introduction

Age is presently the strongest known predictor of dementia and there is no known cure (Barnes & Yaffe, 2009; Dangour & Uauy, 2006). Presently, over 40 million people worldwide are estimated to have the condition and this figure is projected to increase to over 110 million by 2050 (Alzheimer's Disease International, 2013; World Health Organisation, 2015b). This increase is predicted to be heavily influenced by rapidly ageing populations in low and middle-income countries (Ferri et al., 2005).

Research shows that diseases that impair cognition have multiple causes. Several of these however can be modified and have the potential to reduce disease risk. Diabetes, hypertension, smoking, alcohol consumption, education level, diet, and physical activity habits have all been found to have an association with development of dementia (Anstey et al., 2009; Morris, 2009; Scarmeas, Luchsinger, et al., 2009). As such, any intervention that has the potential to reduce the prevalence of these within the population can reduce dementia onset and prevalence in the future (Vickland et al., 2012).

While there have been numerous studies investigating the effect of risk factor prevalence on development of dementia in high income countries, little is known about the effect in low- and middle-income countries like those of Latin America and the Caribbean (LAC) where an estimated 44% of people living with dementia reside (ADI/BUPA, 2013). These countries are known to have limited resources and a shortage in the services needed to support the elderly and those living with dementia and their carers (ADI/BUPA, 2013). Any intervention able to delay or prevent dementia onset by targeting modifiable lifestyle factors has the potential to significantly reduce future dementia prevalence (Vickland et al., 2012). It is possible however that the potential impact of interventions to delay the onset of dementia on future prevalence of the condition may be overestimated since risk reduction leads to increased life expectancy which itself is a risk factor for dementia (Anstey et al., 2014). Understanding the nature of the relationship between risk factors and development of the disease and further devising interventions that target and reduce the prevalence of these risk factors can have an enormous public health impact.

The PAR for dementia in three LAC countries (Barbados, Mexico, and Cuba) was calculated accounting for both independence and non-independence of three modifiable lifestyle factors – diabetes mellitus, physical inactivity and smoking. In addition, the effect of a 5%, 10%, 15%, and 20% reduction in risk factor prevalence every 10 years to 2050 on future dementia prevalence was estimated.

This paper is the first to report on the proportion of dementia cases attributable to common lifestyle risk factors in LAC countries. Further, the use of a method that takes into account non-independence of risk factors and the effect of risk factor reduction on future disease prevalence contributes greatly to the literature as there is a paucity of data on dementia and its prevalence in the LAC region.

11.3 Methodology

The method employed in this study required both relative risk and risk factor prevalence data. These were obtained from published studies and reports (Burroughs Peña, Patel, Rodríguez Leyva, Khan, & Sperling, 2011; International Diabetes Federation, 2014b; Lu, Lin, & Kuo, 2009; International Diabetes Federation, 2014a; Medina, Janssen, Campos, & Barquera, 2013; Pan American Health Organisation, 2012; Prince et al., 2014; World Health Organisation, 2002b; Palaez et al., 2004). Table 11.1 below provides the definitions for each of the three risk factors included in the study. Relative risk data are presented in Table 11.2.

Table 11.1: Risk Factor Definitions

Risk Factor	Definition
Diabetes Mellitus	Adult prevalence of diabetes mellitus
Physical inactivity	The proportion of adults not meeting physical activity guidelines
Smoking	The proportion of smokers

Table 11.2: Relative Risk data – Confidence intervals shown in brackets

Risk Factor	Relative Risk[a]	Communality Barbados[b]	Communality Mexico[b]	Communality Cuba[b]
Diabetes Mellitus	1.50 (1.33 – 1.70)	15.8%	6.13%	14.5%
Physical inactivity	1.39 (1.16 – 1.67)	7.8%	9.9%	1.45%
Smoking	1.28 (0.99 – 1.60)	11.7%	8.3%	13.3%

Notes:
[a]*Obtained from World Alzheimer's Report, 2014 (Prince, Albanese, & Guerchet, 2014).*
[b]*Communality estimated using The Survey on Health, Well-Being, and Ageing in Latin America and the Caribbean (SABE) (Palaez et al., 2004).*

11.3.1 Statistical Analysis

Estimates of the PAR for dementia for each of the three risk factors was calculated using Levin's Population Attributable Risk formula which assumes independence of risk factors (Levin, 1952):

$$PAR = [P \times (RR - 1)/(1 + P \times (RR - 1])]$$

where P = population prevalence of the risk factor and RR = relative risk.

The combined effect of the calculated PAR estimates assuming independence of risk factors was determined using the following formula (Barnes & Yaffe, 2011):

$$\text{Combined } PAR = 1 - \Pi 1 - PAR$$

To account for non-independence of the three risk factors under study, a previously published formula was used (Norton et al., 2014):

$$PAR_{\text{Adjusted Combined}} = 1 - \Pi 1 - (w \times PAR)$$

where w = weight interpreted as 1 minus communality of each risk factor (Norton et al., 2014). The SABE was used to estimate the uniqueness (w) of all three risk factors by first generating a matrix of tertrachoric correlations and conducting exploratory factor analysis using the correlation matrix as input.

Total number of dementia cases related to each of the three risk factors was calculated as the product of their individual PARs and dementia prevalence.

The effect of reducing the relative prevalence of each risk factor by 5%, 10%, 15% or 20% every 20 years until 2050 in Barbados, Mexico, and Cuba was calculated using published dementia prevalence estimates (ADI/BUPA, 2013). Due to limitations in the availability of dementia prevalence data for each decade, the percentage reduction in risk factor prevalence was based on a compounding formula.

11.4 Results

Assuming Independence of Risk Factors

The proportion of dementia cases attributable to each of the three risk factors and the number of attributable dementia cases in 2010 are presented in Table 11.3 below. The total number of dementia cases attributable to each risk factor was calculated as the product of the individual PAR estimates and the present number of cases of dementia obtained from (Access Economics, 2007). See Table 11.3 below.

Table 11.3: PAR of dementia for each risk factor and number of cases attributable in 2010 in Barbados, Mexico and Cuba

Risk Factor	Prevalence of Risk Factor	PAR (95% CI)	Number of attributable cases in 2010 (95% CI)
Barbados (3000 dementia cases)			
Diabetes mellitus	14.9%[a]	6.9% (4.7 – 9.4)	208 (141 – 283)
Physical Inactivity	51.3%[a]	16.7% (7.6 – 25.6)	500 (228 – 767)
Smoking	8.4%[a]	2.3% (-0.1 – 4.8)	69 (-3 – 144)
Combined	–	24.2% (11.8 – 35.8)	727 (355 – 1,075)
Adjusted Combined	–	21.9% (10.6 – 32.7)	658 (318 – 980)
Mexico (621,000 dementia cases)			
Diabetes mellitus	11.9%[b]	5.6% (3.8 - 7.7)	34,874 (23,465 – 47,752)
Physical Inactivity	19.4%[c]	7.0% (3.0 – 11.5)	43,680 (18,696 – 71,433)
Smoking	15.6%[d]	4.2% (-0.2 – 8.6)	25,990 (-970 – 53,151)
Combined	–	16.0% (6.5 – 25.3)	98,907 (40,549 – 157,112)
Adjusted Combined	–	14.7% (6.1 – 23.4)	91,470 (37,763 – 145,401)
Cuba (150,000 dementia cases)			
Diabetes mellitus	8.4%[b]	4.0% (2.7 – 5.6)	6,046 (4,045 – 8,330)
Physical Inactivity	53.0%[e]	17.1% (7.8 – 26.2)	25,694 (11,726 – 39,307)
Smoking	36.8%	9.3% (-0.4 – 18.1)	14,012 (-554 – 27,130)
Combined	–	27.9% (10.0 – 42.9)	41,848 (14,958 – 64,363)
Adjusted Combined	–	26.2% (9.5 – 40.4)	39,366 (14,315 – 60,635)

Note:
[a.] *Barbados prevalence figures obtained from the Barbados Risk Factor Survey 2007 (Pan American Health Organisation, 2012).*
[b.] *Diabetes prevalence in Mexico and Cuba obtained from International Diabetes Federation (2014a).*
[c.] *Physical inactivity prevalence in Mexico obtained from Medina et al. (2013).*
[d.] *Smoking prevalence in Mexico and Cuba obtained from World Health Organisation (2002b).*
[e.] *Physical inactivity prevalence in Cuba obtained from Burroughs Peña et al. (2011).*

Physical inactivity was related to the greatest proportion of dementia cases when compared to the other risk factors under study (16.7% of dementia cases in Barbados, 7.0% in Mexico, and 17.1% in Cuba).

Assuming independence, diabetes, physical inactivity and smoking account for an estimated 24.2% of dementia cases in Barbados (727 cases), 16.0% (98,907 cases) in Mexico, and 27.9% (41,848 cases) in Cuba.

Accounting for non-independence of risk factors

Data from the SABE was used to estimate the shared variance for all three risk factors (shown in Table 11.2). Conducted during 1999 and 2000, the SABE aimed to examine health conditions and functional limitations of persons aged 60 and older in LAC. More specifically, STATA version 22 was used to generate a matrix of tetrachoric correlations and subsequently exploratory factor analysis was performed using the matrix as input in order to determine communality. Similar to other studies, the Kaiser criterion for selecting the number of factors to retain was used (Norton et al., 2014).

In Barbados, the adjusted combined PAR was estimated to be 21.9% (accounting for 658 cases), 14.7% in Mexico (91,470 cases), and in Cuba 26.2% (accounting for 39,366 dementia cases).

Effect of risk factor reduction

Table 11.4 and Figure 11.1 show the effect of a 5%, 10%, 15% and 20% reduction every 10 years in each risk factor on dementia in 2030 and 2050.

Table 11.4: Effect of a 5%, 10%, 15% and 20% per decade reduction in each risk factor on future dementia prevalence in Barbados, Mexico and Cuba (2010 – 2050)

	2010	**2030**	**2050**
Barbados			
Dementia Estimates	3,000	71,000	138,000
5%	3,000 (0.0%)	69,738 (1.8%)	133,253 (3.6%)
10%	3,000 (0.0%)	68,496 (3.7%)	128,924 (7.0%)
15%	3,000 (0.0%)	67,281 (5.5%)	125,043 (10.4%)
20%	3,000 (0.0%)	66,096 (7.4%)	121,625 (13.5%)
Mexico			
Dementia Estimates	621,000	1,437,000	3,195,000
5%	621,000 (0.0%)	1,418,375 (1.3%)	3,115,452 (2.6%)
10%	621,000 (0.0%)	1,400,346 (2.6%)	3,044,950 (4.9%)
15%	621,000 (0.0%)	1,382,945 (3.9%)	2,983,276 (7.1%)

Continued on Next Page...

Table 11.4 – Continued

	2010	2030	2050
20%	621,000 (0.0%)	1,366,226 (5.2%)	2,930,129 (9.0%)
Cuba			
Dementia Estimates	150,000	273,000	421,000
5%	150,000 (0.0%)	267,339 (2.1%)	404,072 (4.2%)
10%	150,000 (0.0%)	261,745 (4.3%)	388,499 (8.4%)
15%	150,000 (0.0%)	256,243 (6.5%)	374,431 (12.4%)
20%	150,000 (0.0%)	250,858 (8.8%)	361,962 (16.3%)

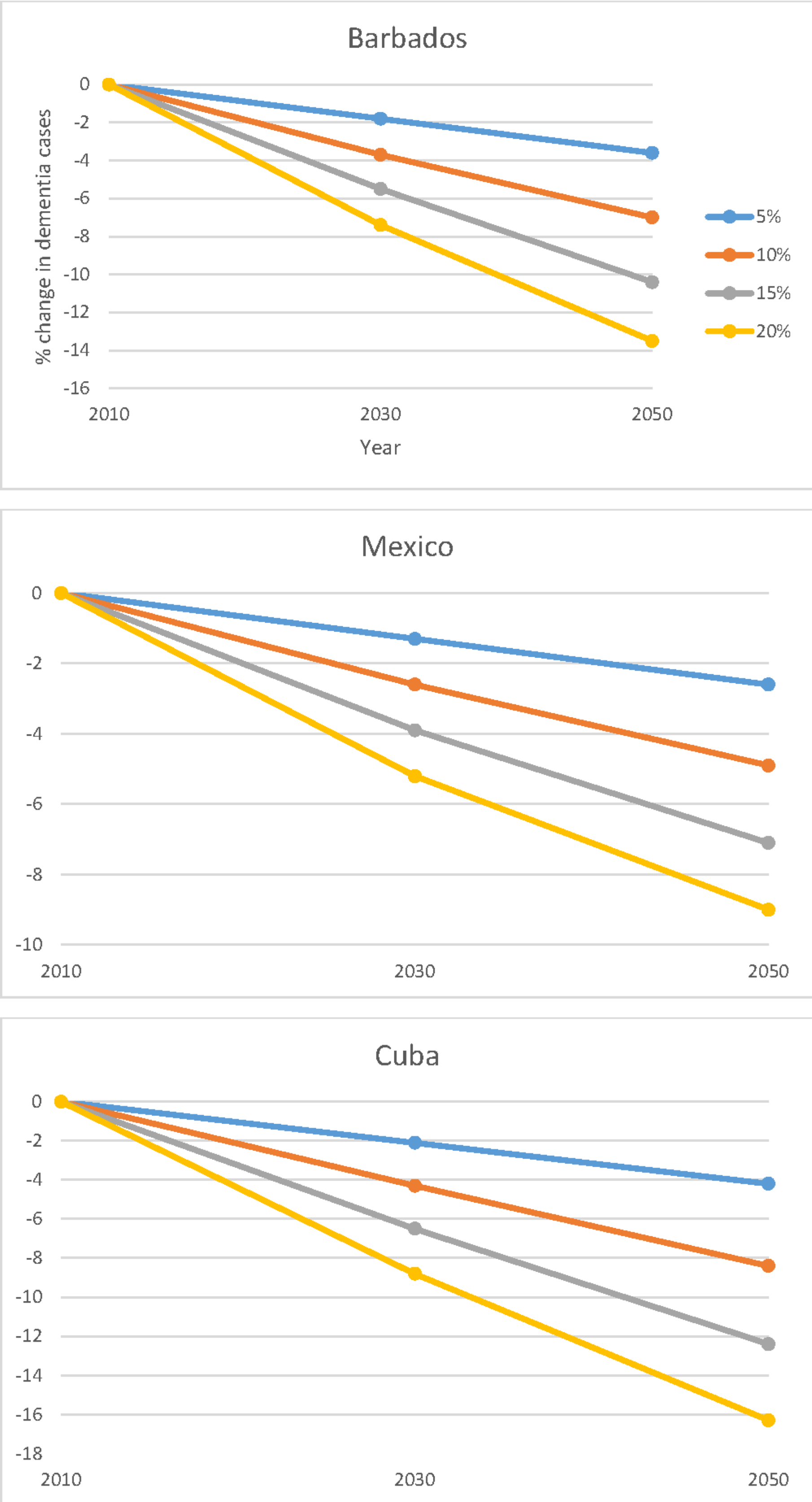

Figure 11.1: Percentage change in dementia cases as a result of a 5%, 10%, 15% and 20% reduction in each risk factor per decade in Barbados, Mexico and Cuba

11.5 Discussion

Assuming that risk factors operate independently, the combined effect of diabetes mellitus, physical inactivity and smoking on dementia estimates was calculated. It was determined that 24.2% of dementia cases in Barbados (727 cases), 16.0% (98,907 cases) in Mexico, and 27.9% (41,848 cases) in Cuba were attributable to the combination of these three risk factors. Accounting for non-independence of risk factors, the adjusted combined PAR was estimated to be 21.9% in Barbados (accounting for 658 cases), 14.7% in Mexico and 26.2% in Cuba accounting for 91,470 and 39,366 dementia cases, respectively. In addition, it was determined that if each risk factor were to be reduced by between 5% and 20% every 10 years to 2050, dementia prevalence would be reduced by up to 13.5% in Barbados, 9.0% in Mexico and 16.3% in Cuba.

Similar to other studies, physical inactivity was attributed to the greatest proportion of dementia cases (Norton et al., 2014). As physical activity has been shown to also reduce cardiovascular disease risk and promote protective changes in the hippocampus, targeting inactivity can result in decreased dementia prevalence. Physical inactivity prevalence was high in Barbados and Cuba which led to high PAR estimates in those countries (16.7% and 17.1%, respectively). In Mexico and Cuba, smoking prevalence was greater than in Barbados which resulted in higher PAR estimates (Mexico PAR: 4.2%, Cuba PAR: 9.3% and Barbados PAR: 2.3%).

While a substantial proportion of dementia cases were found to be attributable to the risk factors under study, the potential contribution of other known modifiable risk factors for dementia such as education level, depression, midlife obesity, and alcohol consumption were not considered as the prevalence of these at the population level were not easily available and accessible for the countries under study.

The results of the present study suggest that interventions focused on risk reduction have the potential to lessen the future impact of dementia. Such information is useful to policymakers who are tasked with developing strategies to reduce the economic impact of disease. While this study shows that risk factor reduction can reduce burden of disease, it is important to note that risk reduction leads to greater longevity and age itself is the strongest known risk factor for dementia (Anstey et al., 2014).

The main strength of this study is its ability to add to the literature available on dementia and the effect of reduction of risk factors on future prevalence of disease in the LAC region. There is a paucity of quantitative data on persons living with dementia in the region and our study adds considerably to this void. As LAC populations age, such information is needed for policymakers to devise interventions and policies that promote healthy ageing. At present, much of the figures available on dementia prevalence are based on international studies which do not take into account the ethnic composition and culture of countries in the LAC (Barbados Alzheimer's Association, 2014).

To the author's knowledge this is the first study to estimate the proportion of dementia cases attributable to modifiable lifestyle factors for countries in the LAC region. This study also gives an estimate of the number of dementia cases related to each risk factor and determines the combined effect of all risk factors working together and goes further using a recently published method to account for non-independence of risk factors (Norton et al., 2014). The traditional Levin's Attributable Risk formula assumes independence of risk factors but risk factors usually do not operate independently. As such, the PAR estimates reported in this study are more realistic. Further, data on the effect of risk factor reduction on future dementia prevalence have not been published prior for LAC countries making our study novel.

Limitations of this study include the inability to provide PAR estimates for a wider range of modifiable risk factors and for a greater number of countries due to data limitations. Diabetes mellitus, physical inactivity and smoking were selected in this study as prevalence data were readily available and accessible. Midlife hypertension, midlife obesity, alcohol consumption, and depression are a few of the modifiable risk factors for which PAR can be calculated once such data becomes accessible. In addition, the method used for calculating PAR assuming non-independence uses biased adjusted relative risk estimates obtained from meta-analyses and its integrity has not been tested. This is expected though as the method is still new. Its use in future studies will test its integrity and robustness. Finally, the use of prevalence data may result in higher PAR estimates than if incidence data were used since although incidence of CIm may be low, prevalence (which is directly influenced by the long duration of the disease) may exert a confounding survival effect.

11.6 Chapter Conclusion

This study presents a case for the development of interventions that target modifiable lifestyle factors to reduce future dementia prevalence. As governments become hard-pressed to develop interventions to lessen the financial and individual burden of dementia on sufferers and their carers, these estimates can provide useful data to determine the risk factors that merit the greatest investment.

Chapter 12

Issues Brief – The Road to Reducing Dementia Onset and Prevalence - Are diet and physical activity interventions worth investing in?

12.1 Chapter Summary

In Australia, deaths as a result of dementia have now taken over cerebrovascular disease as the second leading cause of death. At present, over a quarter million Australians suffer from dementia and projected estimates indicate that the figure can reach a high of nearly one million by 2050.

Diet and physical activity have been shown to promote brain health and offer some protection against cognitive decline (Prince et al., 2014). Moreover, they have also been recognised as risk factors for developing other conditions such as cardiovascular disease, diabetes, hypertensive diseases, and certain cancers all of which are leading causes of death in Australia.

Research shows that higher ratios of saturated fat to monounsaturated fats are predictive of negative mental function (Morris, Evans, Bienias, Tangney, Bennett, Aggarwal, Schneider, & Wilson, 2003; Solfrizzi, Panza, et al., 2011). In addition, high mid-life serum cholesterol levels and excessive caloric intake have been found to be associated with impaired cognitive function. Increased intakes of fish, vegetables and legumes, antioxidant rich foods and adequate amounts of certain B-vitamins have been reported to have a protective brain effect.

Increased levels of physical activity have been found to promote neuro-protective changes in the hippocampus of the brain – a region central to learning and memory (Scarmeas, Luchsinger, et al., 2009). This brain region is one of the first areas affected by dementia. Most studies have demonstrated that a high level of physical activity in adults with no dementia is associated with a 30% to 50% reduction in the risk of cognitive decline and dementia. Some studies have also theorised that poor physical function may precede the onset of dementia and Alzheimer's disease (AD) and higher levels of physical function may be associated with delayed onset. Results from the Australian Bureau of Statistics National Health Survey (2011 – 2013) show that many Australian adults do not meet the National Physical Activity Guidelines (to do at least 30 minutes of moderate intensity physical activity on most days) as more than half the population is inactive. Further, two-thirds of Australians are now overweight/obese and a large proportion of total energy consumed comes from foods considered to be of little nutritional value. An intervention that focuses on improving diet and physical activity habits therefore has the ability to produce inestimable benefits.

There are many factors that must be considered when developing a successful diet and physical activity intervention. These span a gamut of issues from carefully defining the target audience, utilising a multidisciplinary approach, tailoring content and materials, determining forms of delivery, and identifying specific behaviour change techniques to determining financial costs in relation to health benefits and training staff. The success of any intervention also relies on the setting and method that will be employed in its implementation.

Policymakers must be cognizant of the fact that no singular government intervention/policy, operating on its own, can have the effect of directly reducing dementia onset/prevalence and changing lifestyle habits. Six actions for policymakers are identified in this issues brief which have the potential to have immeasurable benefits: i) development of a comprehensive dementia prevention strategy, ii) establishment of a body whose aim is to keep track of scientific research (central to this will be the establishment of a national digital dementia research repository), iii) ensuring a multisectoral approach is adopted in the fight against dementia that includes both 'traditional' and 'incidental' health agencies, iv) continued investment into research and innovation, v) identifying incentives beyond the health domain and vi) development of longevity literacy programs. These actions all have as their foundation the 'Health in all Policies' initiative and social determinants of health approach.

12.2 Background

12.2.1 What is the problem?

Dementia is a collective term for a number of disorders that cause decline in a person's memory, judgement or language that affects everyday functioning (Australian Commission on Safety and Quality in Health Care, 2014). As dementia progresses, forgetfulness and confusion grow and in the most advanced stage, dementia patients become unable to care for themselves. Dementia therefore can range from mild to severe. Persons with mild cognitive impairment (MCI), for example, may develop difficulty multi-tasking and short-term memory losses but are able to perform usual daily tasks with little difficulty and may remain stable without further decline in cognitive abilities for years. More severe cases however may develop short and long-term memory loss, personality and behavioural changes, delusions and difficulty coordinating movement leading to an inability to function independently.

In Australia, deaths as a result of dementia have now taken over cerebrovascular diseases as the second leading causes of death (Australian Bureau of Statistics, 2015b). Without new ways to delay dementia risk and incidence, dementia will quickly outrank heart disease as the leading cause of death in Australia, and government spending on the condition will potentially reach $4.5 billion by 2030 (Australian Institute of Health and Welfare, 2007). At present, over a quarter million Australians suffer from dementia and projected estimates indicate that the figure can reach a high of nearly one million by 2050 (National Health and Medical Research Council, 2014).

There has been considerable investment in scientific research in the fight against dementia by both governments and non-governmental organisations alike, and undoubtedly much more is needed. Scientific studies however take time and it is in our best interest to develop interim intervention strategies using the best evidence presently available for reducing dementia risk, delaying onset of disease and reducing prevalence until more conclusive findings are available.

12.2.2 Why is this relevant to policymakers?

The recently released 2015 Intergenerational Report highlights the demographic changes that Australia is expected to undergo over the next 40 years (Treasury of the Commonwealth of Australia, 2015). These demographic changes have serious health and social expenditure implications. Age is presently the strongest known predictor of dementia and these projected figures seem to highlight that a dementia epidemic may lie ahead. Australians will continue to record long life expectancies and by 2054 males are expected to live an estimated 95.1 years and females 96.6 years (Treasury of the Commonwealth of Australia, 2015). The structure of Australia's population will also continue to change with a greater proportion of the population aged 65 and over (Treasury of the Commonwealth of Australia, 2015). Further, the number of Australians in this age group is projected to more than double by 2054–55 compared to 2015 population estimates. Increases in both the number and proportion of Australians aged 85 and over are also expected accounting for a projected 4.9% of the population, or nearly 2 million Australians (Treasury of the Commonwealth of Australia, 2015). Research suggests that dementia prevalence is highest in the 85–89 age group due to the relatively large number of people within the age bracket and that this will continue to be the trend (Alzheimer's Australia, 2011a). Table 12.1 and Figure 12.1 show dementia prevalence projections for Australia.

The challenges presented by increased dementia prevalence have continued to capture the attention of both governments and other stakeholders. In 2015, the Australian Government announced an AUS$46 million commitment to provide

Table 12.1: Total Australian dementia prevalence projections, by age (2005 – 2050); Source: (Access Economics, 2007)

Age Group	2005 ('000)	2010 ('000)	2020 ('000)	2030 ('000)	2040 ('000)	2050 ('000)
0–59	1.67	1.70	1.74	1.76	1.77	1.76
60–64	8.32	10.76	12.48	13.08	13.14	14.32
65–69	11.28	13.45	18.70	21.76	22.67	23.27
70–74	21.18	24.52	38.54	45.45	47.91	48.33
75–79	33.30	33.43	47.48	67.58	79.47	83.62
80–84	49.07	54.31	66.13	107.35	129.13	138.39
85–89	41.52	55.35	65.30	97.73	142.80	171.96
90–94	28.10	33.73	54.21	70.98	120.28	150.66
95+	10.41	15.25	28.36	39.76	61.92	98.71
% of Population	**1.01**	**1.14**	**1.44**	**1.88**	**2.40**	**2.77**

joint fellowships supporting early-career researchers in the field of dementia research (Alzheimer's Australia, 2015b). The National Health and Medical Research Council (NHMRC) and the Australian Research Council (ARC) have worked jointly on ensuring the newly-supported research takes into account the social, economic, cultural, and complex consequences of dementia (Alzheimer's Australia, 2015b). Prior to this, in 2014, the Australian Government announced its' plan to boost innovation and research in relation to dementia by providing an additional AUS$200 million over five years. In 2012, Australian health ministers recognised dementia as the ninth National Health Priority Area, and the Australian Government announced its intention to reform aged care. Other government initiatives since then have included the formation of the Dementia Collaborative Research Centres (DCRC) and development of other strategic grants aimed to support dementia-related research that could inform policy. Most recently, the Australian government announced its investment of $54.5 million over a four year period in response to the Dementia Forum Options Report produced in late 2014 (Australian Government Department of Social Services, 2015). These funds will be used to establish Severe Behaviour Response Teams – a mobile workforce of clinicians providing expert advice to residential aged care providers (Australian Government Department of Social Services, 2015).

Despite the fact that innumerable reports and studies have been published on government expenditure on dementia and the need for provision of services for people with dementia and their carers and the urgent need for interventions to reduce risk and delay onset (Australian Institute of Health and Welfare, 2007; Nepal et al., 2008), these have not resulted in a comprehensive dementia prevention strategy. As such, while the government actions presented above are promising, more must be done to address the root causes of the disease and to develop

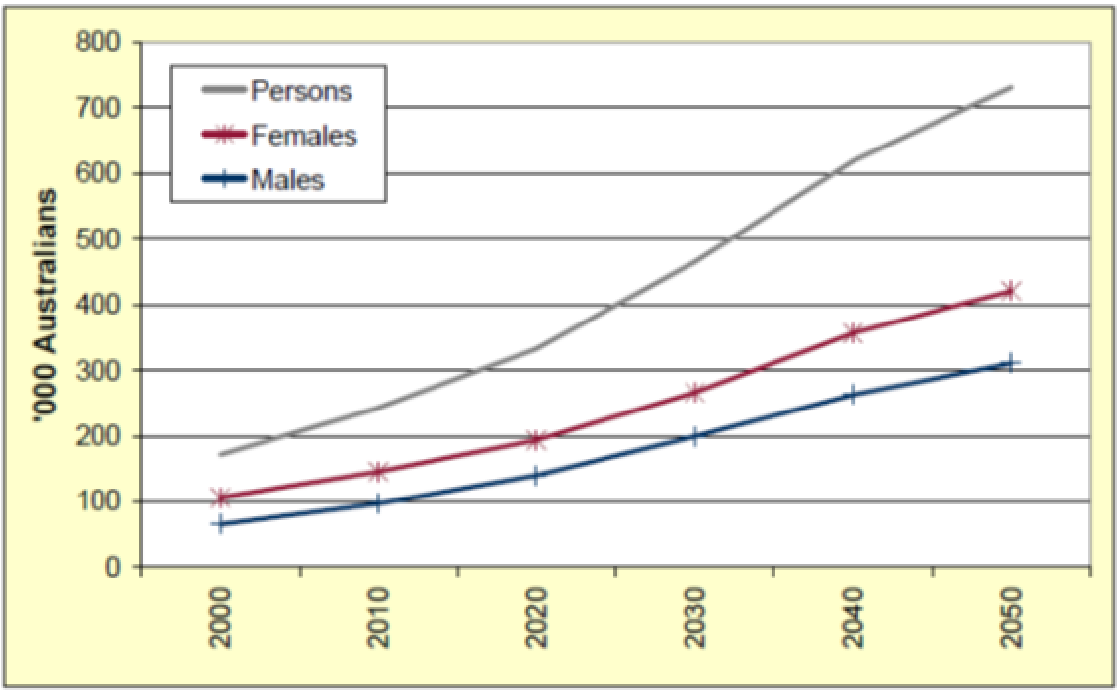

Figure 12.1: Projected increases in dementia cases, elderly population and total population for Australia 2000–2050; Source: (Access Economics, 2007). Dementia Estimates and Projections: Queensland and its Regions

supportive environments that help individuals take ownership of their health. For example, longevity literacy is one initiative that ought to be undertaken by the Australian government in order to promote greater accountability for health at an individual level. Such an initiative would aim to educate the population about increases in life expectancy and the possible implications of this. With increased life expectancy, there is a need for individuals to understand that they may be living far longer than they expect and that as a result of pressures on state resources may be increasingly called upon to be more responsible and accountable for their own health and wellbeing.

12.3 Aims

- To examine published studies and reports in order to make inferences about the effectiveness of diet and physical activity interventions aimed to reduce dementia onset and prevalence.
- To present a case for greater investment in diet and physical activity interventions to reduce dementia onset and prevalence.
- To provide some suggestions to policymakers on the way forward.

12.4 What does the research tell us?

Number of people affected and future projections

In 2013, an estimated 322,000 Australians had dementia and it was predicted that this figure would reach almost 400,000 by 2020 and just fewer than 1 million by 2050 (see Figure 12.2). In addition, 1 in 10 Australians aged 65 and over had dementia in 2011 compared to 3 in 10 Australians aged 85 and over (Australian Institute of Health and Welfare, 2015a). Each week, there are 1,700 new cases of dementia in Australia; approximately one person every 6 minutes (Alzheimer's Australia, 2015c). This is expected to grow to 7,400 new cases each week by 2050 (Alzheimer's Australia, 2015c).

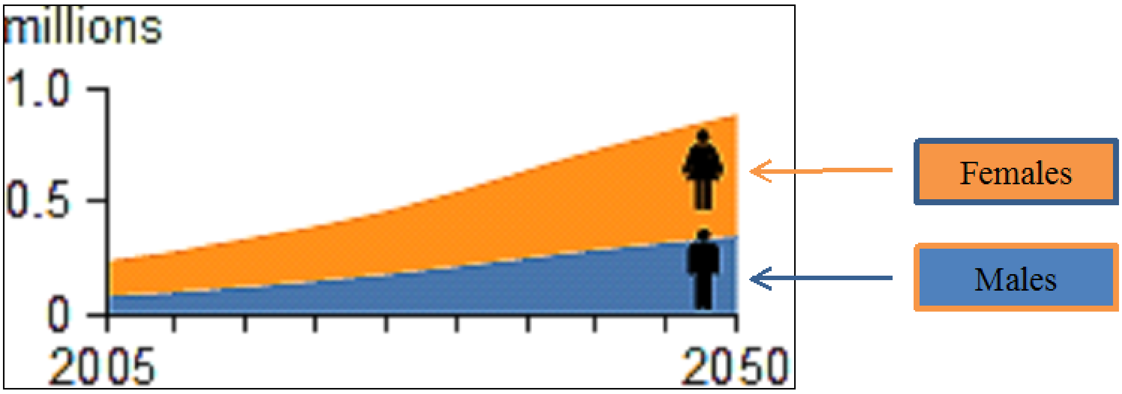

Figure 12.2: Estimated Dementia Projection to 2050; Source: Australian Institute of Health and Welfare (2015a). About Dementia. Available from www.aihw.gov.au/dementia/. (Australian Institute of Health and Welfare, 2015a)

The effect of delaying onset of dementia

Reducing the prevalence or delaying the onset of dementia is crucial to the fight to reduce the impact of the disease, both financially and on individuals (Alzheimer's Australia, 2005). Delaying dementia onset lessens the average number of years spent living with the disease (Access Economics, 2004). Those living with dementia for longer periods tend to require considerably more health services per annum than newly diagnosed individuals and this has substantial public health resource allocation implications (Access Economics, 2004). Even delaying the onset by 5 years is predicted, in time, to halve the number of people with dementia and have significant economic and societal effects (Alzheimer's Australia, 2007).

In a report for Alzheimer's Australia, the potential impact of possible interventions to delay the onset of dementia on future prevalence of the condition was demonstrated (Vickland et al., 2012). Specifically, the report estimated that any intervention that could delay the onset of dementia by 2 years, introduced in 2020, would reduce the cumulative number of people developing dementia between

2012 and 2050 by 13%, or 398,000 people (Vickland et al., 2012). Further, any intervention that would delay the onset of dementia by 5 years would reduce the cumulative number of people developing dementia for the same period to 925,000 people i.e. a 30% reduction (Vickland et al., 2012). Figure 12.3 shows the possible effect of intervention strategies.

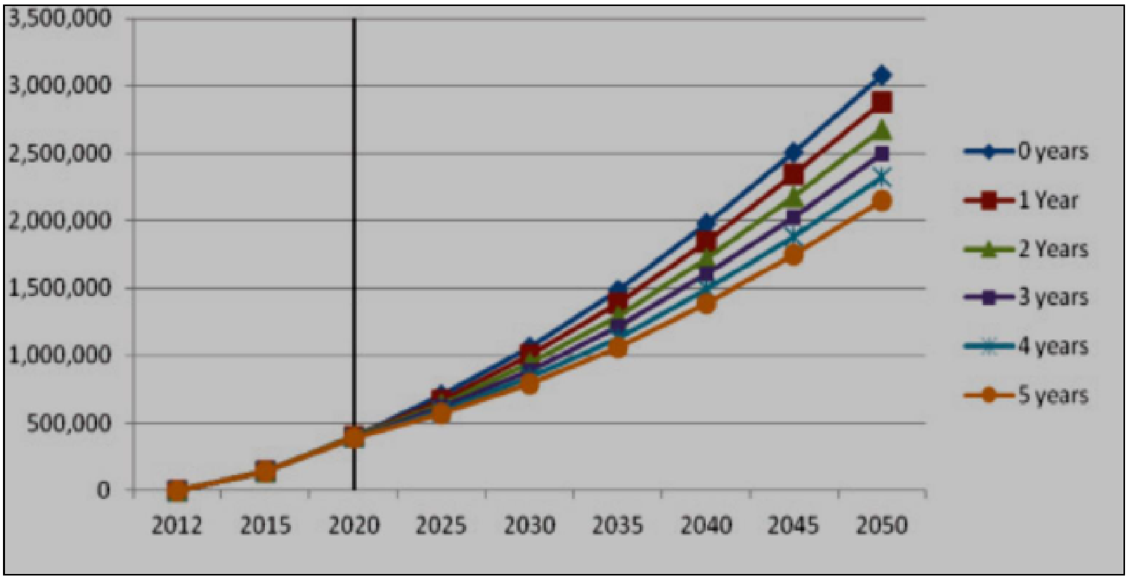

Figure 12.3: Changes in new cases of dementia due to the implementation of an intervention starting in 2020; Source: Vickland, Morris, Draper, Low, and Brodaty (2012). Modelling the Impact of Interventions to Delay the Onset of Dementia in Australia – A Report for Alzheimer's Australia.

These projections are comparable to other Australian studies that have modelled the impact of delaying onset on future prevalence numbers. For example, in a report produced by Access Economics it was estimated that a 5-year delay in Alzheimer's disease onset (the most common form of dementia) from 2005 would decrease prevalence by 48.5% in 2040 (Access Economics, 2004) while a 2005 study estimated that delaying onset of dementia by 5 years from 2000 would decrease prevalence by 44.0% in 2050 (Jorm, Dear, & Burgess, 2005); and a more recent report estimated that delaying onset of dementia by 5 years between 2010 and 2040 would decrease prevalence by 37.0% in 2040 (Vickland et al., 2012).

12.5 Evidence in support of modifiable lifestyle changes

Current evidence suggests that lifestyle choices such as having a healthy diet and engaging in regular physical activity can delay dementia onset. Such actions can also control cardiovascular disease risk factors, including diabetes, high cholesterol, and hypertension which are themselves risk factors for dementia (Prince et al., 2014).

These health and lifestyle choices referred to are also known as modifiable risk factors and can be can be divided into three categories: brain risk factors, lifestyle risk factors, and heart disease risk factors (Alzheimer's Australia, 2014):

12.5.1 Brain Risk Factors

Several large longitudinal studies have found that increased levels of leisure and mental activity in late life is associated with an approximate 50% lower incidence of dementia (Valenzuela & Sachdev, 2006).

I Mental Activities – The beneficial effect of stimulating mental activities has been centred on the theory of brain reserve i.e. the possibility that the activity provides a reserve that delays the onset of the clinical manifestations of dementia. Increased engagement in mentally challenging activities has been shown to improve cognitive function, reduce cognitive decline, and reduce risk of dementia (Alzheimer's Australia, 2011b; Scarmeas, Levy, Tang, Manly, & Stern, 2001). Such activities include those that exercise the brain and build cognitive reserve – they should be complex, involve learning new things and be done frequently (Alzheimer's Australia, 2011b). Reading, doing puzzles, sodoku, playing musical instruments, doing art, and participating in leisure activities such as sports, hobbies, dancing and gardening have all been shown to confer benefit by building cognitive reserve (Alzheimer's Australia, 2011b).

II Leisure Activities – Some studies have also examined the association of leisure-activities i.e. activities that are not categorised as planned exercise for a health purpose, and incident dementia/AD. Evidence shows that individuals participating at least twice a week in a leisure time physical activity have 50% lower odds of dementia compared with sedentary persons (Rovio et al., 2005) and that engagement in leisure activities may reduce the risk of incident dementia, possibly by providing a reserve that delays the onset of clinical manifestations of the disease (Scarmeas et al., 2001). An area requiring further study that has been suggested is the clarification of whether increased participation in leisure activities lowers the risk of developing dementia directly or if this observed relationship is the result of declined participation in leisure activities during the preclinical phase of disease (Verghese, Lipton, Katz, Hall, & et al., 2003).

Evidence suggests that a healthy diet, regular engagement in physical activity and moderate consumption of alcohol are associated with better cognitive outcome.

12.5.2 Lifestyle risk factors (diet, physical activity, alcohol intake)

Evidence suggests that a healthy diet, regular engagement in physical activity, and moderate consumption of alcohol are associated with better cognitive outcome.

Diet

Both single nutrients and dietary patterns have been studied in relation to cognitive health but due to the complex interplay of nutrients, such studies have yielded mixed findings. Evidence pertaining to some key food and nutrient components is presented below. These have been discussed in greater detail in Chapter 3 of this thesis.

I Dietary Lipids – Studies suggest that higher ratios of saturated fat to mono- and poly-unsaturated fats are predictive of negative cognitive outcomes. It is this evidence that has led to increased focus on the Mediterranean diet which is traditionally rich in olive oil (a good source of monounsaturated fat) (Estruch et al., 2013).

II Cholesterol – There is evidence that elevated mid-life serum cholesterol levels are associated with increased risk of AD in old age (Morris, 2009).

III B vitamins – Deficiencies of some micronutrients (especially B1, B2, B6 and B12) commonly described in older ages have been found to be significantly associated with CIm (Solfrizzi, Panza, et al., 2011). A meta-analysis conducted in 2013 using 5 eligible cohort studies examining effects of B vitamins or folate on prevention of AD showed that low baseline serum folate levels was associated with increased risk of AD (Daviglus et al., 2011).

IV Antioxidants – Research suggests that oxidative stress and inflammation can lead to AD because of an increase in free radicals and the damage they cause to neuronal cells. Antioxidant nutrients (vitamin C, vitamin E, carotenoids, flavonoids), found in many fruits and berries are thought to be the key mediators in this mechanism since they can hinder the effects of dangerous free radicals (Wärnberg et al., 2009).

V Fish – The fatty acids found in fish are thought to be linked to cognitive function through atherosclerosis, thrombosis or inflammation via an effect on brain development and membrane functioning or via accumulation of β-amyloid (Gu et al., 2010). Regular consumption of fish (a good source of DHA and Omega-3 polyunsaturated fatty acids) has been shown to lower the risk of dementia by up to 37% (Loef & Walach, 2012).

VI Vegetables and Legumes – Diets rich in vegetables and legumes have been associated with better cognitive outcome in the literature with studies showing that always eating vegetables and always consuming legumes is inversely associated with cognitive decline and risk of developing AD (Chen, Lin, & Chen, 2009; Gu et al., 2010).

VII Caloric Intake – In a recent Australian prospective study it was reported that energy intake was associated with greater risk of CIm with the effect being even more potent for a measure of excessive caloric intake (Cherbuin & Anstey, 2012). However, because the long-term effect of caloric restriction in older age groups is unknown, this management route is not usually recommended (Gillette-Guyonnet et al., 2013).

VIII Mediterranean Diet (MeDi) – The MeDi has been widely reported to be associated with a number of favourable health outcomes including reduced risk of CIm, cancers and cardiovascular disease and increased life expectancy (Scarmeas, Stern, Mayeux, Manly, et al., 2009; Scarmeas et al., 2006; Sofi, Macchi, Abbate, Gensini, & Casini, 2010; Solfrizzi, Frisardi, et al., 2011; Trichopoulou et al., 2003). Figure 12.4 highlights the basic components of the MeDi.

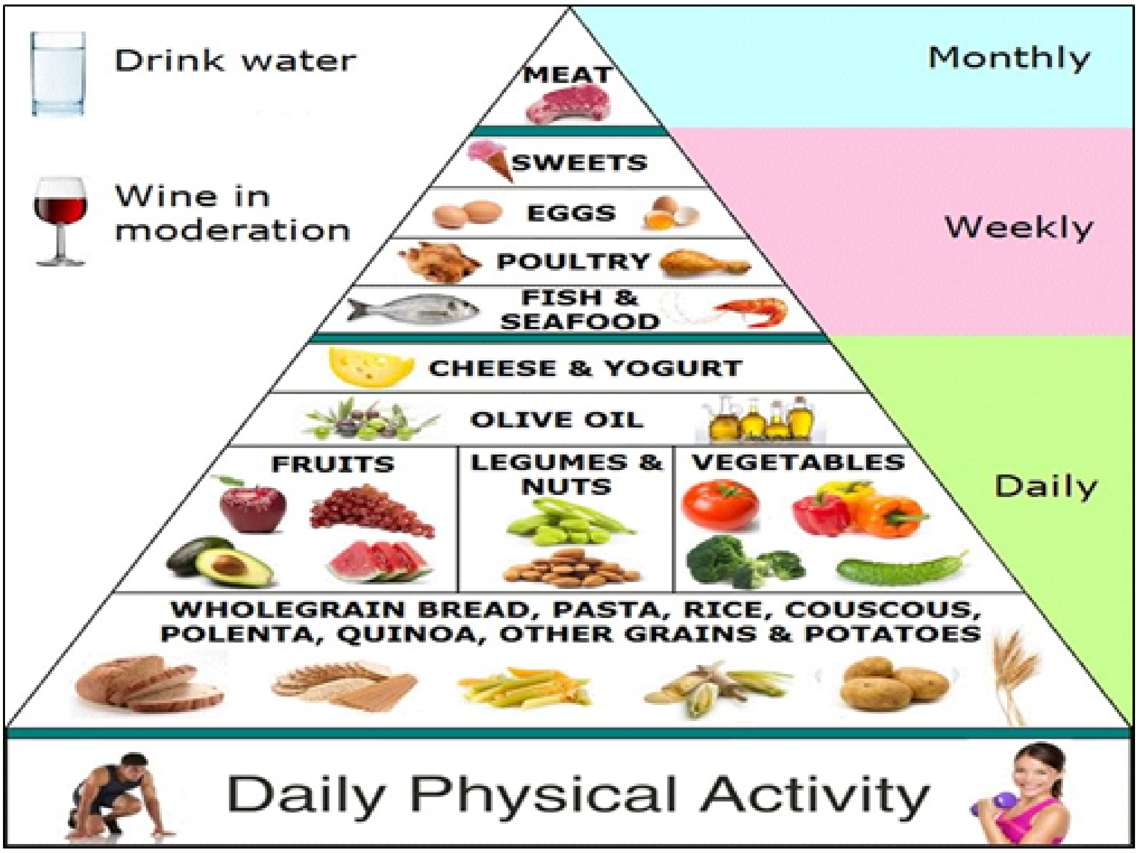

Figure 12.4: Basic Components of the Mediterranean Diet (Diet Blog, 2015).

Physical Activity

Physical activity has been shown to promote functional neuro-protective changes in the hippocampus of the brain – a region central to learning and memory (Erickson et al., 2011). This brain region has been found to be one of the first areas affected by dementia. A brief summary of the results of studies related to physical activity and dementia/mental function is shown below. These are discussed in greater detail in Chapter 4 of this thesis.

I Physical Activity and Incident Dementia/Alzheimer's disease – Most studies have demonstrated that high levels of physical activity in older adults with no dementia is associated with a 30% to 50% reduction in the risk of cognitive decline and dementia (Forbes et al., 2008). Some studies have theorised that poor physical function may precede the onset of dementia and AD and higher levels of physical function may be associated with delayed onset (Wang et al., 2006). The results as it relates to physical activity and incident dementia/AD are convincing as they have been conducted in a variety of ethnic settings with reports being similar.

II Physical Activity and Improving Functional Status – Function and cognition influence each other (Wang et al., 2006). Mobility is one aspect of physical function that is typically compromised as AD symptoms progress due to white matter changes of the brain associated with hippocampal atrophy (Wang et al., 2006). Links between physical activity and improved walking speeds in AD sufferers have been highlighted in the literature and have been linked to the fact that dementia targets those walking parameters that seem to be predictive indicators of falls (shortened stride length, slowing down, and increased double limb support time) (Kemoun et al., 2010). A meta-analysis conducted in 2008 that included 21 exercise trials with cognitively impaired individuals and 20 exercise trials with cognitively intact individuals revealed that those with impaired cognitive function who participated in exercise rehabilitation programs had similar strength and endurance training outcomes as age and gender matched cognitively intact older participants (Heyn et al., 2008). This suggests that individuals with dementia and other forms of CIm should take part in exercise rehabilitation programs (Heyn et al., 2008).

III Physical Activity in CIm Therapy – A Cochrane Review conducted in 2008 highlighted that there is insufficient evidence to be able to say whether or not physical activity programs are beneficial for people with dementia especially since there has been no inclusion of secondary outcomes relating to family caregiver outcomes and use of health services provided in any study (Forbes et al., 2008).

IV Physical Activity in those with Normal Cognitive Function – A recent Cochrane Review conducted analysing 11 randomised controlled trials with participants older than 55 years of age was able to conclude that there is evidence that aerobic physical activities are beneficial for cognitive function in older adults. Further studies are required to determine whether the cognitive benefits noted were a result of improvements in cardiovascular fitness (Angevaren et al., 2008).

Alcohol Intake

In a meta-analysis of 15 prospective studies, results suggested that light to moderate alcohol consumption in older adults is associated with reduced risk of dementia (Anstey et al., 2009). This seeming 'J' or 'U' shaped relationship has been highlighted in other case-control studies (Mukamal et al., 2003). Associations between " former drinkers" and risk of CIm remains unclear in the literature, since it is possible that they may have stopped drinking for reasons such as health issues that also predispose to CIm (Daviglus et al., 2011).

12.5.3 Heart Disease Risk Factors (blood pressure, body mass index, cholesterol, diabetes, smoking)

I Blood pressure – Vascular risk factors have long been known to be involved in the development of both AD and vascular dementia. Hypertension in midlife is thought to be a significant risk factor for the later development of both Alzheimer's disease and vascular dementia. Hypotension in later life appears to be associated with the development of Alzheimer's disease in particular (Kennelly, Lawlor, & Kenny, 2009).

II Body Mass Index – In a meta-analysis of 16 studies it was reported that in midlife, underweight BMI, overweight BMI, and obese BMI were all associated with increased risk of dementia compared with normal BMI (Anstey et al., 2011). The authors suggest a U-shaped relationship between midlife BMI and dementia risk.

III Cholesterol – There is evidence that elevated mid-life serum cholesterol levels are associated with increased risk of AD in old age (Morris, 2009). Studies have focused on the most important genetic risk factor for AD, APOEe4 allele, the protein product of which is the principal cholesterol transport in the brain (Morris, 2009).

IV Diabetes – Research shows a clear link between dementia and Type 2 diabetes. Dementia occurs more frequently in people with Type 2 diabetes than in the general population – a review of relevant studies found that diabetes was associated with a 47% increased risk of any dementia, a 39% increased risk of AD, and a 138% increased risk of vascular dementia (Alzheimer's Australia, 2014). Impaired insulin secretion, insulin resistance, and glucose intolerance are also associated with an increased risk of dementia (Alzheimer's Australia, 2014). While there may be many contributing factors to this increased risk, vascular disease has consistently been implicated as having a possible causal effect.

V Smoking - In a meta-analysis of 19 prospective studies with at least 12 months follow-up, when compared with people who had never smoked, current smokers had an increased risk of dementia and cognitive decline ranging from 40% to 80% depending on the outcome examined (Anstey et al., 2007).

Preservation of cognitive abilities is central to the maintenance of independence and quality of life among older adults (Shatenstein et al., 2012). The evidence presented above highlights that the brain needs to be stimulated and provided with nutrients to build and maintain its structure and to be protected from cognitive decline. Diets low in saturated fat, high in legumes, fruits and vegetables, moderate in ethanol intake, and low in meat and dairy have been highlighted as having a protective effect against the development of dementia. While traditionally, the single nutrient approach has been used to examine the relationship between diet and disease, many researchers now support the examination of dietary patterns such as the MeDi as the dynamic interplay of food items makes the implication of a single nutrient almost impossible (Scarmeas, Stern, Mayeux, & Luchsinger, 2006). Studies suggest that adults who engage in physical activity have a reduced risk of cognitive decline and dementia and have a higher functional status due to improved strength, endurance, and balance. Overall though, further research is needed to examine whether other dietary patterns exist that can prevent/delay dementia onset and also to conclusively state whether physical activity is beneficial to persons who already have dementia.

12.6 Why highlight diet and physical activity interventions?

From the evidence presented above, diet and physical activity have been shown to have an effect on cognitive status. In addition, unhealthy diets and physical inactivity have been shown to be key risk factors for diseases such as Type 2 diabetes and metabolic syndrome, some cancers (colon, breast, endometrial and lung cancer) and cardiovascular diseases (Centers for Disease Control and Prevention, 2011; World Health Organisation, 2015c) which are known to be leading causes of death in Australia (Australian Bureau of Statistics, 2014b). A balanced diet and regular physical activity have also been found to strengthen bones and muscles, improve mental health and mood and improve ability to do daily activities and prevent falls (Centers for Disease Control and Prevention, 2011).

Results from the Australian Bureau of Statistics National Health Survey (2011–2013) show that most Australian adults do not meet the National Physical Activity Guidelines (to do at least 30 minutes of moderate intensity physical activity on most days) as more than half the Australian population is inactive (Alzheimer's Australia, 2015d). Levels of physical activity were also shown to decline with age. Survey data showed that persons 75 years and over recorded the highest levels of inactivity (approximately 20 minutes per day) when compared with other age groups (Australian Bureau of Statistics, 2013a). Sedentary activities occupied an average of 39 hours per week for adults with much of this time spent watching television and using the computer for non-work purposes (Australian Bureau of Statistics, 2013a).

Findings from the diet section of the survey showed that nearly two-thirds (63%) of the Australian population are now classified as overweight or obese (Australian Bureau of Statistics, 2012b). A closer investigation of dietary habits revealed that over 33% of total energy consumed was from foods considered to be of little nutritional value i.e. high in saturated fats, sugars, salt and/or alcohol (Australian Bureau of Statistics, 2014a). Alcoholic beverages (4.8% of energy), cakes, muffins, scones and cake-type desserts (3.4%), confectionery and cereal/nut/fruit/seed bars (2.8%), pastries (2.6%), sweet biscuits and savoury biscuits (2.5%) and soft drinks and flavoured mineral waters (1.9%) were found to be the main culprits (Australian Bureau of Statistics, 2014a). In addition, over 2.3 million Australians aged 15 years and over reported that they were on a diet to lose weight or for some other health reason in 2011–12 (Australian Bureau of Statistics, 2014a). Dieting was most prevalent in the 51–70 age group where 19% of females and 15% of males were on some kind of diet (Australian Bureau of Statistics, 2014a).

The World Health Assembly Resolution WHA55.23 provides an important substratum for action as it urges Member States to, "... promote health and reduce the common risks of chronic non-communicable diseases that stem from poor diet and physical inactivity by essential public health action and integration of preventive measures in the functions of health services" (World Health Organisation, 2002a).

Promoting healthy ageing and the maintenance of physical and mental function in older age are undoubtedly major challenges (Dangour, A. & Uauy, R., 2006)(Dangour & Uauy, 2006). Dementia prevalence has the potential to reach epidemic proportions if there is no risk reduction at the population-level (Anstey et al., 2010; Barnes et al., 2009). As dementia has no cure there is a need for effective treatment approaches. In light of the evidence that highlights the possible beneficial effects of diet and physical activity on brain function, interventions that focus on these should be encouraged as even a modest protective result can result in significant public health impact.

12.7 What works?

A successful diet and physical activity intervention is one that encourages and results in significant and sustainable behaviour changes (Horodyska et al., 2015). In a study aimed to provide a broad list of good practice characteristics in interventions and policies targeting healthy diet and physical activity, it was suggested that researchers, practitioners and policymakers should account for 53 key characteristics. These are categorised into three main domains and should be carefully considered when planning, developing and reporting interventions promoting healthy eating and physical activity (Horodyska et al., 2015). A brief snapshot of some of the items included in each domain is presented below. For the full list of good practice characteristics in interventions see the published issues brief presented in Appendix B.

I Main intervention characteristics – A list of 18 items that ought to be considered are presented. These include the identification of a well-defined target audience/group, well-defined target behaviours and identification of the forms of delivery that will be employed.

II Monitoring and evaluation – Items that ought to be considered within this domain include costs in relation to target outcomes, evaluation of risks, sustainability of the intervention, and determination of whether the effects are generaliseable.

III Implementation – Included here are attrition rate considerations, specification of resources, and stakeholder support (feasibility and acceptability).

In addition to taking into consideration the characteristics mentioned above (and further elaborated on in Appendix B.), it is also critical to consider which interventions will be most successful within a given target group. The World Health Organisation publication 'Interventions on Diet and Physical Activity – What Works' (2009), is a useful resource for researchers and policymakers to determine the effects of various types of diet and physical activity interventions across various age-groups and settings (World Health Organisation, 2009b). As it relates to older adults, research shows that group physical activity programmes have reported improvements in psycho-social outcomes with evidence indicating that such programmes must be easily accessible. Greater accessibility can be accomplished by conducting the intervention at venues where they regularly meet or by making it comfortable and convenient, for example delivery of fruit and vegetables via a meals on wheels programme (World Health Organisation, 2009b). In the published version of this issues brief in Appendix B., the evidence tables from the World Health Organisation publication highlighting the effectiveness of a variety of interventions in older adults are shown.

When deciding on an implementation strategy, a variety of settings and methods can be considered. For example, an intervention can be implemented at schools, workplaces, religious settings or in the community. Depending on the setting, the medium and methods used may differ, for example mass media may be suitable in one context while individualised materials may be more applicable in another. It is critical to know the effectiveness of all settings and modes of message delivery. Often though, strategies and methods employed in one setting are cross-cutting and tend to be broadly applicable in other settings as well:

I Physical Environment Interventions – Interventions/policies that have the ability to make physical modifications and that can reach large populations in the environments where they make their choices are the most successful (World Health Organisation, 2009b). Included in this category are point-of-purchase prompts and messages in stores that encourage shoppers to select options conducive to good health and increasing and maintaining safe public spaces for physical activity. In the published version of this issues brief (presented in Appendix B.), an excerpt of 'The Supportive Environments for Physical Activity and Health Project (2009)' developed in Queensland which highlights physical environment modification approaches that can be carried out by local government is shown (Pretorius, 2008). Such approaches can be developed and enacted in other states at the local government level.

II Workplace Interventions – Research points to the use of carefully organised, accessible and sustainable activities to derive maximum health benefits in the workplace. Including workers in the planning and implementation phase of workplace interventions has been shown to be beneficial (World Health Organisation, 2015b). An evidence-based module produced in Australia reported that effective types of physical activity strategies to include in Australian workplace settings include signage encouraging stair use, providing access to physical activity spaces and providing education and peer support (World Health Organisation, 2009a). This is supported by the available scientific literature where studies have highlighted the effectiveness of signage that encourages use of stairs instead of an elevator or escalator results in a median increase in stair climbing of 53.9% and that experimentally reducing the availability of escalators and modelling more active behaviours increases stair use (Artinian et al., 2010). In terms of nutrition interventions applicable at workplace canteens and shops, point-of-purchase promotions, access and availability of healthy food options and food labelling were pinpointed as being most effective (World Health Organisation, 2009a). Other examples of interventions that have been shown to be effective in a workplace setting include lunch hour walking programs, instructor-led group exercise, and healthy taste clubs (Artinian et al., 2010).

III Community-based Interventions – Evidence within this multidimensional domain points to the effectiveness of diet education and physical activity programmes that target high-risk groups. Community-based interventions that incorporate a variety of activities, include both diet and physical activity components and have a robust educational component with strong theoretical underpinnings seem to be associated with the greatest levels of sustainability (World Health Organisation, 2009b). Policies for providing wide and safe routes for walking and biking in communities, maintaining public parks, reducing exposure to unhealthy fast food or to high-calorie/low-nutrient foods, menu labelling and increasing access and availability to healthy foods appear crucial to sustainable behaviour change (Artinian et al., 2010).

IV Religious Setting Interventions – There is consistent evidence that intervention strategies that are planned with the help of spiritual leaders and members of their congregation have high levels of success. Such interventions tend to include counselling, group education, and self-help strategies (World Health Organisation, 2009b).

V Mass-media based Interventions – Multi-component mass media campaigns that involve a community participation approach have the highest rates of success (World Health Organisation, 2009b). Some evidence however has shown that an individualised material approach tends to be more effective in helping to encourage physical activity and diet change. In a study comparing the effects of motivationally matched print materials versus motivationally matched telephone counselling, both groups had significantly increased physical activity at 6 months, but participants receiving the print materials were more likely to maintain physical activity change at 12 months (Artinian et al., 2010).

VI Group-based Interventions – Group focused interventions allow for social interaction, peer-support, and positive observational learning. Typically administered using a small number of participants, the group initially meets quite often with frequency decreasing over time – this has proven problematic particularly as it relates to interventions to improve eating habits where self-monitoring is encouraged. One technique that can be used to combat this is to include friends and wider support networks to ensure that target goals are achieved and maintained.

VII Individual-focused Interventions – Personalised interventions that allow for the development of tailor-made strategies to suit an individual's health goals have been shown to have some short-term success (up to 1 year) (Artinian et al., 2010). A combined approach incorporating self-monitoring and counselling have also been shown to improve the effectiveness of the intervention (Artinian et al., 2010).

VIII Computer/Technology-based Interventions – Overall, studies aimed to evaluate the effectiveness of technology-based interventions have produced mixed results. What has been established though is that programs incorporating both an online information provision element along with counselling (provided online) have more success than the use of intervention programs alone. Supermarket kiosk programs that provide onsite nutrition information have also been shown to be effective in improving fruit, fibre and saturated-fat intake (Artinian et al., 2010). There are several advantages to using a computer-based intervention as it allows for many people to be reached in the comfort of their own homes and allows for tailored intervention programs to be developed. In addition, they are cost-effective and provide an opportunity for interaction for socially isolated individuals (Artinian et al., 2010).

IX Multicomponent Interventions – Such interventions have reported some success although the optimal combination of behaviour change strategies to be included in a given intervention program requires further study. Multicomponent intervention programs include: some combination of technology/media; group or individual-based delivery strategies; computerised assessment and feedback plus videotapes, telephone follow-up, or individual counselling; physician advice plus motivational videotapes, telephone calls, and interactive mail; group sessions plus individual motivational interviewing; or individual plus group sessions (Artinian et al., 2010).

X Interventions with special considerations for vulnerable groups (minority groups and socio-economically disadvantaged populations) – Differences in education, culture, language, ethnicity, and lifestyle have been proven to affect the effectiveness of any intervention. Multicomponent and group-based interventions have demonstrated positive diet and physical activity changes among vulnerable groups while computer/technology-based interventions reported limited success particularly among low-literacy individuals who may be unwilling to click on links and unable to understand information presented on websites (Artinian et al., 2010). The use of lay health advisors and community health workers who speak the same language, have similar beliefs, and live in the same area can increase the success of an intervention among vulnerable groups as they are able to target messages to meet their unique needs and may be viewed as being more identifiable and trustworthy (Artinian et al., 2010). In addition, factors relating to environment such as neighbourhood, access to safe parks, schools and clinics, along with diagnostic criteria/practices and country-level resources shape both risk and individual behaviours.

Several other interventions have been highlighted in the literature as being effective. These interventions have revolved around the ideas of policy and incentive provision schemes. For example, the lowering of insurance premiums for those who participate in programs aimed to improve diet and physical activity behaviours (Artinian et al., 2010). In addition, enacting and enforcing policies that support information provision (for example, mandatory calorie labelling) and limiting the use of certain food components in the food supply (for example, trans-fats) has been shown to positively influence food choices and foods available (Artinian et al., 2010). These types of approaches can engender supportive environments where making healthy food choices and engaging in regular physical activity are second nature (Artinian et al., 2010).

For an intervention aimed to decrease dementia onset/prevalence to be considered a success, it must encourage and result in significant and sustainable behaviour change. Sustainability is paramount since it takes into consideration individual, social and environmental elements. While health issues are frequently considered to be problems for health departments to solve, the development of diseases such as dementia are impacted by a wide variety of determinants – genetics, education, access to safe and well maintained physical activity spaces, access to affordable healthy foods and existence of a supportive environment. For all these determinants to be addressed there must be support and acceptance from all stakeholders that they have a key role to play. Figure 12.5 identifies some of the stakeholders involved in the implementation of any health intervention (Ottersen et al., 2014).

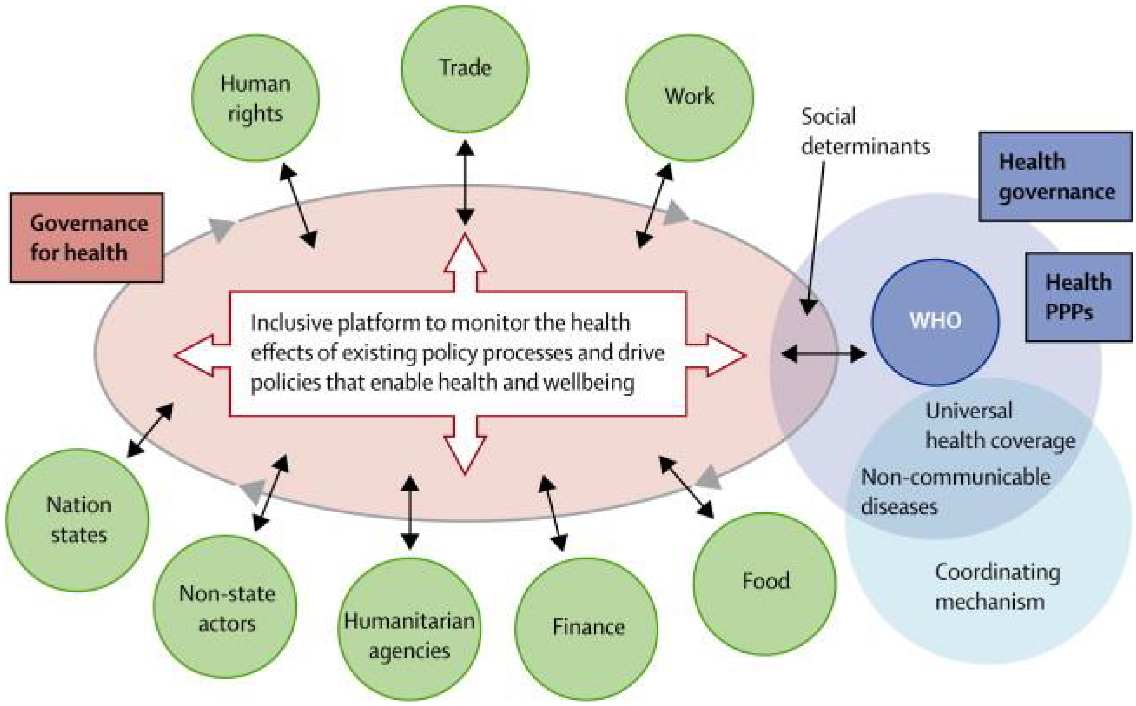

Figure 12.5: Stakeholders involved in the development and implementation of health interventions and policy. Source: (Ottersen et al., 2014). The political origins of health inequity: prospects for change. The Lancet, Volume 383, Issue 9917, 630–667.

12.8 What should policymakers do?

Policymakers must be cognizant of the fact that no singular government intervention/policy, operating on its own, can have the effect of directly reducing dementia onset/prevalence and changing lifestyle habits. To compound this issue, some thinkers postulate that people are in control of what happens to them health-wise while others believe that the environment acts upon people leading to development of various lifestyle habits (Anonymous, 2013). For any government policy/intervention to work there must be recognition that the environment does in fact influence the way we live our lives and our ability to change unhealthy behaviours into healthy ones.

Six actions that can be taken by policymakers are identified below that have the potential to result in inestimable benefit in the fight against dementia. These actions are not limited to dementia risk reduction interventions but rather to any public health intervention. Such actions though must be bolstered by strong education and communication strategies in order to be effective:

I Development of a comprehensive dementia prevention strategy – The National Framework for Action on Dementia (2006 – 2010) was implemented in the 2005 Australian Federal Budget (Alzheimer's Australia, 2011c). This initiative, however, was terminated in 2011 after an evaluation found that it did not address key critical issues (Alzheimer's Australia, 2011c). These issues included primary care, a communications strategy, and risk reduction

(Alzheimer's Australia, 2011c). Australia needs to develop an overarching plan that takes into consideration these key issues if reducing dementia onset and prevalence is a priority. Being the first country to establish dementia as a national health priority with a funded five-year plan (Alzheimer's Australia, 2011c), the Australian government needs to act quickly to develop a coordinated dementia prevention strategy.

II Keeping track of scientific research – A research of the grey and scientific literature in the Australian context reveals that there have been quite a number of dementia initiatives within the past few years – scientific studies, reports by various stakeholders, conferences, and public awareness campaigns. The establishment of a body whose aim is to keep track of scientific research both within Australia and internationally, to establish clear research and public health priorities as it relates to dementia and to outline the way forward based on the best scientific evidence clearly indicating the roles and levels of accountability of all stakeholders (at both state and federal level) is crucial. Central to this initiative will be the establishment of a national digital dementia research repository that will allow for data sharing among researchers.

III Increased engagement of non-health actors/agencies – Key to implementing a successful dementia prevention program is for stakeholders to accept and willingly support the initiative. The establishment of agreed outcomes that are measureable and able to be tracked is the first step and collaborating to develop clear roles for each stakeholder is the second. It is important to note that stakeholders can work through various channels thereby providing access to the broader population as well as well-defined target groups (Middleton, Barnes, Lui, & Yaffe, 2010). This interplay between stakeholders is critical since unlike other singular disease-causing agents targeted by governments such as tobacco, there are innumerable food products on the market. To compound this issue, while individual food items are capable of contributing to disease development if consumed in excess, they can also result in absolutely no harm if other healthy lifestyle choices are adopted (Anonymous, 2013).

Reports have highlighted that some health interventions are best led by 'incidental' and not 'traditional' health agencies (Anonymous, 2013). For example, in the UK, the Sustrans National Cycle Network (an NGO encouraging cycling through various non-governmental partnerships) led an initiative to increase cycling and walking journeys which was reported to have an estimated health benefit of US$625 million in 2009 (Meiro-Lorenzo, Villafana, & Harrit, 2011). As such, states of health and the development of effective and sustainable interventions to reduce dementia onset and prevalence, as with any other health condition, are not simply dependent on the action of ministries/departments of health. Rather, a successful intervention requires that elements of dementia prevention (including the need for healthy eating and active living) be incorporated into the purview of non-health departments such as trade, finance, education, communication, urban planning, agriculture and transport. The health sector in return can also identify policy " windows" across other sectors that can allow them to appreciate the health impact of their initiatives as well (Middleton et al., 2010).

IV Continued investment into research and innovation – Several intervention strategies that have been highlighted in the literature require further investigation to determine their true impact. Policymakers are keen to know what interventions will produce a positive return on investment by reducing both healthcare costs and disease prevalence. One area where research is needed for example, is the development of food taxes and the benefits that could ensue. In 2014, Cancer Council Australia recommended that research be commissioned to identify the impact of a food tax on various socio-economic groups within Australia and the examination of how a food tax and other policy measures could interact to be effective and equitable (Cancer Council Australia, 2013). Further research is also needed to identify innovative ways to detect early signs of dementia and care for those already affected. Individual-level (as opposed to aggregate-level) longitudinal data will ideally be needed in order for these goals to be achieved.

V Provision of incentives – Policymakers often incur challenges when trying to get all stakeholders to engage in meaningful dialogue that results in a series of implementation actions that all can agree on. This is particularly the case as it refers to non-traditional health actors who now must expand their respective portfolios to infuse elements of healthy eating and active living. The identification of incentives beyond the health domain is therefore critical, especially when economic interests conflict (Meiro-Lorenzo et al., 2011).

VI Provision of greater longevity literacy – At a population level, there must be the development a program to help people understand that they may be living far longer than they expect, and that as a result of pressures on state resources, may be increasingly called upon to be more responsible and accountable for their own health and wellbeing. Since dementia has no known cure and age is presently the strongest predictor of the disease, this initiative is quite appropriate. Such an action will involve collaboration from both 'traditional' and 'incidental' health agencies for example, Department of

Social Services, Department of Finance, Department of Health, Department of Human Services, and various community groups.

Chapter 13

A Snapshot of Longitudinal Studies and Health Surveys in LAC

13.1 Chapter Summary

Relative to developed countries, few studies collecting data on older adults have been conducted in Latin America and the Caribbean (LAC). The increasing proportion of persons 60 years and older in the region along with increasing life expectancies makes the elderly a group warranting special attention with regard to health and social issues. Data on diet, physical activity, and cognition are just three elements that need to be included in studies and surveys in order to have a more complete and accurate representation of health and wellbeing throughout the lifecourse.

CIm has been shown to have a significant economic impact. In addition, diet and physical activity habits have been associated with risk of chronic non-communicable diseases which older adults are more likely to have. This chapter provides a brief summary of the longitudinal and survey data available in the LAC region that captures information related to health in older adults. The presentation of these data are meant to showcase the dearth of information on elderly health status in LAC.

Greater investment in health research which collects longitudinal data on a wide variety of health domains is necessary in order to inform and develop effective public health interventions and policies.

13.2 Background

Similar to other regions of the world, the LAC region has undergone a period of rapid epidemiologic transition – with an increasingly older population (United Nations Economic Commisssion for Latin America and the Caribbean, 2004). Governments now have the task of developing programs and policies aimed to improve quality of life in older age groups by targeting lifestyle-related risk factors while simultaneously battling pockets of infectious disease, food insecurity, malnutrition, and micro-nutrient deficiencies.

While some information on ageing and health is available via census data, such data are self-reported and may not provide a complete picture particularly as it relates to diet and mental health. Previously published reports highlight that the prevalence of mental illnesses including dementia, AD, and depression are generally difficult to obtain in low- and middle-income countries for a myriad of reasons. Among these are limited financial resources and the perception that disability (physical and mental) is a natural part of the ageing process.

There have however been some positive strides in the region as it relates to health and ageing which seems to suggest an awareness and recognition of ageing as a process warranting greater attention. These actions though need to be supported by strong follow-up activities and policies. For example, in 2004, the first ever forum that focused on ageing in the Caribbean was held in Trinidad. This forum aptly titled 'The Caribbean Symposium on Population Ageing' allowed all stakeholders the opportunity to learn about the research being conducted in the region as it relates to ageing. Over a decade later, there is still a need for continued acknowledgement of the elderly as a vulnerable group and for them to be considered in the development of all policies (not only those directly under the purview of ministries of health).

In order for governments to make comprehensive and effective ageing-related policy decisions, more research needs to be conducted that focuses not only on older adults but also on health across the lifecourse. Data are needed on various age groups in order to fill the gap in the literature related to quality of life. Information on social and economic security, disabilities, access to healthcare, living arrangements, functional abilities, social networks, and access to public transport are also needed in order to develop targeted programmes that offer support services.

13.3 What Longitudinal Studies Exist in the LAC region that Collect Data on Older Adults?

I *The Mexican Health and Ageing Study (MHAS)* – MHAS is a longitudinal study (n = 20,542) which has had 3 completed Waves of data collection thus far. A fourth round of data collection is planned for 2015 (Instituto Nacional Estadistica y Geografia, 2012). The study collected baseline data in 2001 on those 50 years and over in both rural and urban settings and aims to evaluate how disease and disability affect ability to conduct activities of daily living. The study collects data on housing, sociodemographic characteristics, household income, family life, and health (including history of smoking, alcohol consumption, exercise, depression and cognition) (Instituto Nacional Estadistica y Geografia, 2012).

II *The Costa Rican Longevity and Healthy Ageing Study (CRELES)* – CRELES aims to examine the health and wellbeing of older Costa Ricans using longitudinal data. While the original sample included 3000 adults born in 1945 or before, the study is now composed of multiple Waves of data from two birth cohorts. Data on socioeconomic status, health and health behaviours and indicators including biomarkers are available (Rosero-Bixby, Dow, & Fernández, 2013).

III *WHO Global Study on global Ageing and adult Health (SAGE)* – SAGE is a multi-country study which collects data on adults (18 years and over) in six countries: China, Ghana, India, Mexico, Russian Federation and South Africa (Kowal et al., 2012). Three Waves of data are available and a fourth Wave will be conducted in 2016. The study collects a wide range of information including socio-demographic data, states of health, risk factors, mortality, and health coverage (Kowal et al., 2012).

IV *The Barbados Eye Study (BES)* – Visual health data among older adults is available in this study. Using a simple random sample, data from 4,651 Barbadian-born adults (age 40–84 years) was collected during the period 1988–1992. Participants in the study were followed up after 4 years and re-examined in the Barbados Incidence Study of Eye Diseases (1992–1997).

V *Brazilian Longitudinal Study of Adult Health (ELSA-Brasil)* – This study (n = 15,105) is focused on the risk of obesity, diabetes, and cardiovascular diseases in Brazilian adults aged 35–74 years. The study population is drawn from active and retired employees of 5 universities and 1 research institute located in different regions of Brazil: the federal universities of Bahia, Espirito Santo, Minas Gerais, and Rio Grande do Sul; the University of Sao Paulo; and the Oswaldo Cruz Foundation (Aquino et al., 2012).

13.4 What Health Survey Data Exists in LAC that Collect Information on Older Adults?

I *Argentina National Survey of Nutrition and Health (2004–05)* – This survey represents the only survey in Argentina that examined nutrition and health. 24-hour recalls were conducted and data gathered on children age 6 to 23 months, children age 2 to 5 years, women age 10 to 49, and pregnant women (Ministry of Health and Environment Argentina, 2015).

II *Barbados STEPS Survey* – Conducted in 2007, this survey examined chronic disease risk factors in adults aged 25 years and older in Barbados (n = 1282). The survey collected socio-demographic, health behaviour and health indicator (height, weight, blood pressure, glucose level, and cholesterol) data. The overall response rate was 65% (Pan American Health Organisation, 2012).

III *Barbados Food Consumption and Anthropometric Surveys (2000)* – This survey funded by the Food and Agriculture Organisation (FAO) and the Caribbean Food and Nutrition Institute (CFNI) collected health status data (diabetes, hypertension, heart disease, and cancers), BMI and other anthropometric data, food purchasing habits, lifestyle habits (exercise, food preparation) and 24-hour recall information.

IV *Mexico National Survey of Health and Nutrition (2005 – 2006)* – Designed to estimate health and nutrition conditions, access to health care, health determinants, and prevalence ratios, this survey is a fusion of other health surveys that existed prior. Both household and individual level data were collected. Data is available on diet, physical activity, and overall health. In addition, anthropometric data and blood samples were also taken (Ministry of Health and Environment Argentina, 2015).

13.5 Suggested Actions for Policymakers

In addition to the suggestions to policymakers highlighted in Chapter 12, below are some suggested actions for policymakers, researchers and other stakeholders in LAC to consider. While many of these have been suggested previously in the literature, there is a need for strong follow-up actions using a regional approach:

I Inter-sectorial Collaboration/Health in all policies initiative – Responsibility for health and nutrition in the LAC region is often confined to a single ministry – typically, the Ministry of Health. While there has been some acknowledgement that health is intrinsically linked to arguably all sectors (for example, agriculture, trade, environment), coordinated programs have not resulted. The underlying principle that needs to be incorporated is the adoption of a health in all policies initiative.

II Pooling of resources to develop and conduct longitudinal studies that aim to fill gaps in the literature – Through regional agencies such as the Caribbean Public Health Agency (CARPHA) and the Pan American Health Organisation (PAHO), coordination and communication between territories can be facilitated. Such coordination can reduce/prevent duplication of activities and ensure that resources (human and financial) are utilised to achieve maximum benefit.

III Adoption of a public policy approach with strong scientific and political commitment (Henry, 2007). This suggested action points to the need for researchers to engage in knowledge translation activities that serve to inform policy.

Chapter 14

Limitations, Strengths and Final Thoughts

14.1 Chapter Summary

In this chapter, the strengths and limitations of the thesis are presented along with final thoughts.

14.2 Introduction

This thesis employs a cross-national perspective and examines the relationship of diet and physical activity on cognitive impairment (CIm). Seven low- and middle-income countries in Latin America and the Caribbean (Argentina, Barbados, Brazil, Chile, Cuba, Mexico and Uruguay) along with Australia (a developed country) are included in analyses. The author presents a case for policymakers to focus on modifiable lifestyle factors (which include diet and physical activity) in an effort to delay onset/reduce prevalence of CIm and to depress the costs associated with treatment which can be quite a burden for individuals and governments (particularly in resource-poor settings).

14.3 Limitations

I *Age of the data in the SABE*

The SABE is a 7-country survey conducted in LAC in 2000. However, to date, it remains the only multi-country comprehensive health-related data set for persons over the age of 60 in the LAC region that takes into account cognitive status and other health indicators in older adults.

II *Utilisation of prevalence data*

While it is useful to identify new cases of disease in any population (i.e. incidence), prevalence data were used in this thesis since the SABE survey only collected data at one time point and the AusDiab only measured cognitive function at the most recent Wave of data collection (Wave 3).

III *Use of a dietary pattern and not a single nutrient approach*

A review of the literature examining the relationship between single nutrients and cognition reveals that results have largely been inconsistent. While some studies have shown that higher intake of antioxidant nutrients such as vitamin C, vitamin E, and flavonoids have been related to a lower risk for AD or slower cognitive decline, other studies have found that the risk for AD is not associated with intake of antioxidants, making it difficult for any clear conclusions to be derived. Many researchers argue that examining the relationship between dietary patterns and disease may yield more meaningful results since people do not eat single foods or nutrients but rather combinations of these. In light of the fact that this was a cross-national comparison project, it was felt that a dietary pattern approach would be useful due to expectations of greater heterogeneity in diet based on cultural, geographic, and income differences.

IV *Cognitive testing performed on only a subset of the AusDiab study sample*

An assessment of cognitive status was performed only on a subset of the study sample. An analysis of those for whom no data on cognition was collected (either because of non-selection or drop out) showed that a greater proportion were female and belonged to the low education categories. As both gender and education level are associated with cognitive status it may be that CIm prevalence is underestimated and CIFLE overestimated.

V *Results are not representative of those in institutions*

No data were collected from adults living in institutions in any of the study countries and so may not be representative of that population. In LAC, this may be less of a cause for concern as research indicates that the percentage of the population in institutions is quite small and so this bias is also likely to be small.

VI *Potential for non-response bias*

Response to the AusDiab was low and this could have influenced the results obtained. Overall though, the sample is still large and the potential for non-response bias is relatively low given that there was not great variation between responders and non-responders in the demographic variables examined.

VII *The potential for reverse causality in examining behaviours such as physical activity and dietary characteristics in relation to CIm*

Although engagement in physical activity and healthy eating have been investigated as potential factors to be targeted in order to reduce risk of CIm, it is also necessary to acknowledge that CIm is associated with lower engagement in physical activity and appetite change. This potential for reverse causality becomes particularly acute when using cross-sectional studies.

VIII *The cross-sectional treatment of diet and physical activity data in the Australian sample*

One of the main limitations of this study lies in its cross-sectional and prospective treatment of dietary and physical activity data among older adults in the AusDiab. It is acknowledged that a sample of participants had dietary and physical activity data for all three Waves but these were not analysed longitudinally in the present study as the aim was to look at associations between lifestyle factors and CIm at three distinct periods. It is highlighted in the thesis though that examining the association between change in diet and physical activity habits across all three Waves and CIm measured at Wave 3 is a study that is worth undertaking.

IX *Use of questionnaires to report diet and physical activity habits*

Although the questionnaires used in the SABE and AusDiab have been reported to have reasonable reliability and validity, the use of questionnaires may give rise to over-and-under reporting eating habits and engagement in physical activity.

X *Use of a relatively new method to calculate combined adjusted PAR which takes into account non-independence of risk factors*

Limitations of using this method have been presented in Chapters 10 and 11 of this thesis. These include use of biased adjusted relative risk estimates obtained from meta-analyses and the integrity of the method being untested. However, although the methodology is still new, it is thought to provide a more realistic estimate of PAR. As further studies are conducted using this adjusted PAR calculation, there will be the opportunity to compare results across various geographic locations and test robustness.

14.4 Strengths

Despite the limitations listed above, this thesis makes a unique contribution to the literature. Though highlighted throughout the thesis chapters, below are some of the strengths of this present research:

I *Adoption of a cross-national approach*

The novelty of this thesis is centred on its cross-national approach examining developed and low- and middle-income countries. While in the developed country of Australia health data are collected and reported on systematically, a literature search for articles and studies examining the relationship of dietary and physical activity patterns and their relationship with cognitive function in LAC indicated that this thesis is the first of its kind in the region.

In addition, the degree of control across the individual studies that comprise SABE is a testament to the quality of the data utlised in this thesis. SABE was administered in the official language of each country. The original languages were maintained during processing of the databases. In order to assist users, databases also included translations in the three official languages of the survey.

II *Publication of the first mental health expectancy study in an Australian setting using population-based data*

The salience of this thesis study is underscored by the fact that CIm is costly, and highly age-related. CIm health expectancy data can be used to develop more meaningful guidelines and policies as it relates to the cognition of older adults and can serve to identify specific age groups that merit further study. More specifically, the results from this thesis can also serve to inform the development of population health indicators – a useful marker for the health of a population.

III *First publication of mental health expectancies for a range of LAC countries*

One of the main strengths of this author's work is its production of CIm and CIm-free life expectancies for such a wide range of LAC countries. These have not been published for LAC countries prior to this and provide useful data for policymakers to assess healthy ageing trends. The results also provide a greater understanding of the burden of CIm in LAC and highlight the need for follow-up surveys to be conducted as their populations continue to age.

IV *Analysis of dietary patterns in older age groups*

This author's thesis adds to the sparse body of literature examining the relationship between dietary patterns and CIm among older adults. Further, the author's focus on older age groups whose dietary patterns have not been widely studied and reported is noteworthy.

V *Ability to answer methodological questions as it relates to dietary pattern analysis*

At present, there is no established gold-standard to analyse dietary data. Both data-driven and *a priori* methods are used by researchers. Using a data-driven method (PCA), this thesis was able to answer a methodological question that has been one of the main critiques of PCA – How do variable reduction methods before the application of PCA affect the results obtained? This question is particularly significant when examining the relationship between dietary patterns and cognition since there is a level of subjectivity involved in reducing food variables, and these can affect the associations with cognitive function observed.

VI *Utilisation of a holistic approach that includes diet and physical activity*

Throughout this thesis, both the relationship of diet and physical activity on cognition are examined. These two variables have a direct impact on each other and as such the thesis would have been one-dimensional if either of these had not been included.

VII *Estimation of population attributable risk taking into account non-independence of risk factors*

In reality, risk factors are unlikely to exert an independent effect on disease. Using a recently published formula, PARs and future dementia prevalence were calculated for Australia and three LAC countries taking into account non-independence of common modifiable lifestyle risk factors. The methodology utilised has only been reported on once in the literature and as such results from these thesis studies make a valuable contribution to the literature.

VIII *Inclusion of a focus on knowledge translation and policy*

Chapters 12 and 13 are written in lay-language and highlight the scientific evidence relating to the issue of diet and physical activity interventions to combat dementia. They end by translating this knowledge into useful policy actions that can be taken by stakeholders (identified as being both 'traditional' and 'incidental' health actors).

14.5 Final Thoughts

This author's thesis adds to the literature available on the effect of diet and physical activity on cognition in older adults. As mentioned throughout the chapters, there is a paucity of data on this topic and within this age group, particularly in low- and middle-income countries like those of Latin America and the Caribbean. However, while the results obtained have been noteworthy, they also indicate areas for future research. While these have been outlined in various thesis chapters, a few must be reiterated here.

Firstly, there is a need for more studies that seek to examine the influence of diet on cognition given that there is great inconsistency in the literature. This will assist in deepening the knowledge available and examining nuanced issues.

Some of these issues include whether the MeDi should be applied more broadly to persons in different geographic locations and cultural settings and establishing robust and replicable methods of dietary analysis for use in research into cognitive ageing.

Despite the limitations highlighted above, the author's findings are valid. Both datasets had large sample sizes and were representative of the general non-institutionalised population. One area that should be examined further is the effect of change in diet and physical activity patterns over time as this perhaps can yield more consistent results.

The data searches conducted for this thesis highlighted the disparities that exist between Australia and LAC especially as it relates to information availability. Greater emphasis needs to be placed on systematic data collection and reporting in LAC of risk factor prevalence and disease prevalence (particularly as it relates to mental health). In addition, the need for detailed food consumption surveys to be conducted in the region was also highlighted.

At the policy level, the actions needed to be taken are highlighted in Chapters 12 and 13. It is imperative that all stakeholders including 'traditional' and 'incidental' actors take ownership of health programs in order to reduce risk factor prevalence at the population level and that a 'Health in all Policies' approach be adopted and enforced.

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Appendix A

Supplementary Tables

Table A.1: Characteristics of a few studies investigating the relationship between MeDi and various health outcomes adapted from Sofi et al. (2010)

Study	Year	Country	Type	Sample size, n	Adherence Score	Outcome, n	Follow-up	Age	Results
Valls-Pedret et al.	2015	Spain	Randomised clinical trial	233	0–14	MCI (37)	4.1 years	55–80 years	MeDi supplemented with olive oil or nuts is associated with improved cognitive function.
Koyama et al.	2015	USA	Prospective study	2326	0–55	Incident dementia (207)	7.9 years	70–79years	Greater MeDi adherence may reduce rate of cognitive decline among black but not white older adults.
Ax et al.	2014	Sweden	Prospective study	1044	0–8 points (modified MeDi score)	Prostate cancer (72)	13 years	50–93years	The MeDi was not associated with prostate cancer.

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Table A.1 – Continued

Study	Year	Country	Type	Sample size, n	Adherence Score	Outcome, n	Follow-up	Age	Results
Bosiree et al.	2013	USA	Prospective study	293,453	0–9 points	Prostate cancer (23,453)	8.9 years	50–71 years	No significant association was observed between MeDi score and total prostate cancer.
Buckland et al.	2013	Denmark, France, Germany, Italy, Norway, Spain Sweden, UK	Prospective study	335,062	0–8 points (modified MeDi score)	Breast cancer (10,225)	11 years	25–70 years	Greater adherence was related to a modest reduced risk of breast cancer in postmenopausal women.
Cherbuin et al.	2012	Australia	Prospective study	1528 non-demented subjects	0–9 points	CIm(n =10 CIm; n = 19 clinical dementia; n = 37 mild cognitive disorder)	4 years	60–64 years	Greater adherence to the MeDi was not protective against CIm.

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Table A.1 – Continued

Study	Year	Country	Type	Sample size, n	Adherence Score	Outcome, n	Follow-up	Age	Results
Buckland et al.	2010	UK, France, Denmark, Sweden, Germany, Italy, Spain, Netherlands, Norway, Greece	Prospective study	485,044	18 unit relative MeDi score	Gastric adenocarcinoma (n = 449)	8.9 years	35–70years	Greater adherence to the MeDi is associated with a significant reduction in the risk of incident GC.
Scarmeas et al.	2009	United States	Prospective Study	1,880 non-demented subjects	0–9 points	MCI (n = 275)	5.4 years	76.7 years (mean)	Higher adherence to MeDi and high physical activity associated with a reduced risk of AD.

Continued on Next Page…

Table A.1 – Continued

Study	Year	Country	Type	Sample size, n	Adherence Score	Outcome, n	Follow-up	Age	Results
Feart et al	2009	France	Prospective Study	1,410 non-demented subjects	0–9 points	Cognitive performance and risk of incident dementia(n = 99)	4.1 years	68–95 years	Higher adherence associated with slower cognitive decline with the MMSE test but not with other tests. No association with a reduced risk of incident dementia.
Fung et al.	2009	United States	Prospective study	74,886; women; no CVD or diabetes	0–9 points	CHD Stroke(n =2391)	20 years	38–63 years	Greater adherence to the MeDi associated with lower risk of incident CHD and stroke in women.
Trichopoulou et al.	2009	Greece	Prospective study	28,572 subjects	0–9 points	Overall mortality (n = 275)	3.6 years	20–86 years	Risk of death decreased with higher MeDi compliance; higher MeDi compliance associated with decreased AD and MCI.

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Table A.1 – Continued

Study	Year	Country	Type	Sample size, n	Adherence Score	Outcome, n	Follow-up	Age	Results
Buckland et al.	2009	Spain	Prospective study	41,078	18 unit relative MeDi score	CHD (n = 609)	10.4 years	29–69 years	MeDi diet adherence associated with a significantly reduced CHD risk.
Martinez-Gonzalez et al.	2009	Spain	Prospective study	13,609; no CVD	0–9 points	CVD(n = 100)	4.9 years	38 years (mean)	There is an inverse association between adherence to the MeDi and the incidence of fatal and non-fatal CVD in initially healthy middle-aged adults.
Scarmeas et al.	2007	United States	Prospective Study	192 AD patients	0–9 points	Mortality in AD patients (n = 85)	4.4 years	76.7 years (mean)	Higher adherence to MeDi associated with a reduced risk of mortality in AD patients.
Scarmeas et al.	2006	United States	Prospective Study	2,258	0–9 points	Incident AD (n = 262)	4 years	76.7 years (mean)	Higher adherence to MeDi associated with a reduced risk of AD.

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Table A.1 – Continued

Study	Year	Country	Type	Sample size, n	Adherence Score	Outcome, n	Follow-up	Age	Results
Scarmeas et al.	2006	United States	Case-control nested study	194 AD patients1,790 non-demented subjects	0–9 points	AD risk	–	76.7 years (mean)	Highest tertiles of MeDi adherence associated with a reduced risk of AD either with or without coexisting stroke.

Table A.2: Characteristics of the Various Dietary Pattern Approaches adapted from Reedy et al. (2010) – Methods of Determining Dietary Pattern

Dietary Pattern Approach	Key Questions	Distinguishing Features
Index Analysis	How do individuals score on each index? How do indexes relate to cognitive outcome?	Assigns scores for the total diet based on food guidance recommendations. Ranks individuals with low scores (diets that are less favourable in many respects) versus those with high scores (diets that are more favourable in many respects). Individuals with moderate scores (diets that are favourable in some respect(s) and not in others) constitute a mix of many different exposures.
Cluster Analysis	Which people cluster together with regard to dietary intake within the defined population? What typifies each cluster's diet?	Large clusters represent behaviours shared by many, and small clusters represent very specific behaviours shared by a few individuals (outliers). Food choices common among most individuals contribute little to cluster formation. Clusters are categories where the variation of individual foods is not considered after classification.
Factor Analysis	What foods are correlated, suggesting underlying factors within diets of the population?	Factors are scales based on the correlations among many foods for which individuals have low, medium or high scores.

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Table A.2 – Continued

Dietary Pattern Approach	**Key Questions**	**Distinguishing Features**
Reduced Risk Regression	How can nutrient variations be explained by food intakes in a given population?	Uses both data obtained from the study and evidence in existence. Variation in nutrients or nutrient-related responses can be explained using linear functions of food intakes.

Table A.3: Health Benefits Associated with Regular Physical Activity (Janssen & Leblanc, 2010; Landry & Driscoll, 2012; Reiner et al., 2013; U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 2011)

Children and Adolescents
Strong Evidence
• Improved cardiorespiratory and muscular fitness
• Improved bone health
• Improved cardiovascular and metabolic health biomarkers
• Favourable body composition
Moderate Evidence
• Reduced symptoms of depression
Adults and Older Children
Strong Evidence
• Lower risk of early death
• Lower risk of coronary heart disease
• Lower risk of stroke
• Lower risk of high blood pressure
• Lower risk of adverse blood lipid profile
• Lower risk of Type 2 diabetes
• Lower risk of metabolic syndrome
• Lower risk of colon cancer
• Lower risk of breast cancer
• Prevention of weight gain
• Weight loss, particularly when combined with reduced calorie intake
• Improved cardiorespiratory and muscular fitness
• Prevention of falls
• Reduced depression
• Better cognitive function (for older adults)
Moderate to Strong Evidence
• Better functional health (for older adults)
• Reduced abdominal obesity
Moderate Evidence
• Lower risk of hip fracture

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Table A.3 – Continued

• Lower risk of lung cancer • Lower risk of endometrial cancer • Weight maintenance after weight loss • Increased bone density • Improved sleep quality

Table A.4: Global physical activity recommendations issued by the WHO (World Health Organisation, 2010)

I **Global Recommendations for Persons 5–17 Years Old**

(a) Children and young people aged 5–17 years old should accumulate at least 60 minutes of moderate- to vigorous-intensity physical activity daily.
(b) Physical activity of amounts greater than 60 minutes daily will provide additional health benefits.
(c) Most of daily physical activity should be aerobic. Vigorous-intensity activities should be incorporated, including those that strengthen muscle and bone, at least 3 times per week.

II **Global Recommendations for Persons 18–64 Years Old**

(a) Adults aged 18–64 years should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity.
(b) Aerobic activity should be performed in bouts of at least 10 minutes duration.
(c) For additional health benefits, adults should increase their moderate-intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous-intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity.
(d) Muscle-strengthening activities should be done involving major muscle groups on 2 or more days a week.

III **Global Recommendations for Persons 65 Years of Age and Older**

(a) Adults aged 65 years and above should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity.
(b) Aerobic activity should be performed in bouts of at least 10 minutes duration.
(c) For additional health benefits, adults aged 65 years and above should increase their moderate intensity aerobic physical activity to 300 minutes per week, or engage in 150 minutes of vigorous intensity aerobic physical activity per week, or an equivalent combination of moderate- and vigorous-intensity activity.
(d) Adults of this age group with poor mobility should perform physical activity to enhance balance and prevent falls on 3 or more days per week.
(e) Muscle-strengthening activities should be done involving major muscle groups, on 2 or more days a week.
(f) When adults of this age group cannot do the recommended amounts of physical activity due to health conditions, they should be as physically active as their abilities and conditions allow.

Table A.5: Food Groupings used in Dietary Pattern Analysis

	Method 1	**Method 2**	**Method 3**
Number	**Food Item**	**Food Category**	**Food Category**
1	Bacon	Processed Meats	Meat
2	Ham	Processed Meats	Meat
3	Salami	Processed Meats	Meat
4	Sausages	Processed Meats	Meat
5	Beef	Red Meats	Meat
6	Pork	Red Meats	Meat
7	Lamb	Red Meats	Meat
8	Veal	Red Meats	Meat
9	Hamburger	Red Meats	Meat
10	Fish	Fish	Fish
11	Fried fish	Fish	Fish
12	Tinned fish	Fish	Fish
13	Chicken	Poultry	Poultry
14	Eggs	Eggs	Eggs
15	Butter	Butter	Fats and Oils
16	Margarine	Margarine	Fats and Oils
17	Polyunsaturated margarine	Margarine	Fats and Oils
18	Monounsaturated margarine	Margarine	Fats and Oils
19	Butter and margarine blends	Butter and Margarine Blends	Fats and Oils
20	Reduced-fat milk	Low-fat Dairy Products	Dairy
21	Skim milk	Low-fat Dairy Products	Dairy
22	Low-fat cheese	Low-fat Dairy Products	Dairy
23	Yoghurt	Low-fat Dairy Products	Dairy
24	Full-cream milk	High-fat Dairy Products	Dairy
25	Hard cheese	High-fat Dairy Products	Dairy
26	Firm cheese	High-fat Dairy Products	Dairy
27	Soft cheese	High-fat Dairy Products	Dairy
28	Ricotta or cottage cheese	High-fat Dairy Products	Dairy

Continued on Next Page…

Table A.5 – Continued

	Method 1	**Method 2**	**Method 3**
29	Cream cheese	High-fat Dairy Products	Dairy
30	Ice-cream	High-fat Dairy Products	Dairy
31	Flavoured-milk drink	High-fat Dairy Products	Dairy
32	Red wine	Wine	Alcohol
33	White wine	Wine	Alcohol
34	Fortified wines	Wine	Alcohol
35	Light Beer	Beer	Alcohol
36	Heavy beer	Beer	Alcohol
37	Other spirits	Other Spirits	Alcohol
38	Tinned fruit	Fruit	Fruit
39	Oranges	Fruit	Fruit
40	Apples	Fruit	Fruit
41	Pears	Fruit	Fruit
42	Bananas	Fruit	Fruit
43	Melon	Fruit	Fruit
44	Pineapple	Fruit	Fruit
45	Strawberries	Fruit	Fruit
46	Apricots	Fruit	Fruit
47	Peaches	Fruit	Fruit
48	Mango	Fruit	Fruit
49	Fruit Juice	Fruit Juice	Fruit Juice
50	Cabbage	Cruciferous Vegetables	Vegetables
51	Cauliflower	Cruciferous Vegetables	Vegetables
52	Broccoli	Cruciferous Vegetables	Vegetables
53	Carrot	Dark-yellow Vegetables	Vegetables
54	Pumpkin	Dark-yellow Vegetables	Vegetables
55	Tomatoes	Tomatoes	Vegetables
56	Tomato sauce	Tomatoes	Vegetables
57	Lettuce	Green, leafy Vegetables	Vegetables
58	Spinach	Green, leafy Vegetables	Vegetables
59	Peas	Legumes	Vegetables
60	Green beans	Legumes	Vegetables
61	Bean sprouts	Legumes	Vegetables

Continued on Next Page…

Table A.5 – Continued

	Method 1	**Method 2**	**Method 3**
62	Baked beans	Legumes	Vegetables
63	Tofu	Legumes	Vegetables
64	Other beans	Legumes	Vegetables
65	Soya milk	Legumes	Vegetables
66	Cucumber	Other Vegetables	Vegetables
67	Celery	Other Vegetables	Vegetables
68	Beetroot	Other Vegetables	Vegetables
69	Mushrooms	Other Vegetables	Vegetables
70	Zucchini	Other Vegetables	Vegetables
71	Capsicum	Other Vegetables	Vegetables
72	Avocado	Other Vegetables	Vegetables
73	Onion	Garlic and Onions	Vegetables
74	Garlic	Garlic and Onions	Vegetables
75	Potatoes	Potatoes	Vegetables
76	Chips	Chips/French fries	Chips/French Fries
77	All-bran	Whole Grains	Whole Grains
78	Branflakes	Whole Grains	Whole Grains
79	Weetbix	Whole Grains	Whole Grains
80	Cornflakes	Whole Grains	Whole Grains
81	Porridge	Whole Grains	Whole Grains
82	Muesli	Whole Grains	Whole Grains
83	Wholemeal bread	Whole Grains	Whole Grains
84	Rye bread	Whole Grains	Whole Grains
85	Multi-grain bread	Whole Grains	Whole Grains
86	High-fibre white bread	Refined Grains	Refined Grains
87	White bread	Refined Grains	Refined Grains
88	Rice	Refined Grains	Refined Grains
89	Pasta	Refined Grains	Refined Grains
90	Crackers	Refined Grains	Refined Grains
91	Pizza	Pizza	Pizza
92	Sweet biscuits	Snacks	Snacks
93	Cakes	Snacks	Snacks
94	Crisps	Snacks	Snacks
95	Chocolate	Snacks	Snacks
96	Nuts	Nuts	Nuts
97	Peanut butter	Nuts	Nuts
98	Jam	Condiments	Condiments
99	Vegemite	Condiments	Condiments
100	Sugar	Sugar	Sugar
101	Meat pies	Meat Pies	Meat Pies

Appendix B

Thesis Publications in Published Format

I Ashby-Mitchell, K. (2015). The road to reducing dementia onset and prevalence – Are diet and physical activity interventions worth investing in? *Deeble Institute issues brief No 10/2015.* Deeble Institute for Health Policy Research, Canberra.

II Ashby-Mitchell, K., Jagger, C., Fouweather, T., & Anstey, K. J. (2015). Life Expectancy with and without Cognitive Impairment in Seven Latin American and Caribbean Countries. *PLoS ONE, 10*(3), e0121867. doi:10.1371/journal.pone.0121867

III Ashby-Mitchell, K., Peeters, A., & Anstey, K. J. (2015). Role of Dietary Pattern Analysis in Determining Cognitive Status in Elderly Australian Adults. *Nutrients*, *7*(2), 1052-1067. doi:10.3390/nu7021052.

IV Ashby-Mitchell, K., Magliano, D., Shaw, J., and Anstey, K.J. (2014) Life Expectancy in Australian Seniors with or without Cognitive Impairment: The Australia Diabetes, Obesity and Lifestyle Study Wave 3. *Journal Gerontology and Geriatric Research*, 3:166. doi: 10.4172/2167-7182.1000166.

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The Road to Reducing Dementia Onset and Prevalence - Are diet and physical activity interventions worth investing in?

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HESTA is proud to have sponsored this Deeble Scholar.

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Table of Contents

Executive summary

In Australia, deaths as a result of dementia have now taken over cerebrovascular disease as the second leading cause of death. At present, over a quarter million Australians suffer from dementia and projected estimates indicate that the figure can reach a high of nearly one million by 2050.

Diet and physical activity have been shown to promote brain health and offer some protection against cognitive decline. Moreover, they have also been recognised as risk factors for developing other conditions such as cardiovascular disease, diabetes, hypertensive diseases and certain cancers all of which are leading causes of death in Australia.

Research shows that higher ratios of saturated fat to monounsaturated fats are predictive of negative mental function. In addition, high mid-life serum cholesterol levels and excessive caloric intake have been found to be associated with impaired cognitive function. Increased intakes of fish, vegetables and legumes, antioxidant rich foods and adequate amounts of certain B-vitamins have been reported to have a protective brain effect.

Increased levels of physical activity have been found to promote neuro-protective changes in the hippocampus of the brain – a region central to learning and memory. This brain region is one of the first areas affected by dementia. Most studies have demonstrated that a high level of physical activity in adults with no dementia is associated with a 30% to 50% reduction in the risk of cognitive decline and dementia. Some studies have also theorised that poor physical function may precede the onset of dementia and Alzheimer's disease and higher levels of physical function may be associated with delayed onset. Results from the Australian Bureau of Statistics National Health Survey (2011 – 2013) show that many Australian adults do not meet the National Physical Activity Guidelines (to do at least 30 minutes of moderate intensity physical activity on most days) as more than half the population is inactive. Further, two-thirds of Australians are now overweight/obese and a large proportion of total energy consumed comes from foods considered to be of little nutritional value. An intervention that focuses on improving diet and physical activity habits therefore has the ability to produce inestimable benefits.

There are many factors that must be considered when developing a successful diet and physical activity intervention. These span a gamut of issues from carefully defining the target audience, utilising a multidisciplinary approach, tailoring content and materials, determining forms of delivery and identifying specific behaviour change techniques to determining financial costs in relation to health benefits and training staff. The success of any intervention also relies on the setting and method that will be employed in its implementation.

Policy-makers must be cognizant of the fact that no singular government intervention/policy, operating on its own, can have the effect of directly reducing dementia onset/prevalence and changing lifestyle habits. Six actions for policy-makers are identified in this issues brief which have the potential to have immeasurable benefits: i) development of a comprehensive dementia prevention strategy, ii) establishment of a body whose aim is to keep track of scientific research (central to this will be the establishment of a national digital dementia research repository), iii) ensuring a multisectoral approach is adopted in the fight against dementia that includes both 'traditional' and 'incidental' health agencies, iv) continued investment into research and innovation, v) identifying incentives beyond the health domain and vi) development of longevity literacy programs. These actions all have as their foundation the Health in all Policies Initiative and social determinants of health approach.

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1 Introduction

1.1 What is the problem?

Dementia is a collective term for a number of disorders that cause decline in a person's memory, judgement or language that affects everyday functioning (1). As dementia progresses, forgetfulness and confusion grow and in the most advanced stage, dementia patients become unable to care for themselves. Dementia therefore can range from mild to severe. Persons with mild cognitive impairment for example, may develop difficulty multi-tasking and short-term memory losses but are able to perform usual daily tasks with little difficulty and may remain stable without further decline in cognitive abilities for years. More severe cases however may develop short and long term memory loss, personality and behavioural changes, delusions and difficulty coordinating movement leading to an inability to function independently.

In Australia, deaths as a result of dementia have now taken over cerebrovascular diseases as the second leading causes of death (2). Without new ways to delay dementia risk and incidence, dementia will quickly outrank heart disease as the leading cause of death in Australia and government spending on the condition will potentially reach $4.5 billion by 2030 (3). At present, over a quarter million Australians suffer from dementia and projected estimates indicate that the figure can reach a high of nearly one million by 2050 (4).

There has been considerable investment in scientific research in the fight against dementia by both governments and non-governmental organisations alike and undoubtedly much more is needed. Scientific studies however take time and it is in our best interest to develop interim intervention strategies using the best evidence presently available for reducing dementia risk, delaying onset of disease and reducing prevalence until more conclusive findings are available.

In a study commissioned by Alzheimer's Australia, it was reported that any intervention that could delay the onset of dementia by 2 years has the potential to reduce the number of people developing dementia by 13% while delaying onset by 5 years could reduce that number by up to 35% (5). We know that dementia may be delayed or prevented by targeting modifiable lifestyle factors (6, 7). Diet and physical activity are two such factors that have been shown to promote brain health and offer some protection against cognitive decline. Moreover, diet and physical activity have also been recognised as risk factors for developing other conditions such as cardiovascular disease, diabetes, hypertensive diseases and certain cancers all of which are leading causes of death in Australia (8). Investment in diet and physical activity interventions should be strongly considered in preventing and slowing the progress of dementia as these have the potential to reap other health and wellbeing benefits as well.

1.2 Why is this relevant to policymakers?

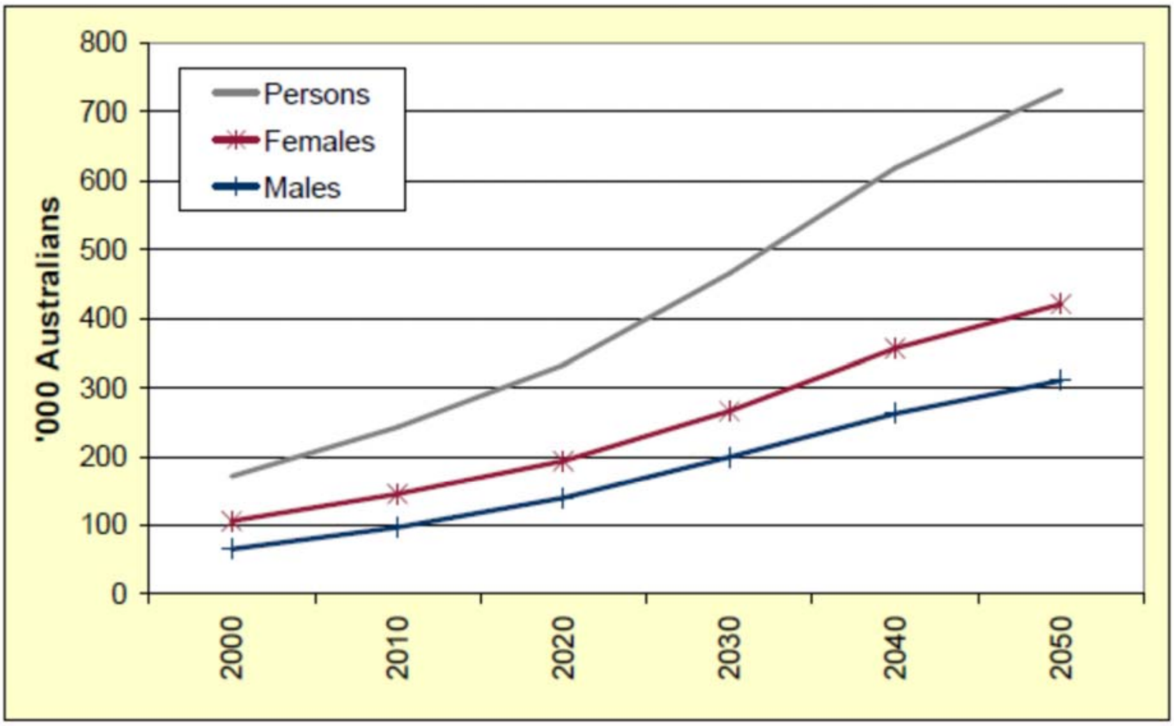
The recently released 2015 Intergenerational Report highlights the demographic changes that Australia is expected to undergo over the next 40 years (9). These demographic changes have serious health and social expenditure implications. Age is presently the strongest known predictor of dementia and these projected figures seem to highlight that a dementia epidemic may lie ahead. Australians will continue to record long life expectancies and by 2054 males are expected to live an estimated 95.1 years and females 96.6 years (9). The structure of Australia's population will also continue to change with a greater proportion of the population aged 65 and over (9). Further, the number of Australians in this age group is projected to more than double by 2054-55 compared to 2015 population estimates. Increases in both the number and proportion of Australians aged 85 and over are also expected accounting for a projected 4.9 per cent of the population, or nearly 2 million Australians (9). Research suggests that dementia prevalence is highest in the 85-89 age group due to the relatively large number of people within the age bracket and that this will continue to be the trend (10). Figures 1 and 2 below show dementia prevalence projections for Australia:

Figure 1: Total Australian dementia prevalence projections, by age (2005 – 2050)

Age Group	**2005** ('000)	**2010** ('000)	**2020** ('000)	**2030** ('000)	**2040** ('000)	**2050** ('000)
0-59	1.67	1.70	1.74	1.76	1.77	1.76
60-64	8.32	10.76	12.48	13.08	13.14	14.32
65-69	11.28	13.45	18.70	21.76	22.67	23.27
70-74	21.18	24.52	38.54	45.45	47.91	48.33
75-79	33.30	33.43	47.48	67.58	79.47	83.62
80-84	49.07	54.31	66.13	107.35	129.13	138.39
85-89	41.52	55.35	65.30	97.73	142.80	171.96
90-94	28.10	33.73	54.21	70.98	120.28	150.66
95+	10.41	15.25	28.36	39.76	61.92	98.71
% of Population	**1.01**	**1.14**	**1.44**	**1.88**	**2.40**	**2.77**

Source: Access Economics. 2005. Dementia Estimates and Projections: Australian States and Territories. (11)

Figure 2: Projected increases in dementia cases, elderly population and total population for Australia, 2000 - 2050



Source: Access Economics. 2007. Dementia Estimates and Projections: Queensland and its Regions. (12)

The challenges presented by increased dementia prevalence have continued to capture the attention of both governments and other stakeholders[1]. Earlier this year, the Australian Government announced a $46 million commitment to provide joint fellowships supporting early-career researchers in the field of dementia research. The National Health and Medical Research Council (NHMRC) and the Australian Research Council (ARC) have worked jointly on ensuring the newly-supported research takes into account the social, economic, cultural and complex consequences of dementia (13). Prior to this, in 2014, the Australian Government announced its' plan to boost innovation and research in relation to dementia by providing an additional $200 million over five years. In 2012, Australian health ministers recognised dementia as the ninth National Health Priority Area, and the Australian Government announced its intention to reform aged care[2]. Other government initiatives since then have included the formation of the Dementia Collaborative Research Centres (DCRC) and development of other

[1] Stakeholders involved in the development and implementation of health intervention and policy are varied. Some examples of these stakeholders are departments of trade, transport, health, finance, human rights along with non-state actors and humanitarian agencies.

[2] The reformation of aged care is a relevant issue for the care of dementia sufferers in aged-care facilities and hospitals but is beyond the scope of this issues brief.

strategic grants aimed to support dementia-related research that could inform policy. Most recently, the Australian government announced its investment of $54.5 million over a four year period in response to the Dementia Forum Options Report produced in late 2014. These funds will be used to establish Severe Behaviour Response Teams – a mobile workforce of clinicians providing expert advice to residential aged care providers.

Despite the fact that innumerable reports and studies have been published on government expenditure on dementia and the need for provision of services for people with dementia and their carers and the urgent need for interventions to reduce risk and delay onset (3, 14, 15), these have not resulted in a comprehensive dementia prevention strategy. As such, while the government actions presented above are promising, more must be done to address the root causes of the disease and to develop supportive environments that help individuals take ownership of their health. For example, longevity literacy is one initiative that ought to be undertaken by the Australian government in order to promote greater accountability for health at an individual level. With increased life expectancy, there is a need for individuals to understand that they may be living far longer than they expect and that as a result of pressures on state resources may be increasingly called upon to be more responsible and accountable for their own health and wellbeing.

1.3 Aims

The aims of this issues brief are as follows:

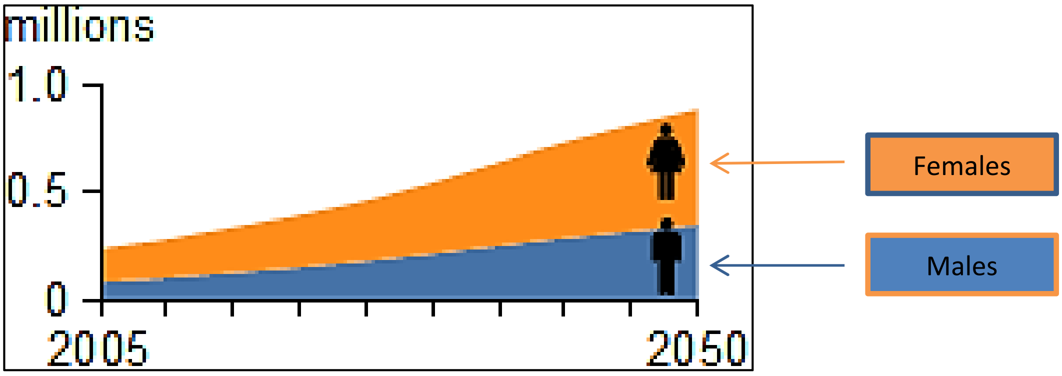
1. To examine published studies and reports in order to make inferences about the effectiveness of diet and physical activity interventions aimed to reduce dementia onset and prevalence.
2. To present a case for greater investment in diet and physical activity interventions to reduce dementia onset and prevalence.
3. To provide some suggestions to policymakers on the way forward.

2 What does the research tell us?

2.1 Number of people affected and future projections

In 2013, an estimated 322,000 Australians had dementia and it was predicted that this figure would reach almost 400,000 by 2020 and just fewer than 1 million by 2050 – See Figure 3 below (16). In addition, one in 10 Australians aged 65 and over had dementia in 2011 compared to 3 in 10 Australians aged 85 and over (16). Each week, there are 1,700 new cases of dementia in Australia; approximately one person every 6 minutes (17). This is expected to grow to 7,400 new cases each week by 2050 (17).

Figure 3: Estimated Dementia Projection to 2050



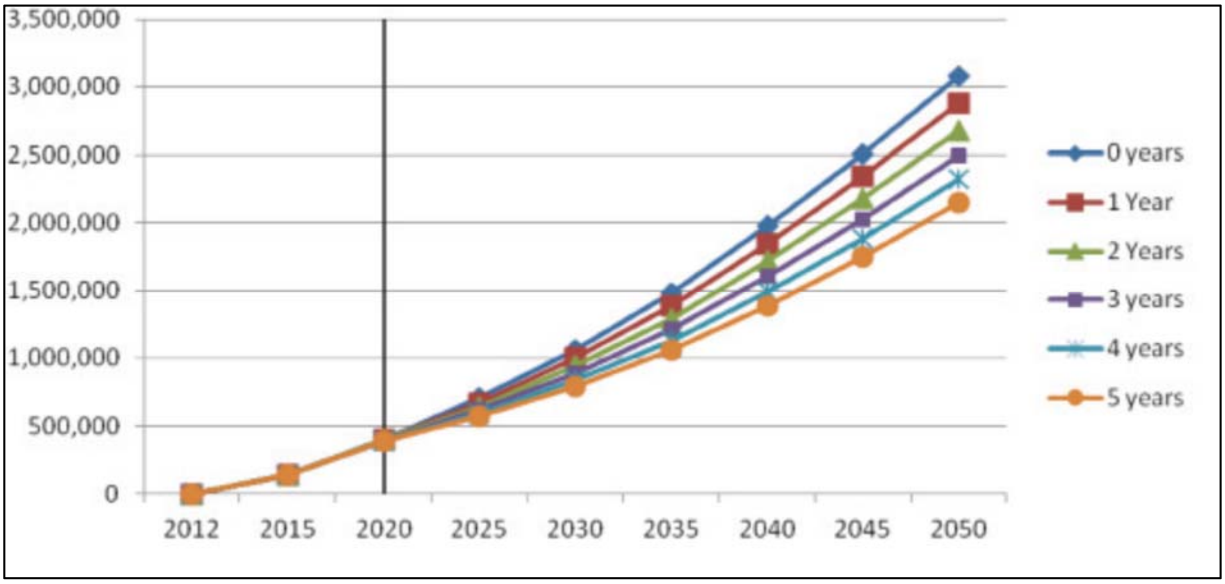
Source: Australian Institute of Health and Welfare. 2015. About Dementia. Available from www.aihw.gov.au/dementia/. (18)

2.2 The effect of delaying onset of dementia

Reducing the prevalence or delaying the onset of dementia is crucial to the fight to reduce the impact of the disease, both financially and on individuals (19). Delaying dementia onset lessens the average number of years spent living with the disease (20). Those living with dementia for longer periods tend to require considerably more health services per annum than newly diagnosed individuals and this has substantial public health resource allocation implications (20). Even delaying the onset by 5 years is predicted, in time, to halve the number of people with dementia and have significant economic and societal effects (21).

In a report for Alzheimer's Australia, the potential impact of possible interventions to delay the onset of dementia on future prevalence of the condition was demonstrated (5). Specifically, the report estimated that any intervention that could delay the onset of dementia by 2 years, introduced in 2020, would reduce the cumulative number of people developing dementia between 2012 and 2050 by 13%, or 398,000 people (5). Further, any intervention that would delay the onset of dementia by 5 years would reduce the cumulative number of people developing dementia for the same period to 925,000 people i.e. a 30% reduction (5). Figure 4 below shows the possible effect of intervention strategies:

Figure 4: Changes in new cases of dementia due to the implementation of an intervention starting in 2020 resulting in various lengths of onset delay



Source: Vickland et al. 2012. Modelling the Impact of Interventions to Delay the Onset of Dementia in Australia – A Report for Alzheimer's Australia. (5)

These projections are comparable to other Australian studies that have modelled the impact of delaying onset on future prevalence numbers. For example, in a report produced by Access Economics it was estimated that a 5-year delay in Alzheimer's disease[3] (the most common form of dementia) onset from 2005 would decrease prevalence by 48.5% in 2040 (20) while Jorm and colleagues estimated that delaying onset of dementia by 5 years from 2000 would decrease prevalence by 44% in 2050 (22); and Vickland et al (2012) estimated that delaying onset of dementia by 5 years between 2010 and 2040 would decrease prevalence by 37% in 2040 (5).

2.3 Evidence in support of modifiable lifestyle changes

According to Alzheimer's Australia:

> "…current research indicates that the onset of dementia may be delayed or prevented by changes to health and lifestyle choices. Some of these preventive factors include having a healthy diet, promoting physical and cognitive activity , and controlling cardiovascular risk factors, including diabetes, high cholesterol, and hypertension (19)".

These health and lifestyle choices referred to are also known as modifiable risk factors and can be can be divided into three categories: brain risk factors, body risk factors and heart risk factors (23):

[3] Alzheimer's disease – The most common form of dementia.

2.3.1 Brain risk factors (mental and social activity)

Several large longitudinal studies have found that increased levels of leisure and mental activity in late life is associated with an approximate 50% lower incidence of dementia (24).

i. Mental Activities - The beneficial effect of stimulating mental activities has been centred on the theory of brain reserve i.e. the possibility that the activity provides a reserve that delays the onset of the clinical manifestations of dementia. Increased engagement in mentally challenging activities has been shown to improve cognitive function, reduce cognitive decline and reduce risk of dementia (25, 26). Such activities include those that exercise the brain and build cognitive reserve - they should be complex, involve learning new things and be done frequently (26). Reading, doing puzzles, sudoku, playing musical instruments, doing art and participating in leisure activities such as sports, hobbies, dancing and gardening have all been shown to confer benefit by building cognitive reserve (26).

ii. Leisure Activities - Some studies have also examined the association of leisure-activities i.e. activities that are not categorised as planned exercise for a health purpose, and incident dementia/Alzheimer's disease. Evidence shows that individuals participating at least twice a week in a leisure time physical activity have 50% lower odds of dementia compared with sedentary persons (27) and that engagement in leisure activities may reduce the risk of incident dementia, possibly by providing a reserve that delays the onset of clinical manifestations of the disease (25). An area requiring further study that has been suggested is the clarification of whether increased participation in leisure activities lowers the risk of developing dementia directly or if this observed relationship is the result of declined participation in leisure activities during the preclinical phase of disease (28).

2.3.2 Body risk factors (diet, physical activity, alcohol intake)

Evidence suggests that a healthy diet, regular engagement in physical activity and moderate consumption of alcohol are associated with better cognitive outcome[4].

2.3.2.1 Diet

Both single nutrients and dietary patterns have been studied in relation to cognitive health but due to the complex interplay of nutrients, such studies have yielded mixed findings. Evidence pertaining to some key food and nutrient components is presented below:

i. Dietary Lipids – Studies suggest that higher ratios of saturated fat to mono and polyunsaturated fats are predictive of negative cognitive outcomes. It is this

[4] Cognitive outcome is of or relating to mental/brain function.

evidence that has led to increased focus on the Mediterranean diet which is traditionally rich in olive oil (a good source of monounsaturated fat).

ii. Cholesterol - There is evidence that elevated mid-life serum cholesterol levels are associated with increased risk of Alzheimer's disease in old age (29).

iii. B vitamins – Deficiencies of some micronutrients (especially B1, B2, B6 and B12) commonly described in older ages have been found to be significantly associated with cognitive impairment (30). A meta-analysis[5] conducted in 2013 using 5 eligible cohort studies examining effects of B vitamins or folate on prevention of Alzheimer's disease showed that low baseline serum folate levels was associated with increased risk of Alzheimer's disease (31).

iv. Antioxidants – Research suggests that oxidative stress and inflammation can lead to Alzheimer's disease because of an increase in free radicals and the damage they cause to neuronal cells. Antioxidant nutrients (vitamin C, vitamin E, carotenoids, flavonoids), found in many fruits and berries are thought to be the key mediators in this mechanism since they can hinder the effects of dangerous free radicals (32).

v. Fish – The fatty acids found in fish are thought to be linked to cognitive function through atherosclerosis, thrombosis or inflammation via an effect on brain development and membrane functioning or via accumulation of β-amyloid (33). Regular consumption of fish (a good source of DHA and Omega-3 polyunsaturated fatty acids) has been shown to lower the risk of dementia by up to 37% (34).

vi. Vegetables and Legumes – Diets rich in vegetables and legumes have been associated with better cognitive outcome in the literature with studies showing that always eating vegetables and always consuming legumes is inversely associated with cognitive decline and risk of developing Alzheimer's disease (33, 35).

vii. Caloric Intake – In a recent Australian prospective study[6] it was reported that energy intake was associated with greater risk of cognitive impairment with the effect being even more potent for a measure of excessive caloric intake (36). However, because the long-term effect of caloric restriction in older age groups is unknown, this management route is not usually recommended (37).

viii. Mediterranean Diet (MeDi) - The Mediterranean diet has been widely reported to be associated with a number of favourable health outcomes including reduced risk of cognitive impairment, cancers and cardiovascular disease and increased life expectancy (30, 38-41). Figure 5 below highlights the basic components of the Mediterranean diet.

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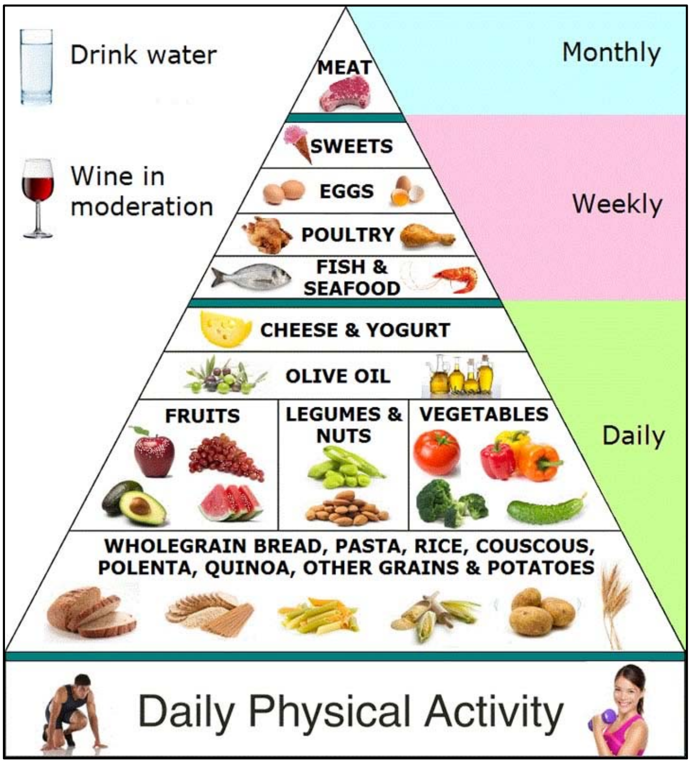
[5] Meta-analysis is a statistical technique for combining the findings from independent studies.

[6] A prospective study watches for outcomes, such as the development of a disease, during the study period and relates this to other factors such as suspected risk or protection factor(s).

Figure 5: Basic Components of the Mediterranean Diet



Source: http://www.diet-blog.com/13/mediterranean-diet-wins-again.php. (42)

2.3.2.2 Physical Activity

Physical activity has been shown to promote functional neuro-protective changes in the hippocampus of the brain- a region central to learning and memory (43). This brain region has been found to be one of the first areas affected by dementia. A brief summary of the results of studies related to physical activity and dementia/mental function is shown below:

i. Physical Activity and Incident Dementia/Alzheimer's disease - Most studies have demonstrated that high levels of physical activity in older adults with no dementia is associated with a 30 to 50% reduction in the risk of cognitive decline and dementia (44). Some studies have theorised that poor physical function may precede the onset of dementia and Alzheimer's disease and higher levels of physical function may be associated with a delayed onset (45). The results as it relates to physical activity and incident dementia/Alzheimer's disease are convincing as they have been conducted in a variety of ethnic settings with reports being similar.

ii. Physical Activity and Improving Functional Status - Function and cognition influence each other (45). Mobility is one aspect of physical function that is typically compromised as Alzheimer's disease symptoms progress due to white matter changes of the brain associated with hippocampal atrophy (45). Links between physical activity and improved walking speeds in Alzheimer's disease sufferers have been highlighted in the literature and have been linked to the fact that dementia targets those walking parameters that seem to be predictive indicators of falls (shortened stride length, slowing down and increased double limb support time) (46). A meta-analysis conducted in 2008 that included 21 exercise trials with cognitively impaired individuals and 20 exercise trials with cognitively intact individuals revealed that those with impaired cognitive function who participated in exercise rehabilitation programs had similar strength and endurance training outcomes as age and gender matched cognitively intact older participants (47). This suggests that individuals with dementia and other forms of cognitive impairment should take part in exercise rehabilitation programs (47).

iii. Physical Activity in Cognitive Impairment Therapy - A Cochrane Review[7] conducted in 2008 highlighted that there is insufficient evidence to be able to say whether or not physical activity programs are beneficial for people with dementia especially since there has been no inclusion of secondary outcomes relating to family caregiver outcomes and use of health services provided in any study (44).

iv. Physical Activity in those with Normal Cognitive Function - A recent Cochrane Review conducted analysing 11 randomised controlled trials with participants older than 55 years of age was able to conclude that there is evidence that aerobic physical activities are beneficial for cognitive function in older adults. Further studies are required to determine whether the cognitive benefits noted were a result of improvements in cardiovascular fitness (48).

2.3.2.3 Alcohol Intake

In a meta-analysis of 15 prospective studies results suggested that light to moderate alcohol consumption in older adults is associated with reduced risk of dementia (49). This seeming "J" or "U" shaped relationship has been highlighted in other case-control studies (50). Associations between "former drinkers" and risk of cognitive impairment remains unclear in the literature though since it is possible that they may have stopped drinking for reasons such as health issues that also predispose to cognitive impairment (51).

2.3.3 Heart Risk Factors (blood pressure, body mass index, cholesterol, diabetes, smoking)

i. Blood pressure – Vascular risk factors have long been known to be involved in the development of both Alzheimer's disease and vascular dementia.

[7] Cochrane Reviews are regarded as the highest standard in evidence-based health care. In a Cochrane Review, all high quality research evidence relevant to a specific research question are identified, synthesised and interpreted in order to draw conclusions.

Hypertension in midlife is thought to be a significant risk factor for the later development of both Alzheimer's disease and vascular dementia. Hypotension in later life appears to be associated with the development of Alzheimer's disease in particular (52).

ii. Body Mass Index – In a meta-analysis of 16 studies it was reported that in midlife, underweight body mass index, overweight body mass index and obese body mass index were all associated with increased risk of dementia compared with normal body mass index (53). They suggest a U-shaped relationship between midlife body mass index and dementia risk.

iii. Cholesterol – There is evidence that elevated mid-life serum cholesterol levels are associated with increased risk of Alzheimer's disease in old age (29). Studies have focused on the most important genetic risk factor for Alzheimer's disease, APOE-e4 allele, the protein product of which is the principal cholesterol transport in the brain (29).

iv. Diabetes – Research shows a clear link between dementia and type 2 diabetes. Dementia occurs more frequently in people with type 2 diabetes than in the general population - a review of relevant studies found that diabetes was associated with a 47% increased risk of any dementia, a 39% increased risk of Alzheimer's disease, and a 138% increased risk of vascular dementia (54). Impaired insulin secretion, insulin resistance and glucose intolerance are also associated with an increased risk of dementia (54). While there may be many contributing factors to this increased risk, vascular disease has consistently been implicated as having a possible causal effect.

v. Smoking – In a meta-analysis of 19 prospective studies with at least 12 months follow-up, when compared with people who had never smoked, current smokers had an increased risk of dementia and cognitive decline ranging from 40% to 80% depending on the outcome examined (55).

Preservation of cognitive abilities is central to the maintenance of independence and quality of life among older adults (56). The evidence presented above highlights that the brain needs to be stimulated and provided with nutrients to build and maintain its structure and to be protected from cognitive decline. Diets low in saturated fat, high in legumes, fruits and vegetables, moderate in ethanol intake and low in meat and dairy have been highlighted as having a protective effect against the development of dementia. While traditionally, the single nutrient approach has been used to examine the relationship between diet and disease, many researchers now support the examination of dietary patterns such as the Mediterranean diet as the dynamic interplay of food items makes the implication of a single nutrient almost impossible (41). Studies suggest that adults who engage in physical activity have a reduced risk of cognitive decline and dementia and have a higher functional status due to improved strength, endurance and balance. Overall though, further research is needed to examine whether other dietary patterns exist that can prevent/delay dementia onset and also to conclusively state whether physical activity is beneficial to persons who already have dementia.

3 Why highlight diet and physical activity interventions?

From the evidence presented above, diet and physical activity have been shown to have an effect on cognitive status. In addition, unhealthy diets and physical inactivity have been shown to be key risk factors for diseases such as Type 2 diabetes and metabolic syndrome, some cancers (colon, breast, endometrial and lung cancer) and cardiovascular diseases (57, 58) which are known to be leading causes of death in Australia (8). A balanced diet and regular physical activity have also been found to strengthen bones and muscles, improve mental health and mood and improve ability to do daily activities and prevent falls (58).

Results from the Australian Bureau of Statistics National Health Survey (2011-2013) show that most Australian adults do not meet the National Physical Activity Guidelines (to do at least 30 minutes of moderate intensity physical activity on most days) as more than half the Australian population is inactive (59). Levels of physical activity were also shown to decline with age. Survey data showed that persons 75 years and over recorded the highest levels of inactivity (approximately 20 minutes per day) when compared with other age groups (60). Sedentary activities occupied an average of 39 hours per week for adults with much of this time spent watching television and using the computer for non-work purposes (60).

Findings from the diet section of the survey showed that nearly two-thirds (63%) of the Australian population are now classified as overweight or obese (61). A closer investigation of dietary habits revealed that over 33% of total energy consumed was from foods considered to be of little nutritional value i.e. high in saturated fats, sugars, salt and/or alcohol (62). Alcoholic beverages (4.8% of energy), cakes, muffins scones and cake-type desserts (3.4%), confectionery and cereal/nut/fruit/seed bars (2.8%), pastries (2.6%), sweet biscuits and savoury biscuits (2.5%) and soft drinks and flavoured mineral waters (1.9%) were found to be the main culprits (62). In addition, over 2.3 million Australians aged 15 years and over reported that they were on a diet to lose weight or for some other health reason in 2011-12 (62). Dieting was most prevalent in the 51-70 age group where 19% of females and 15% of males were on some kind of diet (62).

World Health Assembly Resolution WHA55.23 (page 2) provides an important substratum for action as it urges Member States to, "… promote health and reduce the common risks of chronic non-communicable diseases that stem from poor diet and physical inactivity by essential public health action and integration of preventive measures in the functions of health services" (63).

Promoting healthy ageing and the maintenance of physical and mental function in older age are undoubtedly major challenges (64). Dementia prevalence has the potential to reach epidemic proportions if there is no risk reduction at the population-level (65, 66). As dementia has no cure there is a need for effective treatment approaches. In light of the evidence that highlights the possible beneficial effects of diet and physical activity on brain function, interventions that focus on these should be encouraged as even a modest protective result can result in significant public health impact.

4 What works?

A successful diet and physical activity intervention is one that encourages and results in significant and sustainable behaviour changes (67). In a study aimed to provide a broad list of good practice characteristics in interventions and policies targeting healthy diet and physical activity, it was suggested that researchers, practitioners and policy makers should account for 53 key characteristics. These are categorised into three main domains and should be carefully considered when planning, developing and reporting interventions promoting healthy eating and physical activity (67). A brief snapshot of some of the items included in each domain is presented below. For the full list of good practice characteristics in interventions see Appendix 1.

i. Main intervention characteristics – A list of 18 items that ought to be considered are presented. These include the identification of a well-defined target audience/group, well defined target behaviours and identification of the forms of delivery that will be employed.
ii. Monitoring and evaluation – Items that ought to be considered within this domain include costs in relation to target outcomes, evaluation of risks, sustainability of the intervention and determination of whether the effects are generaliseable.
iii. Implementation – Included here are attrition rate considerations, specification of resources and stakeholder support (feasibility and acceptability).

In addition to taking into consideration the characteristics mentioned above, it is also critical to consider which interventions will be most successful within a given target group. The World Health Organisation publication 'Interventions on Diet and Physical Activity – What Works' (2009), is a useful resource for researchers and policymakers to determine the effects of various types of diet and physical activity interventions across various age-groups and settings (68). As it relates to older adults, research shows that group physical activity programmes have reported improvements in psychosocial outcomes with evidence indicating that such programmes must be easily accessible. Greater accessibility can be accomplished by conducting the intervention at venues where they regularly meet or by making it comfortable and convenient for example delivery of fruit and vegetables via a meals on wheels programme (68). Appendix 2 presents the evidence tables from the World Health Organisation publication highlighting the effectiveness of a variety of interventions in older adults.

When deciding on an implementation strategy, a variety of settings and methods can be considered. For example an intervention can be implemented at schools, workplaces, religious settings or in the community. Depending on the setting, the medium and methods used may differ, for example mass media may be suitable in one context while individualised materials may be more applicable in another. It is critical to know the effectiveness of all settings and modes of message delivery. Often though, strategies and methods employed in one setting are cross-cutting and tend to be broadly applicable in other settings as well:

i. Physical Environment Interventions- Interventions/policies that have the ability to make physical modifications and that can reach large populations in the environments where they make their choices are the most successful (68). Included in this category are point-of-purchase prompts and messages in stores that encourage shoppers to select options conducive to good health and increasing and maintaining safe public spaces for physical activity. Appendix 3 presents an excerpt of 'The Supportive Environments for Physical Activity and Health Project (2009)' developed in Queensland which highlights physical environment modification approaches that can be carried out by local government (69). Such approaches can be developed and enacted in other states at the local government level.

ii. Workplace Interventions– Research points to the use of carefully organised, accessible and sustainable activities to derive maximum health benefits in the workplace. Including workers in the planning and implementation phase of workplace interventions has been shown to be beneficial (55). An evidence-based module produced in Australia reported that effective types of physical activity strategies to include in Australian workplace settings include signage encouraging stair use, providing access to physical activity spaces and providing education and peer support (70). This is supported by the available scientific literature where studies have highlighted the effectiveness of signage that encourages use of stairs instead of an elevator or escalator results in a median increase in stair climbing of 53.9% and that experimentally reducing the availability of escalators and modelling more active behaviours increases stair use (71). In terms of nutrition interventions applicable at workplace canteens and shops, point-of-purchase promotions, access and availability of healthy food options and food labelling were pinpointed as being most effective (70). Other examples of interventions that have been shown to be effective in a workplace setting include lunch hour walking programs, instructor-led group exercise and healthy taste clubs (71).

iii. Community-based Interventions – Evidence within this multidimensional domain points to the effectiveness of diet education and physical activity programmes that target high-risk groups. Community-based interventions that incorporate a variety of activities , include both diet and physical activity components and have a robust educational component with strong theoretical underpinnings seem to be associated with the greatest levels of sustainability (68). Policies for providing wide and safe routes for walking and biking in communities, maintaining public parks, reducing exposure to unhealthy fast food or to high-calorie/low-nutrient foods, menu labelling and increasing access and availability to healthy foods appear crucial to sustainable behaviour change (71).

iv. Religious Setting Interventions – There is consistent evidence that intervention strategies that are planned with the help of spiritual leaders and members of their congregation have high levels of success. Such interventions tend to include counselling, group education and self-help strategies (68).

v. Mass-media based Interventions – Multi-component mass media campaigns that involve a community participation approach have the highest rates of success (68). Some evidence however has shown that an individualised material approach tends to be more effective in helping to encourage physical activity and diet change. In a study comparing the effects of motivationally matched print materials versus motivationally matched telephone counselling, both groups had significantly increased physical activity at 6 months, but participants receiving the print materials were more likely to maintain physical activity change at 12 months (71).

vi. Group-based Interventions – Group focused interventions allow for social interaction, peer-support and positive observational learning. Typically administered using a small number of participants, the group initially meets quite often with frequency decreasing over time - this has proven problematic particularly as it relates to interventions to improve eating habits where self-monitoring is encouraged. One technique that can be used to combat this is to include friends and wider support networks to ensure that target goals are achieved and maintained.

vii. Individual-focused Interventions – Personalised interventions that allow for the development of tailor-made strategies to suit an individual's health goals have been shown to have some short-term success (up to 1 year) (71). A combined approach incorporating self-monitoring and counselling have also been shown to improve the effectiveness of the intervention (71).

viii. Computer/Technology-based Interventions – Overall, studies aimed to evaluate the effectiveness of technology-based interventions have produced mixed results. What has been established though is that programs incorporating both an online information provision element along with counselling (provided online) have more success than the use of Intervention programs alone. Supermarket kiosk programs that provide onsite nutrition information have also been shown to be effective in improving fruit, fibre and saturated-fat intake (71). There are several advantages to using a computer-based intervention as it allows for many people to be reached in the comfort of their own homes and allows for tailored intervention programs to be developed. In addition, they are cost effective and provide an opportunity for interaction for socially isolated individuals (71).

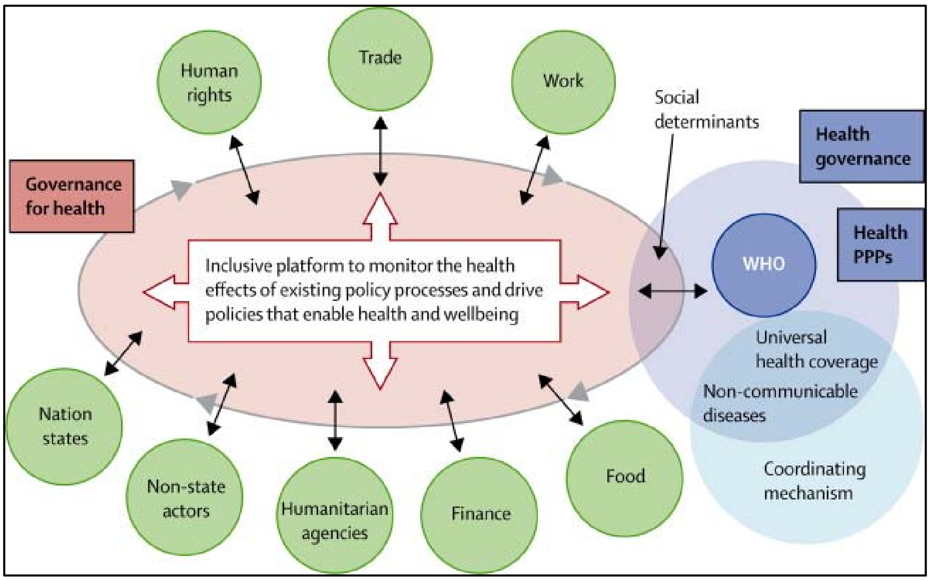
ix. Multicomponent Interventions – Such interventions have reported some success although the optimal combination of behaviour change strategies to be included in a given intervention program requires further study (57). Multicomponent intervention programs include: some combination of technology/media; group or individual-based delivery strategies; computerised assessment and feedback plus videotapes, telephone follow-up, or individual counselling; physician advice plus motivational videotapes, telephone calls, and interactive mail; group sessions plus individual motivational interviewing; or individual plus group sessions (71).

x. Interventions with special considerations for vulnerable groups (minority groups and socio-economically disadvantaged populations) – Differences in education, culture, language, ethnicity and lifestyle have been proven to affect the effectiveness of any intervention. Multicomponent and group-based interventions have demonstrated positive diet and physical activity changes among vulnerable groups while computer/technology-based interventions reported limited success particularly among low-literacy individuals who may be unwilling to click on links and unable to understand information presented on websites (71). The use of lay health advisors and community health workers who speak the same language, have similar beliefs and live in the same area can increase the success of an intervention among vulnerable groups as they are able to target messages to meet their unique needs and may be viewed as being more identifiable and trustworthy (71).

Several other interventions have been highlighted in the literature as being effective. These interventions have revolved around the ideas of policy and incentive provision schemes. For example, the lowering of insurance premiums for those who participate in programs aimed to improve diet and physical activity behaviours (71). In addition, enacting and enforcing policies that support information provision (e.g. mandatory calorie labelling) and limiting the use of certain food components in the food supply (e.g. trans fats) has been shown to positively influence food choices and foods available (71). These types of approaches can engender supportive environments where making healthy food choices and engaging in regular physical activity are second nature (71).

For an intervention aimed to decrease dementia onset/prevalence to be considered a success, it must encourage and result in significant and sustainable behaviour change. Sustainability is paramount since it takes into consideration individual, social and environmental elements. While health issues are frequently considered to be problems for health departments to solve, the development of diseases such as dementia are impacted by a wide variety of determinants - genetics, education, access to safe and well maintained physical activity spaces, access to affordable healthy foods and existence of a supportive environment. For all these determinants to be addressed there must be support and acceptance from all stakeholders that they have a key role to play. Figure 6 below identifies some of the stakeholders involved in the implementation of any health intervention (72).

Figure 6: Stakeholders involved in the development and implementation of health interventions and policy



Source: Ottersen et al. The political origins of health inequity: prospects for change. The Lancet, Volume 383, Issue 9917, 630-667. (72)

5 What should policymakers do?

Policy-makers must be cognizant of the fact that no singular government intervention/policy, operating on its own, can have the effect of directly reducing dementia onset/prevalence and changing lifestyle habits. To compound this issue, some thinkers postulate that people are in control of what happens to them health-wise while others believe that the environment acts upon people leading to development of various lifestyle habits (73). For any government policy/intervention to work there must be recognition that the environment does in fact influence the way we live our lives and our ability to change unhealthy behaviours into healthy ones.

Six actions that can be taken by policy makers are identified below that have the potential to result in inestimable benefit in the fight against dementia. These actions are not limited to dementia risk reduction interventions but rather to any public health intervention. Such actions though must be bolstered by strong education and communication strategies in order to be effective[8]:

i. Development of a comprehensive dementia prevention strategy – The National Framework for Action on Dementia (2006 – 2010) was implemented in the 2005 Australian Federal Budget (74). This initiative however was terminated in 2011 after an evaluation found that it did not address key critical issues (74). These issues included primary care, a communications strategy and risk reduction (74). Australia needs to develop an overarching plan that takes into consideration these key issues if reducing dementia onset and prevalence is a priority. Being the first country to establish dementia as a national health priority with a funded five year plan (74), the Australian government needs to act quickly to develop a coordinated dementia prevention strategy.

ii. Keeping track of scientific research - A research of the grey and scientific literature in the Australian context reveals that there have been quite a number of dementia initiatives within the past few years – scientific studies, reports by various stakeholders, conferences and public awareness campaigns. The establishment of a body whose aim is to keep track of scientific research both within Australia and internationally, to establish clear research and public health priorities as it relates to dementia and to outline the way forward based on the best scientific evidence clearly indicating the roles and levels of accountability of all stakeholders (at both state and federal level) is crucial. Central to this initiative will be the establishment of a national digital dementia research repository that will allow for data sharing among researchers.

iii. Increased engagement of non-health actors/agencies – Key to implementing a successful dementia prevention program is for stakeholders to accept and willingly support the initiative. The establishment of agreed outcomes that are measureable and able to be tracked is the first step and collaborating to develop clear roles for each stakeholder is the second. It is important to note that stakeholders can work through various channels thereby providing access to the broader population as well as well-defined target groups (75). This interplay between stakeholders is critical since unlike other singular disease-causing agents targeted by governments such as tobacco, there are innumerable food products on the market. To compound this issue, while individual food items are capable of contributing to disease development if consumed in excess, they can also result in absolutely no harm if other healthy lifestyle choices are adopted (73).

[8] The actions highlighted in this section take root in the Health in All Policies initiative and social determinants of health approach. These encourage all sectors to consider health and wellbeing in order to improve population health and to take into consideration the social and economic factors that influence the health of all Australians.

Reports have highlighted that some health interventions are best led by ‘incidental’ and not ‘traditional' health agencies (73). For example, in the UK, the Sustrans National Cycle Network (an NGO encouraging cycling through various non-governmental partnerships) led an initiative to increase cycling and walking journeys which was reported to have an estimated health benefit of US$625 million in 2009 (76). As such, states of health and the development of effective and sustainable interventions to reduce dementia onset and prevalence, as with any other health condition, are not simply dependent on the action of ministries/departments of health. Rather, a successful intervention requires that elements of dementia prevention (including the need for healthy eating and active living) be incorporated into the purview of non-health departments such as trade, finance, education, communication, urban planning, agriculture and transport. The health sector in return can also identify policy “windows” across other sectors that can allow them to appreciate the health impact of their initiatives as well (75).

iv. Continued investment into research and innovation – Several intervention strategies that have been highlighted in the literature require further investigation to determine their true impact. Policy makers are keen to know what interventions will produce a positive return on investment by reducing both healthcare costs and disease prevalence. One area where research is needed for example is the development of food taxes and the benefits that could ensue. In 2014, Cancer Council Australia recommended that research be commissioned to identify the impact of a food tax on various socio-economic groups within Australia and the examination of how a food tax and other policy measures could interact to be effective and equitable (77). Further research is also needed to identify innovative ways to detect early signs of dementia and care for those already affected. Individual-level (as opposed to aggregate-level) longitudinal data will ideally be needed in order for these goals to be achieved.

v. Provision of incentives – Policy makers often incur challenges when trying to get all stakeholders to engage in meaningful dialogue that results in a series of implementation actions that all can agree on. This is particularly the case as it refers to non-traditional health actors who now must expand their respective portfolios to infuse elements of healthy eating and active living. The identification of incentives beyond the health domain is therefore critical, especially when economic interests conflict (76).

vi. Provision of greater longevity literacy – At a population level, there must be the development a program to help people understand that they may be living far longer than they expect, and that as a result of pressures on state resources, may be increasingly called upon to be more responsible and accountable for their own health and wellbeing. Since dementia has no known cure and age is presently the strongest predictor of the disease, this initiative is quite appropriate. Such an action will involve collaboration from both ‘traditional’ and ‘incidental’ health agencies e.g. Department of Social Services, Department of Finance, Department of Health, Department of Human Services and various community groups.

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7 Appendix 1: The checklist of good characteristics for healthy diet and physical activity

No.	Best practice characteristic
Main Intervention Characteristics	
1	Target audience well defined
2	Target group needs identified
3	Family involvement*
4	Target behaviour well defined and adjusted to target population
5	Multidimensionality of the approach (individual, social, environmental)
6	Physical environment accounted for
7	Theory applied in the development of the intervention/policy
8	Individual contacts and their intensity specified
9	Duration (number of sessions, their length, and frequency)
10	Forms of delivery
11	Number of components (distinguishable elements/strategies used to prompt healthy diet/physical activity)
12	The use of any theory-based behaviour change techniques
13	Clarity achieved
14	Tailoring content and materials
15	Manuals/exact protocols exist
16	The use of specific behaviour change techniques: self-monitoring and self-management
17	Practitioners well defined
18	Setting characteristics well defined
Monitoring and Evaluation	
19	Costs in relation to obtained general health benefits
20	Costs related to behaviour change
21	Total financial costs of the interventions/policy
22	Outcomes measured with valid, reliable and sensitive tools
23	Effects specified as clinically significant
24	Effects on public-health relevant secondary outcomes
25	Negative consequences (or risks) evaluated
26	Measured outcomes include physiological risk factor indices
27	Efficiency established and reported
28	Sustainable effects
29	Effect sizes
30	Reach
31	Inclusiveness: health, age and gender context
32	Cultural competence and social inclusion of the intervention/policy
33	Generalizability of effects evaluated
34	Participation rates reported
35	Active components identified
36	Ongoing monitoring and measurement of delivery; material monitoring

Implementation	
37	Completion and attrition rates across stages
38	Resources/strategies for staff helping them to invite and follow participants up
39	Strategies promoting long-term participation (maintenance) included
40	Staff training in implementation and facilitation of inter-sectorial collaboration
41	Resources for implementation specified
42	Implementation integrated into existing programs
43	Ongoing support from stakeholders secured
44	Adoption by target staff, settings or institutions
45	Feasible/acceptable for providers, stakeholders and participants
46	Maintenance (the policy/intervention is maintained over time with institutional support)
47	Mutability (the intervention/policy is in the realm of community/target group)
48	Partnership between agencies/organizations to facilitate adoption/implementation
49	Identification of those responsible for implementation; training and feedback for implementers
50	Implementation consistency and adaptations made during delivery assessed
51	Adherence to protocol/protocol fidelity monitored
52	Transferability
53	Contexts of transfer and transfer boundaries

Source: Horodyska et al. Good practice characteristics of diet and physical activity interventions and policies: an umbrella review. BMC Public Health (2015) 15:19. (67)

*Note: * Characteristics identified mainly in documents referring to interventions for children and adolescents*

8 Appendix 2: Excerpt on older adults from WHO publication 'Interventions on diet and physical activity – what works' (2009) (70)

Intervention Components	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
Seattle senior farmers' market nutrition pilot programme - Seattle, USA - Low-income seniors interviewed at 6 months (IG[9]=87, CG=44) - Aimed at increasing F&V[10] intake. ***Activities*** - Market baskets were delivered to the homes of seniors every 2 weeks by *Meals on Wheels* drivers. *(Reference: Johnson et al. 1994; Smith et al. 2004)*	**Not reported**	**Effective** A significant increase of 1.04 servings of F&V per participant/day was noted. The percentage of the elderly eating 5 or more F&V servings a day increased from 22% to 39%.	**Not reported**	This system could work well in other areas that have an established *Meals on Wheels* (or similar) infrastructure. Home delivered baskets brought participants joy, stimulated interest in healthy foods and improved quality of life.

[9] IG = Intervention Group
[10] F&V = Fruit and Vegetable

Intervention Components	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
CHAMPS II (Community Healthy Activities Model Programme for Seniors) - Members of health maintenance organizations in USA - n=164 persons - 12 months - Aimed to have participants active at least 30 minutes per day on most days of the week. ***Activities*** - Trained staff assisted participants to develop and maintain tailored PA[11] programme - Participants were encouraged to participate in PA that addressed more than 1 component of fitness and function - Participants could choose group (community- based) or individual exercise sessions. *(Reference: Stewart et al. 2001)*	**Insufficient evidence/ promising**	**Effective** Both moderate intensity and total weekly PA increased. Equivalent to five 1- mile walks per week.	**Moderately effective** BMI[12] decreased.	The programme was particularly effective for those who were older, sedentary and overweight, and particularly for women. This study was conducted in a high quality health-care setting but did not include minority groups.

[11] PA = Physical activity
[12] BMI = Body Mass Index

Intervention Components	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
CHIPs (Community Health Intervention Programmes) - South Africa; 20 weeks - Under- resourced community - n=98 community dwellings ***Activities*** - Low-intensity seated PA - Peer led; twice a week - Cardiovascular, resistance and flexibility training. *(Ref: Kolbe-Alexander et al. 2006)*	**Not reported**	**Minimally effective** There was an increase in exercise-related energy expenditure, but no increase in total weekly energy expenditure.	**Moderately effective** Balance, strength, lower body muscle strength and systolic blood pressure all increased.	Even if only twice weekly, seated PA resulted in improved measures of functional performance and fitness in seniors. The programme was community-based, and community members were trained as PA leaders. This programme demonstrated sustainability for 8 years.
Strong for life - Massachusetts, USA; 15 weeks - n=102 community dwellings ***Activities*** - 30-minute video programme - 10 exercises (resistance training, 5 min. warm up, 20 min. strength training, 5 min. cool down) - Aim for 3 exercise sessions/week - Occasional calls from trained therapist. *(Reference: Jette et al. 1996)*	**Not reported**	**Minimally effective** 58% participated in PA twice a week. Social functioning scores improved for men and women.	**Moderately effective** Leg muscle strength increased (10%) for those aged < 72 years.	A video-based PA programme may be an effective method to encourage seniors to exercise. However, the exercises might need to be gender specific and target the ‘younger’ versus ‘older’ seniors.

Intervention Components *	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
Active for life - 4 community-based organizations implemented either Active Choices (telephone-based intervention over 6 months) or Active Living Every Day (20-week group- based programme). ***Activities*** - Focus on necessary behavioural skills to become more active. *(Reference: Wilcox et al., 2006)*	**Moderately effective** Depressive symptoms and stress decreased and body satisfaction and appearance increased.	**Moderately effective** Significant increase noted in moderate to vigorous activity in both IGs.	**Moderately effective** Both IGs had a decrease in BMI.	These programmes demonstrate successful translation of evidence-based PA programmes in a community of older adults with diverse backgrounds.
Health enhancement programme - Washington, USA; 12 months - n=304 community dwellings ***Activities*** - Health and functional assessment by nurse; personalized health and action plan - Encouraged to enrol in lifetime fitness programme, chronic NCD[13]	**Promising/ insufficient evidence** 85% of participants were able to improve lifestyle to make sustained	**Moderately effective** The number of inactive participants decreased from 56% to 38%.	**Promising/ insufficient evidence** Health status in IG either improved or remained constant compared to a	This multi-faceted health promotion programme for seniors resulted in increased PA levels. Individual counselling at baseline may positively influence expected outcomes.

[13] NCD = Non-communicable disease

self- management course, and a meeting with social worker. *(Reference: Phelan et al. 2002)*	health changes.		decrease in CG[14].	
Intervention Components	**Psychosocial Changes**	**Behavioural Changes**	**Physical and Clinical Changes**	**Policy/Process Implications**
Sheffield community based exercise programme- Sheffield, United Kingdom - n=6420, community dwelling patients from 12 general practitioner practices - 2 years. ***Activities*** - Free supervised PA sessions twice a week – PA sessions of 45 minutes, including cardiovascular, resistance flexibility and coordination training. *(Reference: Munro et al. 2004)*	**Promising/ insufficient evidence** No change was noted in the use of healthcare services between groups.	**Minimally effective** 26% of participants attended 1 or more sessions over the 2-year period (2040 sessions provided).	**Insufficient evidence**	Participants were recruited from private medical practices, a good opportunity to prescribe exercise to inactive older adults. Economic evaluation of the programme showed it was cost-effective and produced small health benefits. More advocacy may be needed to increase engagement and uptake of this community-based exercise opportunity for senior adults.
Greek minimum PA frequency - Greece - n=55 community dwellings	**Not reported**	**Promising/insufficient evidence**	**Moderately effective**	Improvements occurred even in those exercising only once per week, but greater

[14] CG = Comparison Group

- 10 weeks. ***Activities*** - Groups participated in exercise either 1, 2, or 3 times a week - Sessions of 45 minutes. *(Reference: Ourania et al. 2003)*		The drop-out rate was low, especially for the once a week group.	Dynamic balance, flexibility and endurance and coordination improved.	improvements were noted in those exercising 2 or 3 times per week.

Intervention Components	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
Community-based strength/ resistance training for older adults - USA - n=37, community dwelling men and women aged 70 ± 4 years - 6 weeks resistance training. ***Activities*** - Three 45- minute sessions per week - Intensity increased with improved strength during the intervention - Before each session, 20 minutes stretching. *(Reference: Cavani et al., 2002)*	**Not reported**	**Not reported**	**Moderately effective** Improvements noted in upper and lower body strength (arm curls and chair stand tests), and flexibility (upper back scratch and chair sit and-reach), and agility (8 foot up and go). No improvement in 6-minute walk test.	After only 6 weeks of strength training, results showed significant improvement in functional ability in older adults. Improvement in functional fitness plays a role in maintaining independence and delaying frailty.

Intervention Components	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
Home-based strength and balance training for older adults - Boston, Massachusetts, USA; - 72 community dwelling men and women aged 77 ± 5.3 years. ***Activities*** - 6 months home-based strength and balance training; 3 times/week - Booklet with exercises, sets of dumbbells and ankle weights. *(Reference: Nelson et al., 2004)*	**Not reported**	**Moderately effective** 82% of those in the IG exercised 3 times per week for 6 months.	**Moderately effective** Functional performance and balance improved. No difference in 6-minute walk test.	The compliance in this study was high (82%) suggesting that home-based exercise interventions may be effective in increasing levels of PA and associated benefits in older adults. The older adults received 6 visits during the first month, and 1 per month thereafter. Participants also submitted logbooks monthly which could have facilitated compliance.
Community-based strength/ resistance training for older adults	**Not reported**	**Insufficient evidence**	**Promising/insufficient evidence** IG1 and IG2 improved physical functioning	IG2's absolute workload was lower than the IG1, but the improvements were greater for physical function. This

- n=39 community dwelling men and women; - 16 weeks. - Aged 72.5 ± 6.3 years ***Activities*** - IG1: Strength training - IG2: Power training: week 1–8 same as IG1, week 9–16 performing exercises as fast as possible. *(Reference: Miszko et al., 2003)*		78% of participants completed the study.	(balance and coordination, endurance and upper body flexibility). No significant difference in maximal muscle strength and anaerobic power between IG1 and IG2	suggests that more power training may need to be included in PA programmes for seniors.

Intervention Components	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
Strength training - Maryland, USA - n=23 community dwelling men and women, aged 65–73 years. - 6 months. ***Activities*** - Months 1–3: 1 x 15 repetitions for lower upper and 2 x 15 repetitions for upper body exercises using resistance training machines - After 3 months: warm up followed by exercises until unable to complete a set of 15 repetitions - Intensity: near maximal effort for each repetition and resistance	**Not reported**	**Insufficient evidence**	**Promising/insufficient evidence** Upper and lower body strength increased significantly, with men showing greater improvement. Systolic and diastolic blood pressure decreased significantly. No significant changes in BMI.	Strength training on its own can play a role in reducing blood pressure in addition to improving muscle strength. Greater improvements were noted among men, although the small size of this study may affect generalizations.

increased progressively over 6 months. *(Reference: Martel et al. 1999)*				

Intervention Components	**Psychosocial Changes**	**Behavioural Changes**	**Physical and Clinical Changes**	**Policy/Process Implications**
Korean outdoor walking track - Republic of Korea; - 8 weeks. - n=27 community dwelling women ***Activities*** - Outdoor walking track - 50 minutes building up to 3 hours, 3 times per week - 5-minute warm up, 30–40 minutes walking, 10 minutes stretching and 5 minutes cool down. *(Reference: Shin et al. 1999)*	**Not reported**	**Promising/ insufficient evidence**	**Moderately effective** Blood pressure, flexibility and VO2[15] max improved.	PA is not culturally popular among older women of the Republic of Korea, and walking may be a means of encouraging PA in this group.

[15] VO2 = Volume of Oxygen used

Tai Chi Chih - California, USA; - 10 weeks. - n=46 community dwellings ***Activities*** - 20 simple movements - One 60-minute group session per week - 3 practice sessions per week at home. *(Reference: Schaller 1996)*	**Not reported**	**Promising/ insufficient evidence** 62% of participants attended at least 6 group-based sessions and practiced at least 3 times per week at home.	**Minimally effective** Balance for 'eyes open' test significantly improved, but not the 'eyes closed' test.	The results of this study may be less easy to generalize since participants were well educated, of high socioeconomic status, physically active and healthy.

Intervention Components	Psychosocial Changes	Behavioural Changes	Physical and Clinical Changes	Policy/Process Implications
Seniors Active Living in Vulnerable Elders (ALIVE) programme - Alberta, Canada - 10 months. ***Activities*** - Delivered in seniors' apartment buildings - Included exercise classes, health information sessions and newsletters - Qualitative evaluation. *(Reference: Buijs 2003)*	**Promising/insufficient evidence** Qualitative changes in "feeling better", fun, social support, and perceived "comfort in the programme" were noted.	**Not reported**	**Not reported**	

Health promotion programme for low income elderly (Tai-Pai) - Tai Pai, Taiwan, China - 89 purposely selected low income elderly. ***Activities*** - Health promotion programme for low-income elderly provided by trained low-income home health aides. *(Reference: Li 2004)*	**Promising/insufficient evidence** No change was seen in psychosocial status, decreased perceived need for health promotion services.	**Not reported**	**Promising/ insufficient evidence** Improved nutritional status and independent activities of daily living were both noted.	

Source: World Health Organisation. 2009. Interventions on diet and physical activity – what works? (70)

9 Appendix 3: Examples of physical environment modification approaches that can be carried out by local government

Strategy	Tools	Measures/Examples/Comment
Modification through land use allocation		
Create activity destinations	Planning scheme including: • DEO's[16] • Strategies • Land Use Zones	Ensure land use allocation and "land use mix" places residential, commercial, industrial, recreational and other trip generating land uses within walking or cycling distance from each other.
Increased land parcels allocated to recreational land use	• Corporate plan/budget • Capital works program • Designation of Community Infrastructure • Planning scheme	The more and the higher the density of land parcels dedicated to active recreation, the more opportunities to be physically active.
Protect land for food production	Planning scheme including: • DEO's • Strategies • Land Use Zones	Need to reflect State Planning Policy 1/92: *Development and Conservation of* Agricultural *Land* in planning schemes.
Optimise accessibility to healthy food	Planning scheme including: • DEO's • Strategies • Land Use Zones	Distance to supermarkets and local stores influence the variety and competitive pricing of healthy foods.
Minimise accessibility to unhealthy food	Planning scheme including: • DEO's • Strategies • Planning Scheme Policies • Tables of assessment and Codes	The higher the density of fast food outlets, particularly around schools, the higher the consumption of energy dense, nutrient poor foods.
Support initiatives to change individual lifestyle behaviours	• Corporate plan/budget • Capital works program • Designation of Community Infrastructure • Planning scheme	Allocate, designate and purchase land for Council programs and community groups.

[16] DEO = Desired environmental outcome

Strategy	Tools	Measures/Examples/Comment
Modification through Urban Design at the site/building level		
Prevent crime and increase actual and perceived levels of personal safety	Planning scheme including: • DEO's • Strategies • Planning Scheme Policies • Tables of assessment and Codes	Measures that requires appropriate: levels of lighting; building orientation and setbacks; landscaping, including vegetation and; surveillance
Plan and develop "landscape" and outdoors recreational infrastructure and facilities	• Corporate plan/budget • Capital works program • Planning scheme including: - DEO's - Strategies - Planning Scheme Policies - Tables of assessment and Codes - Priority Infrastructure Plans	Includes the provision of sport fields, walking paths and bicycle ways in parks and reserves.
Plan and develop indoors recreational facilities	• Corporate plan/budget • Capital works program • Planning scheme including: - DEO's - Strategies - Planning Scheme Policies - Tables of assessment and Codes - Priority Infrastructure Plan.	Includes provision of aqua centres, squash and basketball courts, gymnasiums in buildings designated for public and private use (such as an on-site gym for use by employees).
Provide appropriate embellishments i.e. play equipment, benches and water fountains	• Corporate plan/budget • Capital works program • Planning scheme, particularly the Priority Infrastructure Plan.	Includes play equipment, BBQ facilities, benches, water fountains and toilets/change rooms.
Maintenance of parks and gardens	• Corporate plan/budget • Capital works program	Enhance the aesthetic values of the building or site.
Provide or regulate for the provision of public and employer amenities that support physical activity and healthy eating	• Corporate plan/budget • Capital works program • Planning scheme, particularly: Planning Scheme Policies; Tables of assessment and Codes; and Priority Infrastructure Plans	Includes areas for breast feeding and end-of-trip facilities such as bicycle lock-ups and changing facilities.

Strategy	Tools	Measures/Examples/Comment
Establish local community gardens, school gardens, home gardens and edible landscapes	• Corporate plan and budget • Capital works program	Provide fresh produce with potential educational, social and nutritional benefits.
Modification through Urban Design at the street level		
Prevent crime and increase actual and perceived levels of personal safety	• Planning scheme including: - DEO's - Strategies - Planning Scheme Policies - Tables of assessment and Codes	Measures that requires appropriate: levels of lighting; building orientation and setbacks; landscaping, including vegetation and; surveillance
Enhance the aesthetic values of the streetscape	• Corporate plan/budget • Capital works program • Planning scheme, particularly Desired Standards of Service in Priority Infrastructure Plans	Landscaping and embellishments such as bus shelters, sculptures, benches and other street furniture.
Modification through Community /Neighbourhood Urban Design		
Ensure a high level of neighbourhood connectivity	• Planning scheme including: - DEO's - Strategies - Planning Scheme Policies - Tables of assessment and Codes	A high level of interconnectivity of transport infrastructure such as sidewalks (including dedicated walkways) and cycle lanes (including dedicated cycle ways) reduces the time and physical distance between destinations and encourages the use of active transport.
Increase densities	Planning scheme including: - DEO's - Strategies - Planning Scheme Policies - Tables of assessment and Codes	Higher densities increase the number of residential and commercial premises in an area. This has the effect of increasing the number of persons with access to recreational and transport activity infrastructure, retail outlets such as supermarkets, public transport and other facilities that support physical activity and healthy eating. High levels of usage, in turn increases the viability and level of service provided by these facilities and infrastructure.

Strategy	Tools	Measures/Examples/Comment
Transportation		
Optimise linkages between individual buildings and sites and public transport facilities and active transport infrastructure	• Planning scheme, particularly: Planning Scheme Policies, tables of assessment and Codes.	Provide ready access to bus stops and walk and cycle ways.
Integrate active transport infrastructure and recreation facilities in major mixed use developments	• Planning scheme, particularly: Planning Scheme Policies, tables of Assessment and Codes.	Provide for separation of motorised vehicles and pedestrians and provide cycle ways and parks in business parks and regional shopping centres.
Provide active transport infrastructure	• Corporate plan and budget • Capital works program • Planning scheme, particularly: Planning Scheme Policies and Priority Infrastructure Plans	Primarily side-walks and cycle ways. Can be shared (pedestrians/vehicles and cyclists sharing the same reserve) or dedicated infrastructure.
Encourage the use of active transport infrastructure	• Corporate plan and budget • Capital works program • Planning scheme, particularly Desired Standards of Service in Priority Infrastructure Plans	Measures include kerb type, traffic management and control devices, street crossings and crossing aides, verge width, driveway crossovers to aid continuity, vehicular and cycle lane markings and adequate sighting distances.
Encourage public transport and discourage motorised transport	• Corporate plan and budget • Local Laws • Designation of Community Infrastructure • Planning scheme including: - DEO's - Strategies - Planning Scheme Policies - Tables of assessment and Codes - Priority Infrastructure Plans	Measures include imposing neighbourhood parking restrictions and providing park-and-ride facilities close to public transport.

Source: Pretorius. 2008.The Supportive Environments for Physical Activity and Health Project, Phase One: Options Paper. (69)

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RESEARCH ARTICLE

Life Expectancy with and without Cognitive Impairment in Seven Latin American and Caribbean Countries

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Abstract

Background

The rising prevalence of cognitive impairment is an increasing challenge with the ageing of our populations but little is known about the burden in low- and middle- income Latin American and Caribbean countries (LAC) that are aging more rapidly than their developed counterparts. We examined life expectancies with cognitive impairment (CILE) and free of cognitive impairment (CIFLE) in seven developing LAC countries.

Methods

Data from The Survey on Health, Well-being and Ageing in LAC (N = 10,597) was utilised and cognitive status was assessed by the Mini-Mental State Examination (MMSE). The Sullivan Method was applied to estimate CILE and CIFLE. Logistic regression was used to determine the effect of age, gender and education on cognitive outcome. Meta-regression models were fitted for all 7 countries together to investigate the relationship between CIFLE and education in men and women at age 60.

Results

The prevalence of CI increased with age in all countries except Uruguay and with a significant gender effect observed only in Mexico where men had lower odds of CI compared to women [OR = 0.464 95% CInt (0.268 – 0.806)]. Low education was associated with increased prevalence of CI in Brazil [OR = 4.848 (1.173–20.044)], Chile [OR = 3.107 (1.098–8.793), Cuba [OR = 2.295 (1.247–4.225)] and Mexico [OR = 3.838 (1.368–10.765). For males, total life expectancy (TLE) at age 60 was highest in Cuba (19.7 years) and lowest in Brazil and Uruguay (17.6 years). TLE for females at age 60 was highest for Chileans (22.8 years) and lowest for Brazilians (20.2 years). CIFLE for men was greatest in Cuba (19.0 years) and least in Brazil (16.7 years). These differences did not appear to be explained by educational level (Men: p = 0.408, women: p = 0.695).

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Conclusion

Increasing age, female sex and low education were associated with higher CI in LAC reflecting patterns found in other countries.

Introduction

Cognitive impairment (CI) is a condition where a person has trouble remembering, learning new things, concentrating or making decisions that affect their everyday life [1]. CI can be mild or can be severe enough to affect an individual's ability to live independently [1]. The rising prevalence of CI is an increasing challenge with the ageing of our populations but little is known about the burden in low- and middle- income countries. This is a particular concern since low-and middle- income countries, including Latin American and the Caribbean (LAC), are aging more rapidly. At present, over 60% of the world's population 60 years and older live in these countries and this projection is expected to rise to a high of 80% by 2050 [2].

Age is currently the strongest known predictor of cognitive decline [3, 4]. As such, because of the rapid increase in demographic ageing in all world regions, global prevalence of dementia is predicted to double every 20 years to over 80 million people by 2040 [5]. Since CI has been shown to negatively affect quality of life including functional status [6] countries that are ageing most rapidly will face considerable challenges.

Early life education has been associated with reduced risk of dementia [7, 8] but education influences health in varied ways [9, 10], including by encouraging health-seeking behaviours and healthy lifestyles [9]. The role of education in screening and detection tests has however been controversial since it may influence the ease with which a respondent is able to answer questions asked and display the necessary skills to be measured [11].

As the older population grows in both size and proportion it is important to find out whether the additional years lived are spent with more disease and disability [2]. Health expectancies, which combine information on mortality and morbidity are useful population indicators to assess whether the extra years of life expectancy are in good or poor health [12]. The most widely reported health expectancy is disability-free life expectancy and, while there have been some published studies on mental health expectancies in a number of developed countries [13–18], data on the older population, particularly on cognitive status, is not routinely collected in Latin America and the Caribbean. This paper is the first to report life expectancy with and without CI in LAC, utilising data from a survey conducted in seven LAC countries (Argentina, Barbados, Brazil, Chile, Cuba, Mexico and Uruguay) between the period 1999–2000. In addition we undertake cross-national comparisons to investigate burden of CI at various ages and examine the role education plays in determining cognitive status.

Method

Study Design and Sample

The study draws on secondary data derived from The Survey on Health, Well-being and Ageing in Latin America and the Caribbean (SABE). SABE data are freely available from the Inter-university Consortium for Political and Social Research and data was accessed using the search terms 'ICPSR & SABE & Latin America and the Caribbean.' SABE, conducted during the period 1999–2000, represents the most comprehensive study conducted in the Region on the elderly population. As a multi-centre project it involved the collection of baseline data in the capital cities of seven countries: Buenos Aires (Argentina), Bridgetown (Barbados), Sao Paolo (Brazil), Santiago (Chile), Havana (Cuba), Mexico City (Mexico) and Montevideo (Uruguay). The project aimed to examine health conditions and functional limitations of persons aged 60 and older in the countries under study and placed special emphasis on those over 80 years old (n = 10,597). The total sample size of the SABE was 10,597 participants. Response rates varied from 85% in Bridgetown, São Paulo, and Mexico City to 60% in Buenos Aires, 84% in Santiago, 95% in Havana, and 66% in Montevideo. Sampling was based on censuses conducted in 1998 in Buenos Aires, 1996 in São Paulo, 1992 in Santiago, 1999 in Havana, 1999 in Mexico City, and 1997 in Montevideo [19]. Surveys were administered to representative samples in each country with samples being drawn from recent census data or from nationally representative surveys [20].

A multistage, clustered sampling with stratification of the units at the highest levels of aggregation was used [20]. The primary sampling unit was a cluster of independent households within predetermined geographic areas grouped into socioeconomic strata and then divided into secondary sampling units, each containing a smaller number of households [20].

Households and target individuals (persons age 60 and older) were randomly selected and target individuals contacted to schedule an interview at home. The interviews were conducted in English, Portuguese or Spanish depending on the official language of the country in which the survey was administered. If a person who agreed to be interviewed failed the cognitive test, a proxy was selected to respond to some parts of the questionnaire [20].

Definition of CI

The Mini Mental State Examination (MMSE) [21] was used to establish cognitive status in all study samples. The MMSE is a sum-score evaluating various dimensions of cognition (memory, attention and language) and is an index of global cognitive performance [21]. In the SABE Study, a regression analysis had been carried out prior to identify the MMSE questions that would be best to determine cognitive impairment. The Modified MMSE was developed with nine variables instead of the 19 original MMSE variables in a bid to lessen the low literacy bias [22]. Each respondent's score was then computed, with a score of <12 (out of a maximum of 30) indicating cognitive impairment [20].

The Pfeffer Scale measures functional capacity, taking into consideration ability to perform daily tasks as well as instrumental activities such as conduct of simple fiscal transactions, doing laundry and comprehension of current events and it is used to assess and compare normal and demented adults [23]. The modified MMSE was used in conjunction with the Pfeffer Scale for those persons who obtained a score of 12 or less in the modified MMSE and was administered to an informant or carer accompanying the participant with cognitive deterioration in order to confirm that their level of cognitive decline affected functional capacity [20]. A participant scoring 12 or less on the Modified MMSE and 6 or more on the Pfeffer Scale was considered unable to be interviewed and a proxy of the participant was asked to respond instead [20].

Level of education

In this study, a high education level was defined as any learning that occurred after completion of secondary school while a low education level was defined as having either primary and/or secondary school education only.

Statistical Analysis

Logistic regression analysis using Stata version 12 was carried out to assess the relationship of gender, age and education on cognitive status. The Sullivan Method was used to calculate life expectancies with and without CI (CILE and CIFLE) for each country (and gender) by applying country and age-specific CI prevalence from the study outlined above to country-specific life tables. CIFLE reflects the number of remaining years, at a particular age, which an individual can expect to live on average in the absence of CI [24]. Life tables were calculated from mortality rates and population figures obtained from the World Health Organisation. Five year age intervals were used during analysis except for the final age-grouping which was recorded as 85+ years [24]. The curvature of the true survival curve over each age interval (a_x) was estimated as 0.5 since this is generally a reasonable assumption [24, 25]. The standard error of the estimates of CIFLE was calculated for all age and sex groupings in each country [24]. Men and women were analysed separately. We fitted meta-regression models [26] to all 7 countries together to investigate the relationship between education level and CIFLE at age 60 for men and women separately. The analyses conducted and results presented are unadjusted.

Results

The mean age of all persons in the study was 70.8 years (SD = 8.2). Overall 58.7% of study participants were female and there were proportionately more females than males in all countries. Around 80% of men and women overall had a low education level though this ranged from around 93% in Barbados (men: 94.4%; women: 92.5%) to 15% in Cuba (men: 14.9%; women: 16.8%). Table 1 shows descriptive statistics for the populations under study in the seven countries.

The prevalence of CI ranged from a low of 8.9% (Argentina) to 21.3% (Barbados) (Fig. 1). A greater proportion of females were recorded as having CI in all countries. Fig. 1 below highlights the prevalence of CI by gender across the study sites.

Logit models fitted to all study sites with the inclusion of a country effect indicated that age, education, gender and country all had a significant impact on cognitive status. For every 1 year increase in age the odds of CI are increased [Odds Ratio (OR) 1.111; 95% CInt (CInt) (1.098–1.126)]. The odds of CI were lower in males when compared to females [Odds Ratio (OR) 0.737; 95% CInt (0.596–0.911)]. Compared to those with a high education level, the odds of CI are increased for those with a low education level [OR 2.926; CInt (1.974–4.337)]. There was a significant difference in the odds of CI between the countries. Compared to Argentina (reference) the odds of CI were significantly higher in Brazil [OR 1.500; CInt (1.007–2.235), Chile [OR 2.398; CInt (1.617–3.558), Mexico [OR 2.948; CInt (1.938–4.485), and Cuba [OR 2.612; CInt (1.569–4.347) and significantly lower in Uruguay [OR 0.372; CInt (0.213–0.650)]. The

Table 1. Mean Age and Proportion of Males and Females in Study Samples by Country (n = 10,597); Sample size with percentages shown in brackets.

Country	*Mean Age (Years)*	*Males (%)*	*Females (%)*	*Low Education Level Males (%)*	*Low Education Level Females (%)*
Argentina (n = 1043)	70.74	383 (37.0)	660 (63.0)	582 (92.5)	322 (85.6)
Barbados (n = 1508)	72.59	924 (60.7)	584 (39.3)	863 (94.4)	527 (92.5)
Brazil (n = 2143)	73.28	881 (40.8)	1262 (59.2)	583 (86.1)	842 (91.5)
Chile (n = 1301)	71.57	446 (34.3)	855 (65.7)	360 (87.6)	678 (92.0)
Cuba (n = 1905)	71.97	708 (38.4)	1197 (61.6)	50 (14.9)	125 (16.8)
Mexico (n = 1247)	64.71	507 (41.2)	740 (58.8)	340 (81.5)	470 (82.7)
Uruguay (n = 1450)	70.94	530 (36.6)	920 (63.4)	395 (77.3)	728 (84.2)
TOTAL	70.8	4379 (41.3)	6218 (58.7)	3173 (80.0)	3692 (78.5)

*Low education level defined as primary and/or secondary school education

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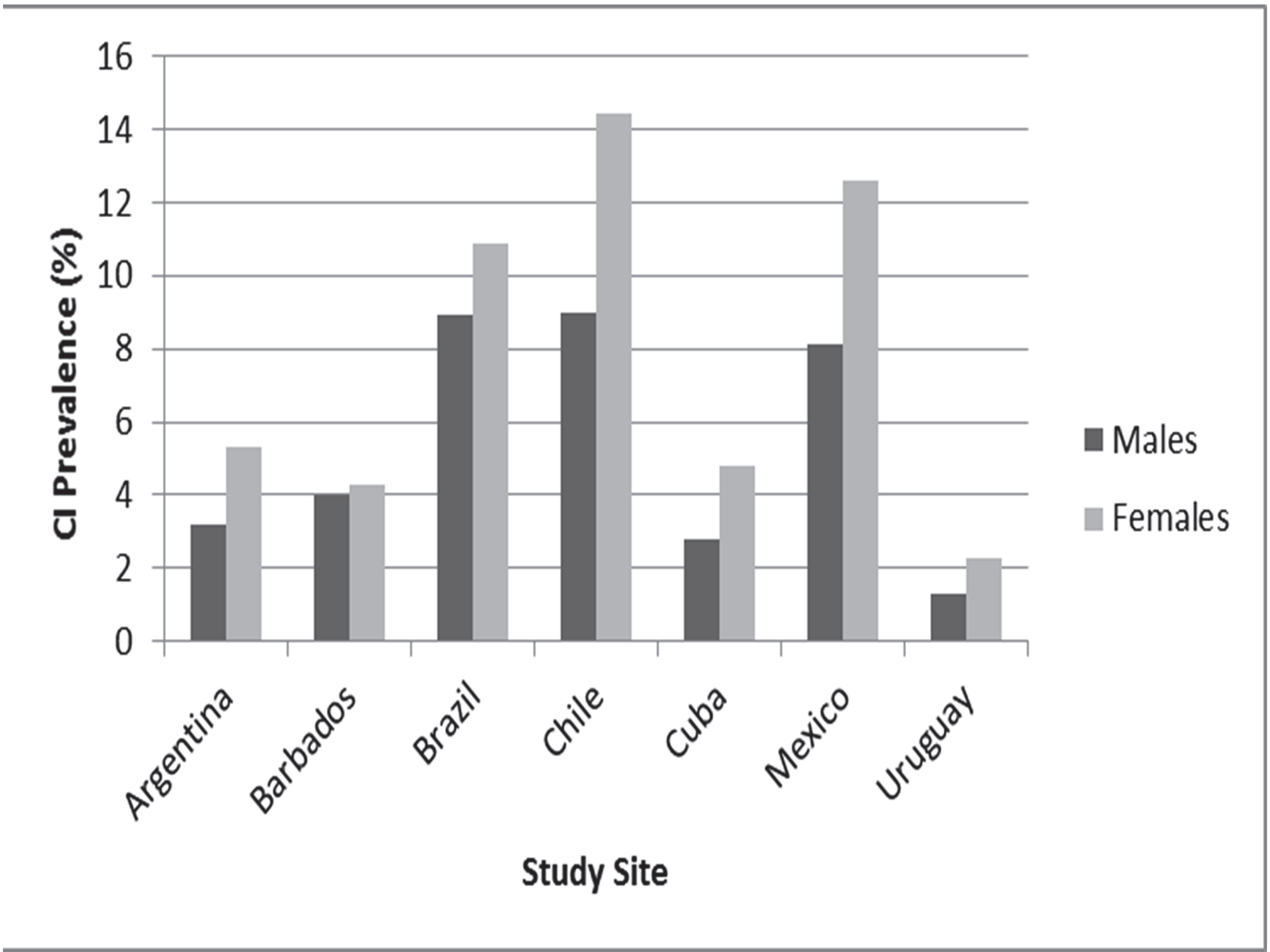

Fig 1. Cognitive Impairment Prevalence by Country and Gender. The cognitive impairment prevalence percentages for each of the seven Latin American and Caribbean countries is shown in this bar graph. Results are stratified by gender.

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odds of CI were not significantly different between Barbados and Argentina (reference) [OR 0.871; CInt (0.564–1.345).

Logistic regression analysis was subsequently performed to assess the impact of age, gender and education levels on cognitive status in each country separately. In Argentina, Barbados, Brazil, Chile, Cuba and Mexico the log odds of CI increase linearly as age increases. Thus a one year increase in age increases the odds of CI by 1.120 (95% CInt 1.077–1.165) in Argentina, 1.169 (95%CInt 1.129–1.211) in Barbados, 1.108 (95%CInt 1.081–1.136) in Chile and 1.099 (95%CInt 1.064–1.134) in Cuba. A quadratic age term significantly improved the models for Brazil (p = 0.044) and Mexico (p = 0.008). In Brazil for example, holding gender and education level constant, increasing age from 60 to 61 increases the odds of CI by 1.019 (95% CInt 0.935–1.111) while increasing age from 70 to 71 increases the odds of CI by 1.075 (95% CInt 1.034–1.119) and increasing age from 80 to 81 increases the odds of CI by 1.135 (95% CInt 1.097–1.174). In Mexico, holding gender and education level constant, increasing age from 60 to 61, 70 to 71 and 80 to 81 increases the odds of CI by 0.960 (95% CInt 0.879–1.049), 1.047 (95% CInt 1.011–1.085) and 1.142 (95% CInt 1.083–1.205) respectively. Conversely, the odds of CI

Table 2. TLE, CILE and CIFLE according to age based on MMSE results from the SABE Study (Upper and Lower 95% Confidence Intervals in Brackets).

	Argentina	Barbados	Brazil	Chile	Cuba	Mexico	Uruguay
Males Aged 60							
TLE	17.7	19.4	17.6	19.1	19.7	19.3	17.6
CILE	0.8	1.1	0.9	0.8	0.7	1.0	0.8
CIFLE	16.9(16.5 17.3)	18.3(18.1 18.6)	16.7(16.4 17.0)	18.3(17.9 18.6)	19.0(18.7 19.3)	18.3(17.9 18.7)	17.0(16.8 17.3)
%CIFLE/TLE	95.2	94.5	95.0	95.8	96.6	94.8	97.0
Females Aged 60							
TLE	22.5	22.0	20.2	22.8	22.5	21.4	22.5
CILE	2.5	1.3	1.8	3.1	2.1	2.1	2.0
CIFLE	20.0(19.4 20.6)	20.7(20.2 21.1)	18.4(18.1 18.7)	20.1(19.7 20.6)	20.0(19.6 20.4)	18.8(18.2 19.3)	20.1(19.6 20.5)
%CIFLE/TLE	88.8	94.1	91.2	88.5	89.0	87.8	89.1
Males Aged 80							
TLE	6.3	6.0	6.8	6.8	6.8	7.2	6.5
CILE	0.1	1.2	0.8	0.2	0.5	0.3	0.5
CIFLE	6.2(5.8 6.5)	4.8(4.5 5.2)	6.2(6.0 6.5)	6.6(6.3 6.9)	6.3(6.0 6.6)	6.9(6.4 7.3)	6.0(5.6 6.4)
%CIFLE	98.4	80.2	91.3	97.0	93.2	95.0	92.9
Females Aged 80							
TLE	7.8	7.5	7.2	8.2	8.2	7.8	7.9
CILE	0.7	1.2	1.2	1.5	1.5	0.7	1.0
CIFLE	6.4(5.8 7.1)	6.7(6.3 7.2)	6.0(5.6 6.3)	6.7(6.2 7.2)	6.7(6.2 7.1)	7.1(6.6 7.7)	6.9(6.4 7.3)
%CIFLE	82.4	89.4	82.8	82.1	81.2	91.3	87.0

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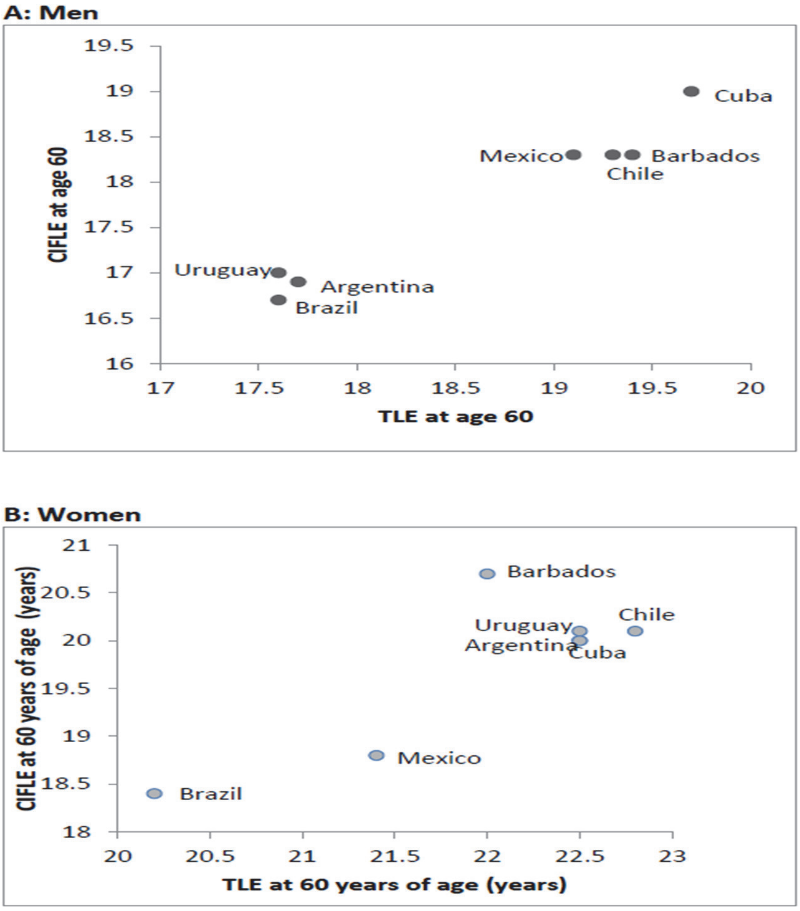
decreased with age in Uruguay. The statistically significant quadratic age term (p = 0.039) included in the final regression model for Uruguay showed that an increase in age from 60 to 61, 70 to 71 and 80 to 81 decreases the odds of CI by 1.723 (95% CInt 1.146–2.591), 1.361 (95% CInt 1.122–1.651) and 1.075 (95% CInt 0.976–1.184) respectively.

A significant gender effect was observed in Mexico (p = 0.006) with males having lower odds of CI compared to females after adjusting for age and education level [OR 0.464; 95% CInt (0.268–0.806)].

In Brazil [OR 4.848; 95% CInt (1.173–20.044)], Chile [3.107 (1.098–8.793)], Cuba [2.295 (1.247–4.225)] and Mexico [3.838 (1.368–10.765)], the odds of CI are increased for persons with a low education level when compared to persons with a high education level.

Table 2 presents TLE, CILE, CIFLE and %CIFLE/TLE for males and females by country and at ages 60 and 80 years. At age 60 years, TLE for males varies from a low of 17.6 years (Brazil and Uruguay) to a high of 19.7 years (Cuba). For females, TLE is generally longer than males and at age 60 varied from a high of 22.8 years (Chile) to a low of 20.2 years (Brazil). By the age of 80, the longest TLE and CIFLE for males were observed in Mexico (TLE: 7.2 years, CIFLE: 6.9 years) while the shortest TLE and CIFLE were observed in Barbados (TLE: 6.0 years, CIFLE: 4.8 years). For females at age 80, Chileans and Cubans recorded the longest TLE (8.2 years) while Mexicans recorded the longest CIFLE (7.1 years). See Fig. 2 below.

At age 60, males in Uruguay (97.0%) and Cuba (96.6%) spend the greatest proportion of their remaining lives free of CI when compared to those at other study sites despite males in Uruguay having the shortest TLE at age 60. Among females aged 60, the greatest proportion of life is spent free of CI in Barbados (94.1%) and Brazil (91.2%). At age 80, males in Argentina (98.4%) and Chile (97.0%) and females in Mexico (91.3%) and Barbados (89.4%) spend the greatest proportion of their lives free of CI.



C	Men		Women	
	TLE	CIFLE	TLE	CIFLE
Argentina	17.7	16.9	22.5	20.0
Barbados	19.4	18.3	22.0	20.7
Brazil	17.6	16.7	20.2	18.4
Chile	19.1	18.3	22.8	20.1
Cuba	19.7	19.0	22.5	20.0
Mexico	19.3	18.3	21.4	18.8
Uruguay	17.6	17.0	22.5	20.1

Figure 2: Total Life Expectancy (TLE) and Cognitive Impairment-Free Life Expectancy (CIFLE) at 60 years of age for Countries under Study. (A) and (B) shows scatter graphs for men and women, respectively. (C) Data for scatter graphs.

Fig 2. TLE and CIFLE at age 60 by Country and Gender. Total Life Expectancy (TLE) and Cognitive Impairment-Free Life Expectancy (CIFLE) comparisons can be made among each of the seven countries included in the study.

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To see the extent to which educational level in a country explained the observed differences in CIFLE we fitted meta-regression models to CIFLE at age 60 separately for males and females but found no association (males: 0.408; females: 0.695). This conclusion remained when the analysis was repeated excluding Cuba which had by far the largest percentage with high education (S1 and S2 Figs).

Discussion

In the LAC countries under study, the odds of CI increased with age in all countries except Uruguay. A significant gender effect was observed only in Mexico with males having lower odds of CI compared to females. For males TLE at age 60 years was highest in Cuba and lowest in Brazil and Uruguay. CIFLE at age 60 for males was highest in Barbados, Chile and Mexico and lowest in Brazil. However, although Uruguay had the lowest TLE and did not have the highest CIFLE at age 60, Uruguayan men experienced the greatest proportion of their remaining life free of CI (97.0%). For females at age 60 years, TLE was highest in Chile and lowest in Brazil. CIFLE for females at age 60 was highest in Barbados and lowest in Brazil. Although higher odds of CI were observed in those with low education in Brazil, Chile, Cuba and Mexico, level of education did not appear to explain the differences in CIFLE at age 60 in LAC countries.

The differences observed among countries in our study are noteworthy and future research is necessary to determine the exact cause. Possible explanations include the effect of confounding factors not controlled for such as race/ethnicity, or differences in the application of the survey instrument at each study site. In addition, published research indicates that among the study countries there is great variation in the structure of the healthcare systems and the role played by the public health sector in protecting the health of the older population and these could account for the differences observed between countries [27].

Worth noting is that while the Uruguay sample had a higher mean age than Mexico (70.94 and 64.71 respectively), TLE at age 60 in Mexico is much higher. This may be explained by the oversampling of the target population in Mexico where all eligible individuals found in a target home were interviewed compared to Uruguay where only one individual was selected per household [20]. It is also possible that in Uruguay stratification and subsequent sampling was defined by socioeconomic as well as geographic and global indicators while in Mexico stratification may have been based solely on geography [27]. Reports on cognitive impairment of older people in developing countries are rare. However, the Mexican Health Ageing Study has produced data estimating prevalence of CI (no dementia) that can be used for comparison with results obtained in the present study. Published data from the Mexican Study estimates CI prevalence at 28.7% [28]. These estimates are higher than those obtained in the present study for the Mexican population (approximately 10.8%) and may reflect the fact that SABE data was collected from city dwellers only who may have greater access to health care, belong to higher socio-economic groupings and have a healthier diet. Additionally, differing methodologies used for diagnosis of CI may have led to variations in results.

Studies on dementia-free life expectancy (DFLE) for some Latin American countries (Uruguay, Chile and Brazil) have been published and estimates range from 3.4% to 7.1% [28]. The results of the present study provide CI prevalence estimates in these countries between 1.9% and 12.5%.

Comparisons with developed countries such as Australia, Canada and England and Wales provide much needed perspective. An analysis of DFLE in Australia during the period 2004–2006 revealed that males and females aged 65 were expected to live a further 18.3 and 21.5 years respectively [14]. Of these years, males could expect to have a DFLE of 17.1 years and females 19.5 years [14]. Figures for the Canadian population are similar, Canadian males and females aged 65 are expected to live a further 16.4 years and 19.4 years respectively. Of these years, 13.8 years for males and 17.2 years for females are expected to be lived free from CI [18]. When compared to Australian and Canadian males, TLE and CIFLE are lower in all LAC countries. For example in Cuba, the country with the highest TLE and CIFLE at age 65, a male is expected to live a further 15.9 years of which 15.3 would be spent CI-free. When comparisons are made among females, the TLE and CIFLE for Australian females are higher than those in Canada but LAC countries record the lowest estimates. In Australia, a female aged 65 is expected to live a further 21.5 years of which 19.5 would be spent free of CI while in Chile, the LAC country with the highest TLE at age 65, a female is expected to live a further 18.7 years of which 16.2 would be spent CI-free.

The Medical Research Council Cognitive Function and Ageing Study (MRC CFAS) allows for comparisons between LAC countries and the older population in England and Wales in 1991 [29]. In both settings, men live shorter lives than women. Among both sexes, TLE is higher across all age-groups in LAC countries when compared to that observed in England and Wales. For instance, males in Cuba and Barbados at age 65 can expect to live a further 15.9 and 15.7 years respectively while those in England and Wales can expect to live a further 14.1 years. In the case of females at 65 years of age those in England and Wales have a TLE of 17.8 years and a CILE of 1.2 years. This is lower than the CILE for the same age in all LAC study countries. It must be noted though these comparisons are based on estimates over a decade apart (CFAS:1991, LAC 1999–2000) [29].

The effect of education on health outcomes including cognitive impairment has been published in relation to previous studies [10, 30]. The results of this study, which show that the odds of CI are greater in persons with low education levels, support previous research from the United Kingdom which concluded that there is a substantial burden of life expectancy with CI for groups with low education [10, 30].

Among the limitations of this current study is the inability to disaggregate CI by type of dementia. However, SABE represents the only comprehensive cross national study on the health of elders in the LAC region and while likely to have underestimated prevalence estimates due to its focus on city dwellers, its results are useful. Secondly, no data were collected from adults living in institutions in any of the study countries and so may not be representative of that population. Research indicates though that the percentage of the population in institutions in LAC countries is quite small and so this bias is also likely to be small [31].

The main strength of this study is the fact that CI and CI free life expectancies have not been published for such a wide range of LAC countries prior to this and provide useful data for policy makers to assess healthy ageing trends.

Conclusion

The results from this study are consistent with other published findings which have indicated that age, sex and education level are significant predictors of cognitive status. Novel though is the comparison of healthy life expectancies among Latin American and Caribbean countries and these show substantial differences in the absolute years lived and the proportion of remaining life spent free of cognitive impairment. These results provide a greater understanding of the burden of CI in Latin America and the Caribbean and highlight the need for follow-up surveys to be conducted as their populations continue to age.

Supporting Information

S1 Fig. Meta-regression Results—Relationship between Education Level and CIFLE at Age 60 Males. Shows the extent to which educational level in a country explained the observed differences in Cognitive Impairment-Free Life Expectancy (CIFLE) at age 60 separately for males. (TIF)

S2 Fig. Meta-regression Results—Relationship between Education Level and CIFLE at Age 60 Females. Shows the extent to which educational level in a country explained the observed

differences in Cognitive Impairment-Free Life Expectancy (CIFLE) at age 60 separately for females.
(TIF)

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Author Contributions

Conceived and designed the experiments: KAM. Performed the experiments: KAM CJ TF. Analyzed the data: KAM CJ TF KJA. Contributed reagents/materials/analysis tools: KAM CJ TF KJA. Wrote the paper: KAM CJ TF KJA.

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Article

Role of Dietary Pattern Analysis in Determining Cognitive Status in Elderly Australian Adults

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Abstract: Principal Component Analysis (PCA) was used to determine the association between dietary patterns and cognitive function and to examine how classification systems based on food groups and food items affect levels of association between diet and cognitive function. The present study focuses on the older segment of the Australian Diabetes, Obesity and Lifestyle Study (AusDiab) sample (age 60+) that completed the food frequency questionnaire at Wave 1 (1999/2000) and the mini-mental state examination and tests of memory, verbal ability and processing speed at Wave 3 (2012). Three methods were used in order to classify these foods before applying PCA. In the first instance, the 101 individual food items asked about in the questionnaire were used (no categorisation). In the second and third instances, foods were combined and reduced to 32 and 20 food groups, respectively, based on nutrient content and culinary usage—a method employed in several other published studies for PCA. Logistic regression analysis and generalized linear modelling was used to analyse the relationship between PCA-derived dietary patterns and cognitive outcome. Broader food group classifications resulted in a greater proportion of food use variance in the sample being explained (use of 101 individual foods explained 23.22% of total food use, while use of 32 and 20 food groups explained 29.74% and 30.74% of total variance in food use in the sample, respectively). Three dietary patterns were found to be associated with decreased odds of cognitive impairment (CI). Dietary patterns derived from 101 individual food items showed that for every one unit increase in ((Fruit and Vegetable Pattern: $p = 0.030$, OR 1.061, confidence interval: 1.006–1.118); (Fish, Legumes and Vegetable Pattern: $p = 0.040$, OR 1.032, confidence interval: 1.001–1.064); (Dairy, Cereal and Eggs Pattern: $p = 0.003$, OR 1.020, confidence interval: 1.007–1.033)), the odds of cognitive impairment decreased. Different results were observed when the effect of dietary patterns on memory, processing speed and vocabulary were examined. Complex patterns of associations between dietary factors and cognition were evident, with the most consistent finding being the protective effects of high vegetable and plant-based food item consumption and negative effects of 'Western' patterns on cognition. Further long-term studies and investigation of the best methods for dietary measurement are needed to better understand diet-disease relationships in this age group.

Keywords: dietary pattern; principal component analysis; cognitive impairment; Australia

1. Introduction

Cognitive impairment is a condition in which a person has difficulty with memory, learning, concentrating or making decisions that affect their daily life [1]. Diet is among several modifiable factors found to influence cognitive function [2–4]. Age is presently the strongest known predictor for cognitive decline, and cognitive impairment (CI) has been shown to adversely affect quality of life and functional ability [5,6]. Risk reduction is especially important because there is still no effective treatment for dementia [7].

Studies aimed at elucidating the association between diet and cognitive function have utilised both the single nutrient and dietary pattern approaches [8,9]. While the single-nutrient approach has addressed various public health problems, many researchers theorise that due to high correlations between individual food constituents, there should be a shift toward analysis using a dietary pattern approach [10,11]. Evidence on the effect of dietary lipids, B-vitamins, antioxidants, fish, alcohol, vegetables and legumes have all produced varying results, and further research is needed into biomarkers for particular nutrients and cognitive endpoints in order for any definitive population-based conclusions to be reached [2,12–15]. Diets low in saturated fat, high in legumes, fruits and vegetables, moderate in ethanol intake and low in meat and dairy have also been highlighted as being beneficial to neurological function. One of the most studied dietary patterns is the Mediterranean diet, a diet rich in cereals, olive oil, fish, fruits and vegetables and low in dairy and meat, with a moderate consumption of red wine. This diet has been linked to increased survival, reduced risk of cancers, cardiovascular disease, longevity and cognitive impairment [16]. However, it is important to consider that there may be other dietary patterns, yet to be identified, that may have similar benefits and that can be applied to various sociocultural and demographic settings.

Few studies have examined the effect of dietary patterns on cognitive function using a data-driven method and even fewer of these studies have utilised Australian data. We identified only two studies utilising a data-driven approach to dietary analysis that have examined links with cognition in an Australian sample. The first used data from the Melbourne Collaborative Cohort Study in conducting factor analysis to determine the effect of dietary intake on psychological distress in older Australians [17] and the second utilised data from the Personality and Total Health (PATH) Through Life Study to examine the diet-depression relationship in three cohorts [18].

PCA is a data-driven approach that reduces a large number of food variables into a smaller set that captures the major dietary traits in the population [19]. In nutritional epidemiology, PCA can be used to investigate exposure-disease associations. As it relates to older age groups, such information can serve to develop age-specific guidelines and policies. One of the major criticisms of PCA, however, is that results can differ based on the methods employed during variable reduction and classification [20,21] and there is presently no accepted gold standard for dietary analysis to guide researchers.

The present study therefore has two aims. First, it addresses the question of how classification systems used to reduce food variables before the application of PCA affect the observed association between diet and cognitive function. Second, it evaluates the association between dietary patterns and cognitive function in a population-based cohort of Australian adults. In addition, it aims to determine the variance in food use explained by the different variable reduction methods employed, *i.e.* using 101 individual food items, 32 food groups and 20 food groups.

2. Experimental Section

2.1. Study Design and Sample

The study utilised secondary data derived from the AusDiab study, a population-based national survey of the general (non-institutionalised) Australian population aged 25 years and older [22]. The baseline examination was undertaken in 1999–2000 (n = 11,247), with follow-ups conducted in 2004–2005 (n = 8798) and 2011–2012 (n = 6186) [22]. Dietary data were obtained from a sub-group of the sample using a questionnaire (Wave 1: n = 3298) [22]. Measurement of cognitive function was conducted on those who attended survey sites in the third Wave of data collection (n = 4764) [23]. The present study focuses on the older segment of the sample (age 60+ at baseline) that completed the food frequency questionnaire at Wave 1 and the mini-mental state examination and tests of memory, verbal ability and processing speed at Wave 3 (n = 577).

We excluded 2721 participants from the current analysis since these participants had no dietary and/or cognitive data recorded.

2.2. Cognitive Outcome Measurement

The mini-mental state examination (MMSE) was used for data collection in 2011–2012 (AusDiab Wave 3) to determine CI status. Participants were classified based on their MMSE score as either cognitively impaired (score of 0–23) or not cognitively impaired (score of 24–30) [24].

The California Verbal Learning Test (CVLT) was used to assess memory using a 16-point scoring system. For this test, participants were asked to recall and repeat a list of 16 common shopping items that had been read to them by an interviewer. During a short delay of 20 min, during which participants were given other tasks to perform, the interviewer then asked the participant to recall the 16 common shopping list items again (delayed recall). The Spot-the-Word test (STW) was used in this study to test participants' vocabulary and verbal knowledge with scores ranging from 0 to 60. STW testing involved presenting participants with pairs of items, one of which was a real word and the other a non-word, and then requiring participants to identify the word. Performance on the STW has not been shown to decline with age and is highly correlated with verbal acumen [25]. Finally, processing speed was tested using the Symbol-Digit Modalities Test (SDMT). Participants were provided with a reference key and asked to pair geometric figures with specific numbers. Using the SDMT, participants were scored from 0–60 on the number of correct answers provided in 90 s.

2.3. Food Consumption Data and Classification

The AusDiab semi-quantitative food frequency questionnaire consisted of 121 items that asked participants about their consumption of 101 food items [26]. This questionnaire assessed usual intake and recorded the amount and types of specific food items consumed by participants. In some cases, for example casseroles and potatoes, pictures of serving sizes were provided so that persons could indicate whether they had more or less of a given food item each day and each week, using the past 12 months as a reference. Participants were asked to specify the number of times they had specific food items in the past year by checking 1 of 10 frequency categories ranging from 'never' to 'three or more times per day'. The average daily intake of food weight in grams was subsequently computed and used in the present analysis.

Three methods were used in order to classify these foods before applying PCA. In the first instance, the 101 individual food items asked about in the questionnaire were used (no categorisation). In the second and third instances, foods were combined and reduced to 32 and 20 food groups, respectively, based on nutrient content and culinary usage—a method employed in several other published studies for PCA [21,27] (see Table 1). Some foods were not categorised and were kept separate since they did not comfortably fit into any of the categories, e.g. pizza and meat pies [21,28]. More specifically, for the reduction of 101 items to 32 food groups, individual items were classed into groups, e.g., the item 'Processed Meats' was a tally of a participant's bacon, ham, salami and sausage consumption in grams/day, while the item 'Red Meats' was a tally of beef, pork, lamb, veal and hamburger in grams/day. In the final classification system, the 32 food groups were further categorised into broader groups, which resulted in 20 food groups, e.g. the item 'Meats' was a tally of a participant's 'Processed Meats' and 'Red Meats' consumption in grams/day.

Table 1. Food groupings used in the dietary pattern analysis.

Method 1	***Method 2***	***Method 3***
Food Item	**Food Category**	**Food Category**
Bacon, ham, salami, sausages	Processed Meats	Meat
Beef, pork, lamb, veal, hamburger	Red Meats	Meat
Fish, fried fish, tinned fish	Fish	Fish
Chicken	Poultry	Poultry
Eggs	Eggs	Eggs
Butter	Butter	Fats and Oils
Margarine, poly/mono-unsaturated margarine	Margarine	Fats and Oils
Butter and margarine blends	Butter and Margarine Blends	Fats and Oils

Table 1. *Cont.*

Reduced-fat/skim milk, low-fat cheese, yoghurt	Low-fat Dairy Products	Dairy
Full-cream milk, hard/firm/soft/ricotta/cottage/cream cheese, ice-cream, flavoured-milk drink	High-fat Dairy Products	Dairy
Red/white/fortified wine	Wine	Alcohol
Light/heavy beer	Beer	Alcohol
Other spirits	Other Spirits	Alcohol
Tinned fruit, oranges, apples, pears, bananas, melon, pineapple, strawberries, apricots, peaches, mango	Fruit	Fruit
Fruit juice	Fruit Juice	Fruit Juice
Cabbage, cauliflower, broccoli	Cruciferous Vegetables	Vegetables
Carrot, pumpkin	Dark-yellow Vegetables	Vegetables
Tomatoes, tomato sauce	Tomatoes	Vegetables
Lettuce, spinach	Green, leafy Vegetables	Vegetables
Peas, green beans, bean sprouts, baked beans, tofu, other beans, soya milk	Legumes	Vegetables
Cucumber, celery, beetroot, mushrooms, zucchini, capsicum, avocado	Other Vegetables	Vegetables
Onion, garlic	Garlic and Onions	Vegetables
Potatoes	Potatoes	Vegetables
Chips	Chips/French fries	Chips/French Fries
All-bran, bran flakes, Weet-Bix, cornflakes, porridge, muesli, wholemeal/rye/multi-grain bread	Whole Grains	Whole Grains
High-fibre white/white bread, rice, pasta, crackers	Refined Grains	Refined Grains
Pizza	Pizza	Pizza
Sweet biscuits, cakes, crisps, chocolate	Snacks	Snacks
Nuts, peanut butter	Nuts	Nuts
Jam, vegemite	Condiments	Condiments
Sugar	Sugar	Sugar
Meat pies	Meat Pies	Meat Pies

2.4. Statistical Analysis

PCA using SPSS version 22 was conducted to identify underlying dietary patterns. In determining the number of components to retain for further analysis, we considered component eigenvalues greater than 1 along with examination of scree plots. Components were rotated by an orthogonal (varimax) rotation to improve interpretability. Overall though, the comprehensibility and interpretability of the rotated factors were considered along with the aforementioned criteria. Similar to other studies, derived components were labelled based on our description of the observed patterns [29].

Dietary pattern scores were calculated for each individual at Wave 1 using all three classification methods (individual food items, 32 food groups and 20 food groups). Scores for an observed pattern were computed using the following equation: $i = \sum_j \left[\left(b_{ij}/\lambda_i\right)X_j\right]$ [29]. Variables with factor loadings of ≥0.30 were included in the weighted average [30,31].

Logistic regression analysis was performed to determine the association between dietary pattern scores at Wave 1 and cognitive status at Wave 3 using all three food item categorisation methods, *i.e.* PCA based on 101 individual food items, 32 food groups or 20 food groups. The interaction between dietary pattern score and exercise time was also examined to determine whether there was any association with cognitive status using all three food categorisation methods.

Generalized linear models (GLM) were used to estimate the associations between dietary pattern scores at Wave 1 and memory, verbal ability and processing speed using all three food variable reduction methods.

3. Results

Descriptive statistics for the sample are presented in Table 2. A total of 577 participants (49.22% female) had both diet and cognitive data recorded at Wave 1.

Table 2. Descriptive statistics at Wave 1 for the AusDiab sample included in the study (n = 577).

Variables	Wave 1
Age Range	60–83
Mean Age (SD)	66.07 (4.85)
Female (%)	284 (49.22)
BMI (SD)	26.89 (4.09)
Secondary School (%)	242 (24.4)
Tertiary Level (%)	229 (40.1)
Other - Trade, Technician, Primary Only (%)	100 (17.4)
Current Smoker (%)	29 (5.1)
Ex-Smoker (%)	182 (32.0)
Non-Smoker	357 (62.9)
Exercise Mean (SD), mins./week	292.45 (324.21)
MMSE Score	27.41 (2.44)
CVLT Score	5.17 (2.30)
STW Score	50.30 (6.84)
SDMT Score	38.63 (10.74)
Impaired (%)	44 (7.63)

3.1. Dietary Pattern Analysis

Classification method affected the number and components of the patterns identified. Variable reduction using 20 food groups explained a greater proportion of variance in the sample than variable reduction using 32 food groups and 101 individual food items. Use of 20 food groups explained 30.74% of total variance in food use in the sample. Comparatively, use of 101 individual foods explained 23.22% and use of 32 food groups explained 29.74% of total variance in food use.

Table 3. Results of logistic regression analyses showing associations between CI at Wave 3 and dietary patterns obtained using 101 food items, 32 food groups and 20 food groups at Wave 1 (odds ratios with 95% confidence intervals shown in brackets).

	Dietary Pattern 1	**Dietary Pattern 2**	**Dietary Pattern 3**	**Dietary Pattern 4**	**Dietary Pattern 5**	**Dietary Pattern 6**	**Dietary Pattern 7**
101 Food Items	Fruit & Vegetable	Snack & Processed Foods	Vegetable	Meat	Fish, Legumes & Vegetable	Vegetable, Pasta & Alcohol	Dairy, Cereal & Eggs
OR (95% CI)	1.061 (1.006–1.118) *p* = 0.030 *	1.051 (0.967–1.143) *p* = 0.239	0.986 (0.916–1.061) *p* = 0.701	1.005 (0.964–1.048) *p* = 0.806	1.032 (1.001–1.064) *p* = 0.040 *	1.000 (0.965–1.037) *p* = 0.994	1.020 (1.007–1.033) *p* = 0.003 **
32 Food Groups	Western	Prudent	Vegetable, Grains & Wine	High-Fat			
OR (95% CI)	1.005 (0.994–1.016) *p* = 0.409	0.997 (0.984–1.010) *p* = 0.643	1.008 (0.995–1.020) *p* = 0.229	0.999 (0.992–1.007)			
20 Food Groups	Variety	Western	Dairy, Grains & Alcohol				
OR (95% CI)	1.006 (0.994–1.018) *p* = 0.333	1.008 (0.986–1.031) *p* = 0.497	1.001 (0.998–1.005) *p* = 0.383				

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time; * $p < 0.05$; ** $p < 0.01$.

3.1.1. Wave 1 Dietary Patterns Using 101 Individual Food Items

Seven dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Supplementary Table 1.

The first dietary pattern identified was labelled 'Fruit and Vegetable' because of the high loadings of unprocessed fruit and vegetables observed. The second dietary pattern identified was labelled 'Snack and Processed Food' due to the high factor loadings observed for foods that could be qualified as such, e.g., cakes, jam, ice cream, sausages, and salami. Dietary pattern labels for the other observed dietary structures can be viewed in Supplementary Table 1. Together, the dietary patterns identified accounted for 23% of total variance in the sample.

3.1.2. Wave 1 Dietary Patterns Using 32 Food Groups

After applying PCA, four dietary patterns were extracted. The rotated component matrix with factor loadings is shown in Supplementary Table 2.

The first pattern identified was labelled 'Western' because of the predominantly high loadings of processed meats, refined grains and convenience foods. The second dietary pattern identified was labelled 'Prudent' and had characteristically high factor loadings of fish, vegetables and fruit. Dietary pattern labels for the other observed dietary structures can be viewed in Supplementary Table 2. Together, the dietary patterns identified accounted for 30% of total variance in the sample.

3.1.3. Wave 1 Dietary Patterns Using 20 Food Groups

Three dietary patterns were extracted using PCA with varimax rotation. The rotated component matrix with factor loadings is shown in Supplementary Table 3.

The first pattern identified was labelled 'Variety' because of the high loadings of a wide variety of foods—vegetables, fruit, fish, meat and nuts. The second dietary pattern was labelled 'Western' because of the high factor loadings of high-fat and high-sugar foods. The final dietary pattern was labelled 'Dairy, Grains and Alcohol' due to the high factor loadings of these foods recorded. Together, these dietary patterns identified accounted for 31% of total variance in the sample.

3.2. Dietary Pattern as a Predictor of CI Using the MMSE

Logistic regression analysis using dietary pattern scores obtained from all three variable reduction techniques (*i.e.*, 101 individual food items, 32 food groups and 20 food groups) was conducted to examine the relationship between dietary pattern and CI. Covariates included the independent variables age, sex, energy, education, BMI, smoking status, exercise time and Spot-the-Word (as a control for premorbid intelligence) [32].

The only significant dietary predictors of CI were obtained using 101 individual food items. Three of the seven dietary patterns identified were observed to be significant predictors of CI. For every one unit increase in these pattern scores, the odds of CI decreased ((Fruit and Vegetable Pattern: $p = 0.030$, OR 1.061, confidence interval: 1.006–1.118); (Fish, Legumes and Vegetable Pattern: $p = 0.040$, OR 1.032, confidence interval: 1.001–1.064); (Dairy, Cereal and Eggs Pattern: $p = 0.003$, OR 1.020, confidence interval: 1.007–1.033)).

Table 4. Results of GLM showing associations between cognitive function at Wave 3 and dietary patterns obtained using 101 individual food items, 32 food groups and 20 food groups at Waves 1, 2 and 3 (β values with Standard Errors shown in brackets).

	Dietary Pattern 1	**Dietary Pattern 2**	**Dietary Pattern 3**	**Dietary Pattern 4**	**Dietary Pattern 5**	**Dietary Pattern 6**	**Dietary Pattern 7**
101 Food Items	Fruit & Vegetable	Snack & Processed Foods	Vegetable	Meat	Fish, Legumes & Vegetable	Vegetable, Pasta & Alcohol	Dairy, Cereal & Eggs
CVLT	0.012 (0.013) *p* = 0.336	0.020 (0.015) *p* = 0.186	−0.001 (0.012) *p* = 0.930	0.000 (0.005) *p* = 0.984	−0.002 (0.007) *p* = 0.793	0.004 (0.006) *p* = 0.551	−4.474 (0.002) *p* = 0.986
SDMT	0.097 (0.057) *p* = 0.091	0.060 (0.067) *p* = 0.365	0.013 (0.054) *p* = 0.801	0.014 (0.023) *p* = 0.536	−0.062 (0.032) *p* = 0.054	−0.003 (0.028) *p* = 0.916	−0.016 (0.011) *p* = 0.149
STW	0.077 (0.039) *p* = 0.051	0.080 (0.046) *p* = 0.086	0.046 (0.037) *p* = 0.224	0.007 (0.020) *p* = 0.722	0.000 (0.022) *p* = 0.994	0.000 (0.021) *p* = 0.982	0.002 (0.008) *p* = 0.799
32 Food Groups	Western	Prudent	Vegetable, Grains & Wine	High-Fat			
CVLT	−0.008 (0.003) *p* = 0.001 **	−0.005 (0.003) *p* = 0.067	0.001 (0.003) *p* = 0.764	−0.001 (0.001) *p* = 0.711			
SDMT	−0.024 (0.011) *p* = 0.035 *	−0.035 (0.011) *p* = 0.002 **	0.024 (0.012) *p* = 0.034 *	0.005 (0.006) *p* = 0.403			
STW	−0.006 (0.008) *p* = 0.467	−0.006 (0.008) *p* = 0.425	0.013 (0.008) *p* = 0.119	0.001 (0.005) *p* = 0.774			
20 Food Groups	Variety	Western	Dairy, Grains & Alcohol				
CVLT	−0.003 (0.003) *p* = 0.272	−0.004 (0.005) *p* = 0.376	−0.002 (0.001) *p* = 0.005**				
SDMT	−0.026 (0.011) *p* = 0.018 *	−0.007 (0.021) *p* = 0.740	−0.005 (0.003) *P* = 0.149				
STW	−0.008 (0.008) *p* = 0.291	0.002 (0.015) *p* = 0.901	−0.001 (0.002) *p* = 0.618				

Model adjusted for age, sex, energy, education, BMI, smoking status, STW and exercise time; * $p < 0.05$, ** $p < 0.01$.

When the interaction term 'dietary pattern score × exercise time' was included in the model, no significant results were obtained.

3.3. Dietary Pattern as a Predictor of Memory, Vocabulary and Verbal Knowledge and Processing Speed

Using dietary pattern scores calculated from 101 individual food items, there were no dietary patterns observed to be significantly predictive of memory, processing speed or verbal knowledge.

Using 32 food groups, however, the 'Western' dietary pattern was a predictor of poorer memory and processing speed ($\beta = -0.008$, SE = 0.003, $p = 0.001$ and $\beta = -0.024$, SE = 0.011, $p = 0.035$). In addition, the 'Prudent' dietary pattern was also a predictor of poorer processing speed ($\beta = -0.035$, SE = 0.011, $p = 0.002$).

When 20 food groups were used to calculate dietary pattern scores, the 'Dairy, grains and alcohol' dietary pattern was predictive of poorer memory while the 'Variety' dietary pattern was associated with poorer processing speed ($\beta = -0.002$, SE = 0.001, $p = 0.005$ and $\beta = -0.026$, SE = 0.011, $p = 0.018$ respectively).

4. Discussion

The present study is one of the few that use a data-driven method of dietary analysis to assess the relationship between diet and cognitive function in older Australian adults. A number of findings from this study are noteworthy. First, the broader the categories used in grouping foods, the greater the variability in food use that was explained. It was observed, however, that the results of logistic regression were more sensitive when dietary analysis was based on individual food items than food groups. From these data we observed that for every one unit increase in 'Fruit and Vegetable', 'Fish, Legumes and Vegetable' and 'Dairy, Cereal and Eggs' dietary pattern scores, the odds of CI decreased.

When looking at the relationship between dietary pattern and memory, processing speed and vocabulary, no significant results were observed using 101 individual food items. Using 32 food groups, the 'Western' dietary pattern was found to be predictive of poorer memory and processing speed, the 'Vegetable, Grains and Wine' pattern was a predictor of better processing speed while the 'Prudent' pattern was predictive of poorer processing speed. Using 20 food groups we observed that the 'Variety' dietary pattern was a predictor of poorer processing speed and the 'Dairy, Grains and Alcohol' pattern predictive of poorer memory.

We found that the method of reducing food variables affected the amount of variance in food use that was explained. Similarly to other published findings, the broader the categories used, the greater the variability in food use explained [21]. We suggest this may be due to the inclusion of foods that are both weakly and strongly correlated with a specific pattern in the broader categorisations which leads to an increase in the information captured [21]. Interestingly, for logistic regression analyses, it was only when the level of detail in the items included in PCA-derived dietary patterns increased that significant associations between diet and cognitive impairment were observed, *i.e.*, it was variable reduction that utilised dietary pattern scores from individual foods that produced the only significant results. This may be because analysis using individual foods captures more meaningful results as it is able to show whether consumption or non-consumption of specific food items is associated with disease.

Our results are consistent with previous studies in showing that diets with high loadings of vegetables and other plant-based food items (fruit, grains and legumes) resulted in reduced odds of disease and improved cognitive function [21,27]. In a study of 6911 Chinese subjects aged 65 and older who formed part of the Chinese Longitudinal Health Longevity Study, lower intakes of vegetables and legumes were associated with cognitive decline when using MMSE as a measure of cognitive function [33]. Multivariate logistic regression showed that always eating vegetables and always consuming legumes were inversely associated with cognitive decline [33]. Additionally, in a study of 2,148 community-based elderly subjects without dementia in New York, higher intakes of cruciferous and dark and green leafy vegetables were found to be associated with a decreased risk of developing AD [34]. The benefits of diets high in vegetables extend beyond the cognitive domain. In a European study aimed to investigate the effect of the Mediterranean diet (MeDi) on mortality, greater adherence was associated with a more than 50% lower rate of all-causes and cause-specific mortality [35]. McCann *et al*. [21], in a study examining the effect of dietary patterns on estimation of endometrial cancer risk, found that dietary patterns high in fruit, vegetables and whole-grains resulted in reduced endometrial cancer risks. Similarly, dietary patterns high in vegetables, grain and fruit have been found to be associated with a modestly lower risk for type 2 diabetes [27]. This seemingly protective association between plant-based foods and disease may be the result of the high concentration of antioxidant nutrients present in vegetables and fruits and their role in suppressing inflammation. There is evidence that oxidative stress and inflammation can lead to impaired cognitive function because of an increase in free radicals and the damage they cause to neuronal cells [14].

The Mediterranean diet (MeDi), one of the most studied dietary patterns, describes a diet rich in cereals, olive oil, fish, fruits and vegetables and low in dairy and meat with a moderate consumption of red wine. This diet has been linked to increased survival, reduced risk of cancers, cardiovascular disease, longevity and CI [11,16,36–38]. In the present study, diets rich in vegetables, grain and wine were found to be predictive of better processing speed and diets high in vegetables and plant-based food items were generally associated with better cognitive outcomes.

Worth noting is the finding that the ‘Prudent’ dietary pattern was predictive of poorer processing speed. This dietary pattern was so labelled because of its high loadings of fish, fruit and vegetables, nuts and whole-grains. Perhaps an explanation of this lies in the method in which food items are prepared or in analysing whether there is actually a protective effect of foods contained in this pattern. For instance, while many studies have examined the effect of fish consumption on cognition, some clarification is still needed on the purported link between the two. In a study of 6150 Chicago residents aged 65 and older to examine whether intake of fish and omega-3 fatty acids protects against age-related cognitive decline, it was reported that fish consumption may be associated with slower cognitive decline with age [39]. Similar findings were also reported by Kalmijn *et al*. in 1997, who found statistically significant decreased risks of AD with higher fish consumption [40]. In two more recent Australian studies, one reported that higher fish consumption was associated with an increased risk of cognitive disorder [15] while the other found no evidence to support the hypothesis that higher proportions of fish intake benefits cognitive performance in normal older adults [41].

The ‘Variety’ dietary pattern was also found to be predictive of poorer processing speed. This pattern, so named because of high factor loadings in a variety of foods, is of interest because dietary guidelines for Australia and the rest of the world highlight the benefits of consuming a wide variety of foods.

Therefore, in food and nutrition policy, there is a need to ensure that messages about the method of food preparation, processing and portion sizes of consumables are equally stressed.

In the present study, the 'Western' dietary pattern was predictive of poorer memory and processing speed. This is supported by other research which has reported that the 'Western' dietary pattern is associated with cognitive decline and reduced executive function [42].

One of the limitations of this study lies in its inability to report disease incidence as cognitive data were only collected at one time point (Wave 3). Additionally, no data were collected on executive function, and dietary intake is self-reported. There is also some subjectivity in determining food groups before application of PCA, but the method of food variable reduction we employed has been widely used in other studies [21,27]. It is also possible that the results observed may represent a selection bias, as only older adults with dietary and cognitive data were included in the study (n = 577). This has the effect of limiting the generalizability of the study's findings. Finally, while we focused on the methodology of grouping foods in this paper, we were still unable to clearly identify guidelines for future researchers to follow. This is a major issue for diet-cognition research and suggests the need for further investigation and development of more robust and consensus-led methodologies in the field.

Despite its limitations, this study adds to the sparse body of literature examining the relationship between dietary patterns and CI among older adults, both in Australia and internationally. Furthermore, the study's focus on older age groups whose dietary patterns have not been widely studied and reported is noteworthy. Finally, the study's ability to answer a methodological question that has been one of the main critiques of PCA makes it noteworthy—how do variable reduction methods before the application of PCA affect the results obtained? This question is significant when examining the relationship between dietary patterns and cognition since there is a level of subjectivity involved in reducing food variables, and these can affect the observed associations with cognitive function [27].

Future studies examining the association between dietary intake and cognitive status will be useful to identify other patterns associated with CI and to examine more nuanced issues as they relate to diet and cognitive function.

5. Conclusions

Our findings showed that diets with high factor loadings of fruit, vegetables and plant-based food items conferred cognitive benefits, while those with high factor loadings of high-fat and convenience foods are linked to poorer cognitive outcomes. These results are similar to those of other studies which show that diets with high loadings of vegetables, fruit and grain reduce the odds of a myriad of diseases [21,27,43]. In addition, we demonstrated that the method of variable reduction in dietary studies may influence results, and suggest that further work is required to establish robust and replicable methods of dietary analysis for use in research into cognitive ageing. Additional studies that focus on the dietary habits of those over age 60 would be useful in order to further elucidate more specific details between dietary patterns, types and amount of fat, protein and carbohydrates, number of calories, and micro and macronutrients that are linked with optimal cognitive function and reduced risk of CI in older adults. Such information is required to provide support for the development of policies that promote optimal cognitive health in ageing.

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Author Contributions

Kimberly Ashby-Mitchell was responsible for designing the study, conducting analyses, interpreting the output of analyses and preparing the manuscript for submission. Anna Peeters interpreted data and revised the manuscript for intellectual content. Kaarin J. Anstey interpreted data and revised the manuscript for intellectual content.

Conflicts of Interest

The authors have reported no conflicts of interest.

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Research Article Open Access

Life Expectancy in Australian Seniors with or without Cognitive Impairment: The Australia Diabetes, Obesity and Lifestyle Study Wave 3

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Abstract:

Objective: To determine prevalence of cognitive impairment (CI) and to estimate life expectancy with and without cognitive impairment in the Australian population over age 60.

Method: Adults aged 60 and older participating in the 12 year follow-up of the Australia Diabetes Obesity and Lifestyle Study (AusDiab) were included in the sample (n=1666). The mean age was 69.5 years, and 46.3% of the sample was male. The Mini-Mental State Examination was used to assess cognitive impairment. Logistic regression analysis was used to determine the effect of predictor variables (age, gender, education), measured at baseline, on cognitive impairment status. The Sullivan Method was used to estimate Total Life Expectancy (TLE), Cognitively Impaired (CILE) and Cognitive Impairment-free life expectancies (CIFLE).

Results: Odds of CI were greater for males than females (OR 2.1, 95% confidence interval: 1.2-3.7) and among Australians with low education levels compared with Australians with high education levels (OR 2.1, 95% confidence interval: 1.2-3.7). The odds of CI also increased each year with age (OR 1.1, (95% confidence interval: 1.0-1.1). It was found that in all age groups females have greater TLE and CIFLE when compared to their male counterparts.

Keywords: Sullivan health expectancy; Cognitive impairment; Australia; Prevalence

Introduction

Increases in life expectancy observed in the past decade have given rise to a need for increased focus on mental health conditions that impair cognitive function and that are strongly associated with increasing age [1]. The calculation of health expectancies has become increasingly relevant to international health policy as emphasis is placed on healthy and active aging. Healthy life expectancy is used to quantify the burden of disease and enables researchers to monitor the overall health of the population [2]. Cognitive impairment affects the functional status and quality of life not only of sufferers but also impacts their relatives and carers [2,3]. Dementia is Australia's third leading cause of death and there is no cure [4].

While data on mental health expectancies are scarce for most countries, previously published data are available for Australia but these are based on a regional study rather than data drawn from a national study [5,6]. Hence we aimed to produce the first Australian estimates of Cognitive Impairment Free Life Expectancy using cognitive function data from a national and population-based study. Additionally, recently published findings have shown a reduction in late life cognitive impairment in the UK, Denmark and Sweden and this moving target of dementia prevalence makes the conduct of this study worthwhile to investigate if similar changes have occurred in Australia [7-9].

Methods

Sample Selection and Survey Protocol and Procedures (AusDiab)

The AusDiab study is a population-based national survey of the general (non-institutionalised) Australian population aged 25 years and over residing in private dwellings in each of the six states and the Northern Territory. A stratified cluster sampling method was used and sample size selection based on estimates of national diabetes prevalence obtained from previous surveys [10]. The baseline examination was undertaken in 1999-2000 (n=11,247), with follow-up conducted in 2004-05 (n=8,798) and 2011-12 (n=6,186). Measurement of cognitive function was conducted on those who attended survey sites in the third wave of data collection (n=4,764). Data were collected using questionnaires, physical examinations, blood sampling, urine collection, anthropometry and blood pressure reading.

Figure 1 below shows the sampling frame for AusDiab follow-up in 2011-12.

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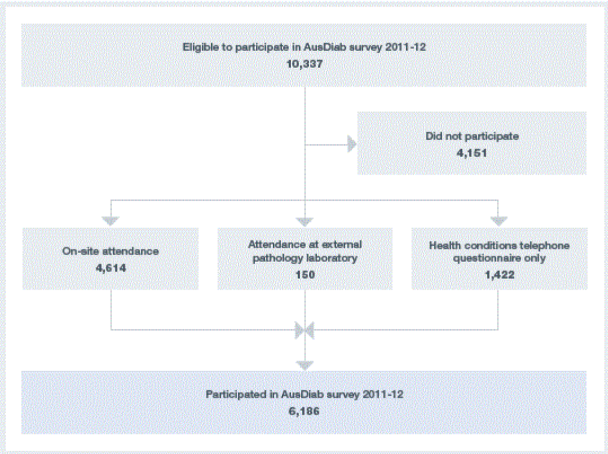

Figure 1: Sampling frame AusDiab follow-up (Source: AusDiab Report, 2013)

Study Methodology

The Mini Mental State Examination (MMSE) was used in data collection 2011-12 (AusDiab wave 3) to determine cognitive outcome with participants classed as being either cognitively impaired (score of 0-23) or not cognitively impaired (score of 24-30) [11]. The MMSE is commonly employed by clinicians to screen for cognitive impairment and dementia [12] and is the most common measure used in research on cognitive health expectancy [12]. Use of this measure allows international comparison of rates of cognitive impairment. It is a sum-score that evaluates various dimensions of cognition (memory, attention and language) and used as an index of global cognitive performance [13]. The MMSE test can be affected by level of education, cultural background and language fluency [14,15].

In this study, a high education level was defined as any learning that occurred after completion of secondary school while a low education level was defined as having either primary and/or secondary school education only.

The Sullivan Method used to estimate population health indicators was applied to determine total life expectancy, life expectancy with impairment and cognitive impairment free life expectancy [16]. This method requires age-specific prevalence (proportions) of the population in healthy and unhealthy states (often obtained from cross-sectional surveys), and age-specific mortality information taken from a period life table [16]. Cognitive Impairment Free Life Expectancy (CIFLE) reflects the number of remaining years, at a particular age, which an individual can expect to live in the absence of disease [2]. For this study, five-year age intervals were analysed with the final age group recorded as age 85+. Five-year age-specific prevalence of CI in Australia was determined using data from the AusDiab 60+ cohort. Data were stratified based on gender. Confidence intervals using this method are only produced for the computation of CI-free life expectancies.

Age-specific population and mortality data were obtained for 2012 from the Australian Bureau of Statistics [17] and cross-sectional prevalence data were obtained from the AusDiab Study (2011-12 wave).

Logistic regression analysis was used to determine the effect of various predictors on cognitive status. The variables age, gender, education level, age^2, age*gender, age*education and gender*education were all considered in developing the model. The final regression model contained 3 predictors (age, gender and education level) each of which had a unique statistically significant contribution to the model.

Results

The age and gender distribution of the sample is given in Table 1. Overall 53.7% of respondents were female. The greatest proportion of participants (30.0%) was recorded in the 60-64 age group.

	Number of Subjects		
Age (Years)	Men	Women	All
60-64	234 (14.0%)	266 (16.0%)	500 (30.0%)
65-69	187 (11.2%)	247 (14.8%)	434 (26.1%)
70-74	144 (8.6%)	170 (10.2%)	314 (18.8%)
75-79	109 (6.5%)	113 (6.8%)	222 (13.3%)
80-84	62 (3.7%)	63 (3.8%)	125 (7.5%)
85+	36 (2.2%)	35 (2.1%)	71 (4.3%)
Total	772 (46.3%)	894 (53.7%)	1666 (100.0%)

Table 1: Age and gender distribution of sample

Males recorded higher CI prevalence estimates than females in three of the six age groups. The CI prevalence for males in the 60-64 age-group was 8.6% compared to 1.7% for females, the CI prevalence for males in the 75-79 age-group was 20.7% compared to 8.6% among females and in the 80-84 age-group CI prevalence for males was 13.8% compared to 6.9% among females. Further inferences can be drawn from Figure 2 below.

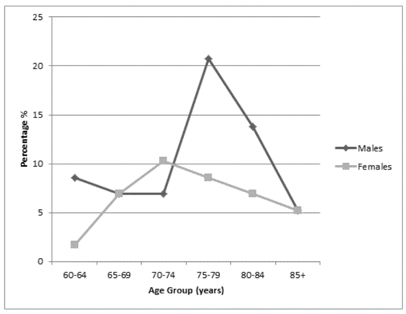

Figure 2: Cognitive Impairment Prevalence by Gender and Age-Group

Logistic regression analysis showed that holding gender and education constant, the odds of CI increase with age (OR 1.1, 95% Confidence interval: 1.0-1.1). The odds of CI also vary depending on gender with males having higher odds (OR 2.1, 95% Confidence interval 1.2–3.7). Finally, for those with a low education level the odds of CI are higher when compared to the odds of CI for those with a high education level (OR 2.1, 95% Confidence interval: 1.2-3.7).

Total life expectancy, cognitive impairment free life expectancy and life expectancy with cognitive impairment for the sample are shown in Table 2 below.

Age (years)	TLE	CIFLE	CILE	% of Total Remaining Life Spent CIF
Males				
60-64	23.5	21.1	2.4	89.8
65-69	19.4	17.2	2.2	88.7
70-74	15.4	13.6	1.8	88.3
75-79	11.9	10.1	1.8	84.9
80-84	8.9	8.1	0.8	91.0
85+	6.5	6.1	0.4	93.8
Females				
60-64	26.8	25.3	1.5	94.4
65-69	22.4	21.0	1.4	93.8
70-74	18.2	17.0	1.2	93.4
75-79	14.2	13.0	1.2	91.5
80-84	10.6	10.2	0.4	96.2
85+	7.7	7.4	0.3	96.1

Table 2: Total Life Expectancy (TLE), Cognitive Impairment-free Life Expectancy (CIFLE), Life Expectancy with Cognitive Impairment (CILE) and % of Total Life Spent Cognitive Impairment-free (CIF) for the sample by Age and Gender

Females have longer life expectancy and also spend a greater proportion of their lives without CI across all age groups when compared to their male counterparts. At age 60, males can expect to live a further 23.5 years. Of these, 21.1 years (95% confidence interval: 20.8–21.4) are expected to be CI-free and 2.4 years with CI. Comparatively, females at age 60 can expect to live a further 26.8 years (95% Confidence interval: 25.0–25.6). Of these, 25.3 years are expected to be CI-free and 0.5 years with CI. Further inferences can be drawn from Table 2 as it relates to CI and CI-free life expectancies across gender and age groups.

Discussion

In this study, the odds of CI were greater for Australian males (OR 2.1, 95% confidence interval: 1.2-3.7) and among those with low education levels (OR 2.1, 95% Confidence interval: 1.2-3.7). The odds of CI also increased each year with age (OR 1.1, 95% Confidence interval: 1.0-1.1). Females were shown to have longer life expectancies than males. For example, at age 60 females are expected to live a further 26.8 years compared with males who are expected to live a further 23.5 years. Females also spend a greater proportion of their lives without CI across all age groups when compared to their male counterparts. For example, females at age 60 are expected to spend 94.40% of the remainder of their lives without CI while males are expected to spend 89.8% of the remainder of their lives free of CI.

The novelty of these results lie in the fact that this is the first time that national population-based data have been used to measure mental health expectancies in the Australian setting. These findings allow Australia to be compared with other countries for which CI data are available using the same outcome measure. This provides a basis for evaluation of health policy and planning and a benchmark by which to assess population-level changes in risk of CI and changing CIFLE given increasing longevity of populations. The salience of this study is underscored by the fact that diseases that negatively affect cognitive function such as dementia are common, costly, and highly age related [18]. CI health expectancy data can be used to develop more meaningful guidelines and policies as it relates to the cognition of older adults and can serve to identify specific age groups that merit further study. More specifically, these results can also serve to inform the development of population health indicators–a useful marker for the health of a population. In the past, this health indicator centred primarily on physical functioning [1]. Recently though, there has been recognition of the need to also consider the mental health of populations in order to predict the services it needs [1].

The CI prevalence rates obtained in the present study can be compared to estimates from a study that reported possible cognitive impairment in Australia using a pooled dataset of Australian longitudinal studies (DYNOPTA) and two Australian Bureau of Statistics National Surveys of Mental Health and Wellbeing (NSMH) [19]. When comparing the present study to DYNOPTA and the NSMH surveys, the probable dementia category was selected as the reference since it coincided with the MMSE score cut-off for CI in the AusDiab i.e. <24. When compared to DYNOPTA, results differed greatly for both males and females between the studies. For example, males in the 65-69 and 70-74 age-groups recorded probable dementia rates of 3.02% and 6.90% respectively in DYNOPTA compared to estimates of 6.90% and 6.90% in AusDiab [19]. For females in the same age-group, probable dementia rates in DYNOPTA were recorded as 4.47% and 4.30% compared to 6.90% and 10.30% respectively in AusDiab [19]. Prevalence estimates for the 2007 NSMH Survey were also observed to be much lower than those in AusDiab. For example males in the 65-69 and 70-74 age-groups recorded probable dementia prevalence rates of 4.63% and 4.34% while females in the same age-groups had prevalence rates of 3.43% and 5.70% respectively [19]. Generally, the results of the present study are more closely aligned to the probable dementia estimates calculated using 1997 NSMH Survey rather than the estimates calculated using DYNOPTA and the 2007 NSMH. Probable dementia prevalence recorded in 1997 among males in the 65-69 age-group and 70-74 age-group was estimated at 6.72% and 11.16% while for females probable dementia estimates were 5.70% and 7.66% [19]. Differences in the results obtained between the AusDiab and these studies may be due to differences in methodology and sample selection.

Previous mental health expectancy calculations in the Australian population have looked at dementia-free life expectancies [5,6]. It is however important to quantify the burden of cognitive impairment in the population since this allows for a more comprehensive understanding of the effect of mental disability in older age groups. The availability of data for the cognitive domain, from the AusDiab Study 2012 wave of data collection facilitated the calculation of CIFLE in this study.

Data on CI-free life expectancies has been published for a few countries (e.g. in Canada and the United Kingdom) however these data are typically representative of populations in the 1990s. It is useful to compare trends observed between these two developed countries and Australia [2,3]. Compared to their Canadian and UK counterparts, Australian males and females live longer and spend a greater proportion of their life without CI. For example, at age 65 Australian males can expect to live a further 19.4 years of which 17.2 would be spent without CI. In Canada, males at the age of 65 can expect to live a further 16.36 years of which 13.76 would be spent CI-free and in the UK males at the age of 65 can expect to live a further 15.3 years of which 11.4 would be spent CI-free [2,3]. In the case of females, Australian females 65 years of age can expect to live a further 22.4 years of which 21.0 would be spent without CI. Comparatively, Canadian females at 65 are expected to live a further 19.10 years with 15.46 of these years spent without CI while in the UK females age 65 are expected to live a further 19.5 years with 12.9 years spent CI-free [2,3].

Dementia-free life expectancies previously published in Australia in 1994 and 2008 also help to put the burden of disease calculated in this study into perspective since 'Cognitive Impairment No Dementia' is considered an intermediate state between 'No Cognitive Impairment' and dementia [3]. Using data from a field survey conducted in the over-70 population in Canberra and Queanbeyan in 1990-1991 (n=1,045) it was found that at 70 years of age, men were expected to live a further 11.95 years and women a further 15.12 years [6]. Of these years, 10.98 and 13.66 would be spent without dementia respectively [6]. More recently, using published dementia prevalence rates and complete life tables published by the Australian Bureau of Statistics, dementia-free life expectancy was calculated for the Australian population for the period 2004-2006 [5]. When the 2004-2006 study is compared to the 1990 results, total life expectancy was observed to have increased among both males and females (14.5 years and 17.3 years respectively). Additionally, when both studies are compared, there was a slight increase in years of life spent without dementia in males and females (1.45 years for males and 0.18 years for females). This is consistent with recent findings showing reduction in late life CI in Denmark, Sweden and England and Wales [7-9]. Worth noting though is that the studies highlighted utilised different methodologies. For example, the AusDiab unlike the other studies did not include those in institutions and this may explain some of the differences in the results obtained. Cut-off points for the MMSE used to classify those with CI may also have influenced the results obtained. For example, in the UK study, a score of <26 was used to classify those with CI while the present study used a score of <24. Additionally, in the Canadian study there was independent assessment by a nurse, physician, and neuropsychologist to confirm the presence or absence of CI which may have led to increased diagnostic accuracy. While inclusion of those in institutions may have led to increased CI prevalence rates in AusDiab, the adoption of stricter diagnostic criteria may have led to many previously classified as 'cognitively impaired' being considered as 'normal'.

The prevalence rates of cognitive impairment obtained in this study and reflected in logistic regression analysis showed an unexpected distribution particularly for males. This merits further analysis but the higher prevalence rates observed in males in the 75-79 and 80-84 age groups may be the result of selective attrition and also small numbers in the older age groups in the study. It was observed that the number of females and males enrolled in the study fell disproportionately from 170 to 113 and 144 to 109 (in the 75-79 age group) and again from 113 to 63 and 109 to 62 (in the 80-84 age group). This may be indicative of the fact that more females requested no further contact in AusDiab, moved abroad or suffered from severe illness and as such were ineligible to continue in the study.

The association between education level and cognitive status in other studies has been published previously [2,20]. Education is known to affect both the level of cognition and its measurement, though it is not clear whether the measure is better with or without adjustment [2]. It has been suggested that education improves health and encourages health-seeking behaviours and healthy lifestyles [21]. The role of education in screening tests such as the MMSE has been highlighted since education may influence a person's ability to display the necessary skills measured [22]. In the present study, education level was found to be a significant predictor of cognitive status. Similar findings have also been reported in studies conducted in England and Wales and the United States where it was found that differences in TLE by education groups are large in the elderly population [2,23].

While the results obtained in this research compare well with other studies, this study makes a substantial contribution to the field as to the authors' knowledge the present study is the first that reports on CIFLE in Australia. Additionally, the use of a national, population-based Australian sample from the AusDiab Study allows for greater accuracy. Previous mental health expectancy calculations in Australia utilised data from the affluent Canberra region or extrapolated data from European countries with similar characteristics. Another strength of this study lies in the use of the Sullivan Health Expectancy. This method permits comparison with other countries and also allows us to observe trends within the same country. It should be noted though that this study is not representative of those in institutions. Additionally, an assessment of cognitive status was performed only on a subset of the sample. An analysis of those for whom no data on cognition was collected (either because of non-selection or drop out) shows that a greater proportion were female (56.8%). A greater proportion of those who did not do cognitive testing also belonged to the low education category (31.7%). As both gender and education level are associated with cognitive status it may be that cognitive impairment prevalence is underestimated and CIFLE overestimated in this present study.

Conclusion

Monitoring healthy life expectancy trends is key to maintaining quality of life in older age groups, proactive policy making and development of effective interventions. The results of this study highlight the growing need for greater investment in overall health in general and mental health in particular given the disease burden (direct, indirect and non-financial costs) to individuals and their families, communities and society.

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