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HEALTH POLICY IN AGEING POPULATIONS

ECONOMIC MODELING OF CHRONIC DISEASE POLICY OPTIONS IN AUSTRALIA

Agnes E. G. Walker
James R. G. Butler
Stephen Colagiuri

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Health Policy in Ageing Populations: Economic Modeling of Chronic Disease Policy Options in Australia

Edited By

Agnes E.G. Walker, James R.G. Butler

Australian Centre for Economic Research on Health,
Australian National University
Canberra
Australia

and

Stephen Colagiuri

The Boden Institute of Obesity
Nutrition, Exercise & Eating Disorders
University of Sydney
Australia

DEDICATION

To the many teachers across four countries I learnt so much from, and my loving family who unconditionally supported me throughout my busy working life.

CONTENTS

FOREWORD

There are many paradoxes in health care. For instance ageing is one of the most potent risk factors for conditions like stroke, heart disease, and cancer. Ageing is also blamed for the crisis in the rising costs of health care. Yet when the effects of ageing are examined objectively, they're actually only a minor contributor to our health care crisis. The crisis, by the way, is another paradox. There's no doubt that our emergency departments are clogged, waiting lists of elective surgery are long and often out of control and new technologies like targeted chemotherapy and robotic surgery cost a fortune. Yet at the moment, the proportion of GDP spent on health is only rising gently and Australians are long lived with declining rates of stroke, heart attack and cancer. It also looks – from overseas data – as though dementia rates are declining too.

So what's the problem and why would you bother writing this book?

Let's take our clogged emergency departments (EDs) to illustrate. Health ministers shout from the rooftops that the problem with our bursting emergency departments is that general practitioners (GPs) are no longer providing adequate after hours cover and as a result, minor conditions that should be treated in general practice are flooding through the doors of our hospitals. The Australian Government has even given quite large sums of money to boost after hours care by GPs. Yet if they'd looked at the data, our politicians and bureaucrats would have realised that their analysis is misplaced. A survey in Melbourne's northern suburbs has confirmed what ED physicians have been saying for years. The problems EDs face are during the day (midday till 4pm) and involve older people with chronic complex illnesses which have spun out of control. A small number of patients consume a significant proportion of time and resources. You don't need after hours GPs to solve this problem. You need a health care system that works during daylight hours to keep these people from deteriorating.

There is a growing number of people with conditions like heart disease, diabetes and arthritis that they'll have for the rest of their lives. These are the cause of unacceptable life expectancy gaps related to post codes, poverty and aboriginality. The more diseases, the more miserable is a person's life.

It is rare these days for doctors to see people with just one diagnosis because the risk factors for chronic illness overlap. So the illnesses pile up. The data in this book show that it's more expensive to treat a single person with two diagnoses (say heart disease and diabetes) than two people with one of these diagnoses each. The arithmetic is multiplication not addition.

The underlying thrust of this book is that our health gains are precarious and the future of our health care system is wobbly to say the least. There is a real chance it will fail to provide the kind of care it does now.

You could argue the signs are already before us. We are already losing the important concept of universal health cover. We have among the highest out of pocket costs for health care in the world. Anecdotally, people are not going to see their doctor, not filling in their scripts and living with surgically treatable conditions because they haven't the cash to pay for them, even with full private health insurance cover. We have disjointed funding arrangements and a new payment system (Activity Based Funding) which will make it hard for hospitals to invest in demand reducing community based care.

Many estimate that in a healthcare system like Australia's, 20-30% of what we do is waste. The examples are legion. Two recent papers between them identify 300 either worthless or low value interventions still in use. PSA testing has resulted in an epidemic of prostatectomies with high levels of disability with a 1 in 48 chance of benefit. We are over using medical imaging which is finding curiosities on the screen which doctors don't understand but lead their patients into even more expensive and potentially harmful interventions. One side effect of the overuse of pulmonary CT scans, I'm told anecdotally, is the over diagnosis of incidental kidney tumours noticed at the bottom of the screen.

We have cardiologists obsessed with inserting stents into blocked arteries yet a survey by the Baker IDI Institute published the day I am writing this, shows that people with established coronary heart disease are not receiving or taking the intensive medical and preventive care they need to treat all their other arteries.

Chronic complex illness is a major driver of health system costs, reduced life and increased disability in the community and the health system will be judged on

how well we do at helping this enormous public health challenge. But the stakes and the risks are high. The potential to waste millions if not billions of dollars on what seemed like good ideas at the time is enormous.

This book offers one solution to make sense of what are formidable complexity and a way for policy makers to test assumptions relatively safely before they commit huge sums of money.

By developing sophisticated mathematical and economic modeling using data down to the micro level, the work on *HealthAgeingMod* shows that it's possible to predict the effects on changing the settings for care. Fascinating work reported here on a hypothetical vascular risk intervention shows net costs and the difference between a practice nurse performing tasks compared to a GP. Another example quantifies the benefits of obese people losing 10% of their body weight.

We talk endlessly about the need for evidence based policy development. The trouble is that there will never be the rolled gold evidence from say randomised trials. But what modeling can do, is plug in what we do know and give our assumptions a good thrashing safely tucked away from the Herald Sun and the Courier Mail.

If we are to preserve a fair Australia with a social contract which includes affordable universal health cover in the face of a chronic disease pandemic, ever more expensive technologies and issues such as antibiotic resistance, we have to fight complexity with complexity to give us answers which we may not like but which may move us to a better place.

Norman Swan

Host, The Health Report
Radio National
Australian Broadcasting Corporation
Sydney
Australia

PREFACE

This book focuses on non-communicable chronic diseases, which are disabling conditions causing premature death worldwide. In Australia such diseases – *e.g.* diabetes, heart disease, cancer, arthritis and mental disorders – affect around 80% of older persons and account for 70% of total health expenditures. The already high proportion of Australians with chronic diseases is projected to increase significantly in future. So the ability to identify 'best value for money' health investments is important if future cost increases are to be contained.

Identifying 'best value for money' health investments is the essence of what the major research project we report on in this book is about. A new chronic disease model is described, covering the initial proposal, the model's building and validation, and examples of its applications to assessing and ranking policy relevant prevention and treatment investment proposals.

Use of models of this kind can help identify the most effective policy interventions that could reduce the prevalence and severity of chronic diseases. To date, model findings indicate that such policies would have considerable benefits to Australians in terms of better health, productivity and well-being. Health expenditures would be lower, the pool of skilled people in the workforce would be greater, and living independently would be a possibility for a greater number of the frail old.

The book also discusses the lessons learnt from our project and from recent Australian health reforms; identifies existing and future health challenges; and puts forward possible improvements to health modeling approaches that could better account for the emerging new environment.

With its broad topic of health and ageing, the book can be of interest to the general web-searching public, as well as serving as basis of study for students and established researchers in the field.

ACKNOWLEDGEMENTS

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CONFLICT OF INTEREST

The author(s) declared no conflict of interest regarding the contents of each of the chapters of this book.

Agnes E.G. Walker

Australian Centre for Economic Research on Health
Australian National University
Australia

List of Contributors

Agnes E.G. Walker

Australian Centre for Economic Research on Health, Australian National University, Australia

James R.G. Butler

Australian Centre for Economic Research on Health, Australian National University, Australia

Stephen Colagiuri

The Boden Institute of Obesity, Nutrition, Exercise & Eating Disorders, University of Sydney, Australia

Crystal M.Y. Lee

The Boden Institute of Obesity, Nutrition, Exercise & Eating Disorders, University of Sydney, Australia

PART I: CHRONIC DISEASES, LIFE EXPECTANCY AND POLICY REFORMS

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CHAPTER 1

Introduction

Agnes E.G. Walker*

Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: With ageing populations, increasing life expectancies and more sedentary lifestyles, today non-communicable chronic diseases are major disabling conditions for people in both developed and developing countries. In Australia chronic diseases, such as heart disease, diabetes, cancer, mental disorders and arthritis, affect around 80% of older persons; are the main causes of disability and premature death; and account for around 70% of total health expenditures. Health expenditures associated with ageing and chronic disease continue to be of concern worldwide to both patients and governments.

Keywords: Chronic diseases, health of Australians, life expectancy, health system structure, patient and government health costs, 'best value for money' investments.

1.1. NON-COMMUNICABLE CHRONIC DISEASES AND THE HEALTH OF AUSTRALIANS

Australians enjoy one of the highest life expectancies in the world — 79.5 years for males and 84.0 years for females in 2012, both 25 years longer than a century ago. On many fronts Australians' health continues to improve. The incidence of heart attacks is declining, cancer survival is improving, less people are smoking and life expectancy continues to increase.

However, with ageing populations together with advances in medical technologies, both the demands made by chronic diseases on health systems and the related health expenditures are rising rapidly [1]. Because such expenditures are associated with ageing, chronic diseases are of greater and greater concern worldwide to both patients and governments. With recession or slow growth in

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

Agnes E.G. Walker, James R.G. Butler and Stephen Colagiuri (Eds.)

many countries, the ability to identify 'best value for money' in health investments has become particularly important.

In Australia chronic diseases, such as heart disease, diabetes, cancer, mental disorders and arthritis, are the main causes of disability and premature death. In 2004-05, expenditure on the major chronic diseases accounted for over 50% of total health expenditure [2]. Although people of all ages can acquire such diseases, it is mainly older persons who are diagnosed and treated with them.

1.2. STRUCTURE OF AUSTRALIA'S HEALTH SYSTEM

Australia's health system is mainly publicly funded, however private health insurance is available for those who require - and can afford - services not covered by the public system. Under Medicare, introduced in 1984, the Australian government aims to provide a fair and affordable health insurance system to all Australians. Currently Medicare provides services such as free treatment in public hospitals, rebates for doctor visits, cheaper medicines, cancer screening, immunisation, optometry, diagnostic imaging and pathology. The Pharmaceutical Benefits Scheme (PBS), introduced in 1948, aims to provide all Australians with reliable and affordable access to prescribed medicines [3, 4].

Today, both Medicare and the PBS are generally seen as having served Australians well since their introduction.

Hospital services are provided by the States, but are part-financed by the Australian government which provides around two-thirds of public health expenditures. Funding for public hospitals is the major item of State health expenditure. The Australian government also funds a range of other health-related services (*e.g.*medical research, public health, indigenous services) and subsidises the cost of private health insurance through a rebate of around 30 per cent [3, 4].

As will be seen in Chapter 3, the Australian government recently initiated major health policy reviews, with some of the review recommendations currently being implemented.

1.3. THE PRESSURE OF HEALTH EXPENDITURES

In 2010, Australia's total expenditure on health was 8.7 per cent of GDP, with 80 per cent having been government funded and 20 per cent 'out-of-pocket' expenditure by patients [5]. As will be seen in Chapter 2, Australia's health expenditure to GDP ratio is below the OECD average.

It is the above GDP growth of this expenditure that puts pressure on budgets worldwide. So why do health expenditures increase more rapidly than GDP?

One reason is that health is different from basic market-oriented goods and services, such as food and clothing. As incomes and GDP rise, expenditure on basic goods and services tends to decrease as a proportion of total spending. However, the reverse is true for health: the higher are incomes the more people spend on health as a proportion of their total expenditure. Health is thus what economists call a 'superior' good. It is the consequent increases in demand for health as incomes rise that is of concern to governments.

As many Australians only perceive the 20% out-of-pocket component of their health expenditures, the related income-induced demand increases appear to be 'concealed' in their minds. This is because most are unaware that, on average, around 80% of their health costs are subsidised by taxpayers, and thus are not responsive to the actual price signals that operate in the market for health.

Such perceptions by consumers may change in future, since in recent years the *total cost* of prescribed PBS pharmaceuticals has been regulated to be printed on drug packets, in addition to the amount paid by the patient.

Expenditure Pressures at the National Level

Expenditure on health in Australia was estimated to be, in Australian dollars, AUD 130.3 billion in 2010-11, up from AUD 77.5 billion in 2000-01 [6]. However, this increase would not have been of concern had GDP also grown at

the same rate. Indeed, it is the steady growth of 'health expenditure to GDP ratio' that adds to expenditure pressures at the national level. This ratio increased from 7.9% in 1999–00 to 9.4% in 2009–10 [6]. One cause of major concern is that this upward trend is expected to continue in future [7].

Historically Australians have consistently chosen health and education as the most important areas determining how they would vote at federal or State elections. So tax increases to finance above GDP growth in health costs are likely to be acceptable to Australians, but only up to a certain limit. This issue touches on a core feature of most public health policy debates. It concerns what resources should be made available for health services, so that to the ever increasing demands can be met with minimum funds and without excessive health service shortages and delays. In times of global fiscal crises – as the western world has experienced since 2007 - such growth in health expenditures cannot be expected to be met by commensurate increases in productivity, GDP and incomes.

The need to ease such cost pressures highlights the urgency to search for bold and innovative approaches when reforming existing health systems.

Expenditure Pressures at the Person Level

At the level of the individual, Australians are concerned about the accessibility and affordability of health care, especially when they have unexpected major and/or long term health problems. Since 2008, Australians' confidence in their health care system improved significantly. By 2012 over 85% reported that they were confident that the system would serve them well if they became severely ill. However, those with lower levels of education, or under financial stress, were uncertain about their ability to afford the required care. While among people without financial stress 77% were confident that they could afford the required care, among those with high financial stress only 37% did so [8]. Although in previous decades statistics on affordability were scant, the information then available suggests that a decade or so ago the extent of PBS subsidies was still sufficiently high to ensure that patients in general did feel that they could afford their prescribed medications [9, 10, 11].

The recent finding that some Australians are now uncertain whether they can afford health care suggests that, during budget preparations, governments should not only focus on limiting increases in health expenditures, but also give due weight to Australia's aim to make health care affordable to all (section 1.2).

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CHAPTER 2

Can Australia Maintain its High Ranking in Health?

Agnes E.G. Walker[1,*] and Stephen Colagiuri

[1]Australian Centre for Economic Research on Health, Australian National University, Australia and [2]The Boden Institute of Obesity, Nutrition, Exercise & Eating Disorders, University of Sydney, Australia

Abstract: In general Australia compares well with other countries in terms of: population ageing; health expenditures *versus* health outcomes; and the extent to which chronic diseases impact on life expectancies. Its expenditures are close to the average of the OECD's 34 member countries, and its health outcomes – indicated by life expectancies - are among the best in this country-group. In the past decade, while the value of Australia's total health expenditure increased, it remained virtually unchanged as a per cent of GDP. So far, Australia's heath system has delivered top health outcomes at expenditures close to the OECD average. Thus, compared with other developed countries, Australia's health expenditures represent 'value for money' in terms of health outcomes.

However this may not continue in future. For example, rapid rises in child and adult obesity – and the related chronic diseases – are now major health issues which federal and State governments find difficult to constrain. Recent developments - such as breakthroughs in medical technology, continued upward costs of health care, and a general preference for more sedentary lifestyles – suggest that, without major policy and patient-level changes, Australia may not be able to maintain its high OECD ranking in the health field.

Keywords: Health comparisons across OECD countries, expenditure as per cent of gross domestic product, life expectancy, 'market' *versus* 'universal' health systems, obesity.

In Australia, lively public discussions about health are common-place. These often concern inadequacies, such as insufficient general practitioners (GPs) in rural areas, insufficient public funding for hospitals, excessive elective surgery waiting times, and lack of progress in reducing the large life expectancy gap between indigenous communities and other Australians. Some of these difficulties may arise from complex historical arrangements, such as the operation of hospitals being a State responsibility while hospital funding involves both State

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

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and national governments. Other difficulties are thought to arise from Australians having the choice to pay for private health insurance, although they also have access to the country's tax payer funded near-universal Medicare scheme.

2.1. COMPARING AUSTRALIA WITH OTHER COUNTRIES

How does Australia's health system compare with those of other similar countries, in terms of health outcomes per dollars spent on health?

Taking life expectancy at birth as a nationwide indicator of health outcomes, and health expenditure as per cent of gross domestic product (GDP) as the indicator of total expenditure, Australia is ranked high among the OECD's 34 member countries (Fig. **1**).

Fig. **1** shows that in 2010 Australia's expenditure on health, at 8.7% of GDP, was below the OECD average of 9.5%. In 2009, life expectancy at birth in Australia was 82 years, which was among the best within the countries listed in Fig. **1**. Further examination of World Health Organisation (WHO) and OECD statistics showed that, over the past decade or so, the rankings within these countries remained virtually unchanged.

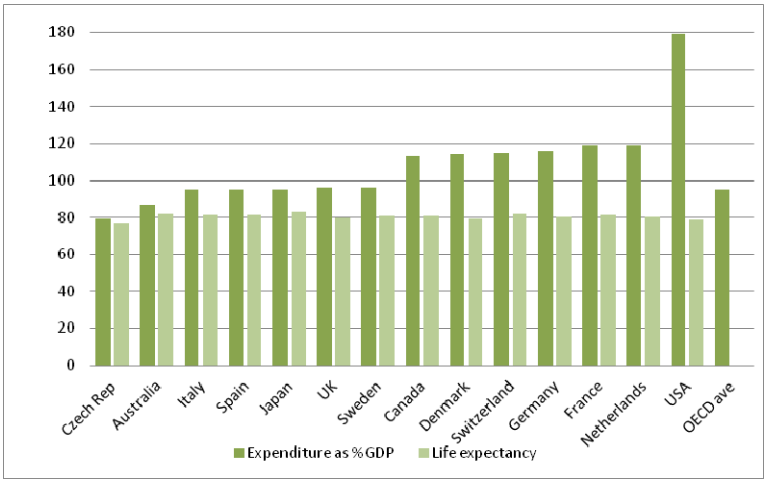

Figure 1: Health expenditures and life expectancies, OECD countries, 2009-10:
Note: Expenditure as % GDP multiplied by 10; Life expectancy is the arithmetic average for men and women.
Source: World Health Organisation: Global Health Observatory Statistics, year 2010 for Expenditures and 2009 for Life expectancies.

An important finding is that greater health expenditure as per cent of GDP does not automatically result in better health outcomes (Fig. **1**). The most obvious example is the USA, where a much higher expenditure than in the other countries charted only delivered a below average life expectancy.

In the US health is closer to a 'market' system - and thus is further away from a 'universal' health care system - than in most developed countries. For example, in 2008 its private health expenditures accounted for over half of total expenditures, compared with just under one third in Australia [13]. The fact that the US's high expenditures only resulted in a below average life expectancy suggests that, in general, a 'universal' style health system is likely to be better 'value for money' than a 'market' style health structure.

Many factors may have contributed to the across-country comparisons in Fig. **1**. One concerns the above mentioned differences in health systems, which are often a consequence of a country's political history. Other differences may have arisen from the degree to which the country's population had aged. However, due to the similarity of the extent of ageing in the main English speaking countries combined with the considerable differences in their health outcomes, this is unlikely to be a significant explanatory factor.

The OECD's 'Elderly population aged 65 and over' indicator shows that, in 2010, 65+ year olds made up 13.1% of the US population, and 13.5% and 14% of the Australian and Canadian populations respectively. In Japan, with top life expectancy of 83 years and expenditures close to the OECD average, 23.1% of the population was aged 65 years or more. So even a country with a much older age structure than Australia's can have excellent health outcomes with per cent of GDP expenditures close to the OECD average.

2.2. CAN AUSTRALIA MAINTAIN ITS HIGH INTERNATIONAL RANKING IN HEALTH?

There are a number of recent developments that suggest that Australia may find it hard to maintain its high 'value for money' health status on the world scene.

Obesity: A Major Health Risk Now and in Future

Probably the most researched health issue internationally is the rapid rise in the proportions of children and adults who are overweight or obese. The OECD's 'Overweight and obese aged 15 and over' indicator [13] shows that, in 2007, 61.2% of Australian adults were overweight or obese. This was similar to Canada (60%), but below the USA (68%). The indicator was very much lower for several other developed countries, such as France (38.2%) and Japan (25%).

More up-to-date statistics are available for Australia than what is available from the OECD. These indicate significant deterioration of the adult (18+ years) overweight and obese situation: 63.4% in 2012, compared with 61.2% in 2007-08 and 56.3% in 1995 [14]. However, for children aged 5-17 years, the 2012 statistics were somewhat better, their prevalence of 'overweight and obesity' remaining at their earlier 25.3% level.

Australia's obesity statistics put this nation squarely among the 'worst' within OECD countries. This poor ranking, together with rapid rises in Australia's obesity rates, have caused major policy concerns. Because obesity is a major risk factor for chronic diseases, some Australian and US researchers are foreseeing a future whereby many children will die before their parents.

To date no clear explanation has been found as to why the highest obesity rates have consistently been in the major English speaking countries. Many of the suggested reasons for obesity - such as sedentary habits; eating more 'convenience foods', and parents being more safety conscious - also apply to non-English speaking countries. Of concern is that, between 2000–01 and 2009–10, GP visits in Australia for advice about nutrition and weight loss decreased from 5.6% to 3.7% of all GP visits [12].

Excess weight is a major risk factor for chronic diseases such as heart disease, diabetes, cancer and arthritis. The implications of this for health service use have been widely researched [15]. One implication of considerable concern is the doubling of the proportion of the population with diabetes between 1989–90 and 2007–08 (to 4.1%). Another is that indigenous Australians are three times more likely to report some form of diabetes as non-indigenous Australians.

However, for planning in future it is worth remembering that obesity – as well as diabetes - is lifestyle related, so they are often preventable.

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CHAPTER 3

Recent Policy Reforms

Agnes E.G. Walker*

Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: In response to above GDP increases in health costs, the ageing of the population, and concerns about the long term sustainability of Australia's health system, Australian government has announced major health policy reforms. At the federal level some are still at the 'announcement' stage, others have already been legislated, and some have been partially implemented. This Chapter documents current situation regarding the already announced health policy reforms.

Keywords: Sustainability of Australia's health system, already announced health policy reforms, prevention, primary care, hospitals, aged care, mental health, standards, e-health.

In many countries, governments have already announced reforms to their health systems. Major health policy reforms announced in Australia since 2007 aim to fill in the 'gaps' in health service provisions, and to position Australia's health system for success in the 21st century.

As a first step, the federal government initiated two major health reviews, one focusing on the health system overall [16] and the other on prevention [17]. One of the reasons why the former was commissioned was because the States had difficulty financing the hospitals they operated, given above GDP growth increases in Australia's health expenditures. The main reason for the latter arose from the recognition that Australia had historically not invested enough effort and funding in preventing chronic and life threatening diseases [18].

Since 2005, Australia already had a National Chronic Disease Strategy. This was a nationally agreed agenda to encourage coordinated action in response to the

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

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growing impact of chronic disease on health and the health care system [19]. In August 2011, the federal government took action to address the challenges of increased demands on the health system. These arose from the ageing of the population, increased rates of chronic and preventable diseases, new treatments becoming available, and rising health care costs. A National Health Reform Agreement [20] had been secured. The aim was to deliver funding to public hospitals with unprecedented levels of transparency and accountability, less waste and less waiting for patients. The agreement builds on work undertaken across eight streams of health reform:

1 *Hospitals:* with the federal government increasing its share of the efficient growth funding in public hospital costs to 45 per cent from 2014-15 and then to 50 per cent in 2017-18.

2 *Primary Care:* with two initiatives. One concerns *Medicare Locals* to coordinate health care needs and tackle local service gaps, with all 61 Australia wide centers planned already operational. The other concerns *GP Super clinics* which aim to shift health care services from hospitals to primary care settings (with over 60 planned). A recent example of such a shift is the announcement by the federal government on 11 June 2013 – as part of its launch of the 'Medicare For All' advertising campaign – that from 1 July 2013, 60 per cent more funding will be available for Medicare Locals for expanded GP after-hours services. These clinics are also expected to improve chronic disease prevention by promoting healthier lifestyles; risk factor and lifestyle modification; and early diagnosis.

3 *Aged Care*: for basic community care, most funding responsibility is shifting to the federal government, in addition to its existing responsibilities for residential care and community care packages [21]. Its Australian dollar AUD 3.7 billion national reform package has a strong focus on helping people stay in their own home as they get older. It also aims to provide better care for older people, both in their homes and in aged care settings.

4 *Mental Health*: federal government announced an AUD 2.2 billion mental health package. Focus is on providing better care for people with severe and debilitating mental illness.

5 *National Standards and Performance*: new transparency measures – in both hospital financing and health system reporting – aim to inform Australians about how health resources are used and what results are being achieved. There will also be reports on performance, including on waiting times on elective surgery and in emergency departments, as well as on safety and quality issues such as hospital infection rates.

6 *Workforce*: aiming to address current workforce shortages and ensure that Australians will have enough doctors and other health professionals, from 2010–11 the federal government is investing AUD 1.8 billion over four years.

7 *Prevention:* the federal government's investment in prevention includes initiatives to tackle the rising burden of obesity, tobacco and alcohol consumption, support people to adopt healthier lifestyles and educate Australians about the risks of chronic disease. Recently, the federal government enacted a world first legislation for tobacco. Since 1 December 2012 all tobacco in Australia is being sold in plain packaging, with logos, brand imagery, symbols, other images, colours and promotional text banned on all tobacco products and packaging. The aim is to reduce the appeal of tobacco products to consumers, particularly young people; and increase the effectiveness of mandated health warnings on the packages.

8 *eHealth*: provides new ways of managing health information and the delivery of healthcare online, making it more accessible regardless of where in Australia one lives, while *Telehealth* gives Australians living in rural, remote and outer metropolitan locations greater access to a range of subsidised consultations with GPs and specialists.

9 *Personally Controlled Electronic Health Records*: from 1 July 2012, Medicare data, including doctor visits and prescribed pharmaceuticals,

> can be incorporated into the *eHealth* record system for those people who want such information to be part of their record. As more patients and medical professionals join this electronic system, *eHealth* records will help make getting the right treatment faster, safer and easier.

The above reforms were all drawn from [20] unless otherwise stated. Other major reforms include extending federal government subsidies to dental care and providing adequate support to disabled persons aged less than 65 years, as well as to their carers (often elderly parents).

These reforms indicate a considerable attempt to position Australia's health system for future success. However, so far reform implementation tended to hit major obstacles and progressed very slowly. Apart from the obstacles that arose from a hung Parliament, delays occurred due to very wide ranging consultation processes and major operational difficulties arising from insufficient attention to implementation. It seems that obtaining agreements with the States and getting legislations through a hung Parliament have left little time for planning the details that are essential for smooth and timely implementation.

Although by mid 2013 most announced health reforms were legislated, many are still years away from being fully operational. One possibility is that at the federal elections announced for late 2013 there may be a change of government. Then some of the well overdue and generally supported health reforms are likely to be withdrawn.

Experience with the reforms announced since 2007 shows that, even when there is political will, implementation is likely to follow a rocky road. Already legislated reforms may be withdrawn and implementation of those that remain is more likely to happen across several electoral cycles. These issues are further discussed in section 9.1. Also, as will be seen in section 10.2, there are a number of health reforms that numerous studies have found to be 'best value for money', but which had not as yet attracted government funding.

Given the many recent health policy initiatives worldwide, there is clearly a role for supporting cost benefit and cost effectiveness studies. In Australia the

influence of such studies on policy decisions is expected to be a continuation of present and past practices.

As a long-term example of such a practice, applications for new drugs to be listed on the Pharmaceutical Benefits Scheme currently need – and have needed for several decades now - to include proof that the new drug is an improvement on what is already on the list. Often this proof had been provided by pharmaceutical companies through cost effectiveness analyses. Another example is the enactment in 2013 of Australia's National Disability Insurance Scheme (NDIS). This Act is mostly based on the 2011 Productivity Commission inquiry report which was carried out in response to a request by the Australian Government. That inquiry report contains – among many other things – a cost-benefit analysis of the NDIS as proposed by the Commission.

Other examples of the influence of cost effectiveness studies on policy decisions in Australia are described in sections 10.1 and 10.2. Also, more general information on this issue can be found in Chapter 10 under the heading: "When does 'best value for money' lead to project implementation?"

PART II: AUSTRALIA'S CHRONIC DISEASE MODEL SYSTEM AND ITS APPLICATIONS

For several decades now chronic diseases and comorbidities – *i.e.* the accumulation of chronic diseases at the level of the individual – have been of concern worldwide. In Australia, concerns have also been expressed about a general focus on treatment rather than on prevention.

PART II reports on the planning, building and validation of a chronic disease model system for Australia which aims to close research gaps existing at the time of its proposal. Research gaps arose from focus on individual diseases rather than on comorbidities, and from treating particular diseases, rather than the person as a whole. Based on microdata, the model system tracks both the risk factors and the diseases of individuals over time. It is thus what is often referred to as a microsimulation model.

An innovative feature of the model-system is that, while it is able to track individuals' risk factors over time (*e.g.* obesity, blood pressure, glucose level, cholesterol), predict the onset of chronic diseases (heart disease, stroke, diabetes) and estimate the related treatment costs, it is also able to scale these individual-level statistics up to the national level so that costs and benefits associated with reform proposals can be estimated at the national level.

Models of this kind are meant to be used for assessing and ranking policy relevant reform options. Thus their credibility with decision makers is very important. As a result, Part II also covers model validation, generalisability and limitations (Chapter 6).

PART II also presents two illustrative applications of the model system, as well as an evidence-based policy relevant application proposed by Australian policy developers in health departments and in chronic-disease-based non-profit organisations (Chapters 7, 8).

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CHAPTER 4

Overview of Australia's Chronic Disease Model

Agnes E.G. Walker[1,*] and James R.G. Butler[2]

[1]Australian Centre for Economic Research on Health, Australian National University, Australia and [2]Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: This chapter starts with the initial proposal for building the *HealthAgeingMod* model-system. It then follows through the major steps involved in carrying out the initial literature searches; research on how to implement the novel features proposed; assessment of the best way to treat each element of the system; examination of the data and methods to be used; and the building and validation of a complex individual-based and nationally representative chronic disease model-system. It also documents the difficulties and modeling pitfalls encountered and describes how the project evolved from the initial detailed plans, through the building of a prototype, and the final, validated version of *HealthAgeingMod*.

The outcome is a policy relevant tool in which chronic disease progression models are linked to a population-wide microsimulation projection model. The system accounts for individuals' demographic, socio-economic and health characteristics, comorbidities, health expenditures, quality of life, work prospects. Its outputs are estimates of the costs and benefits of simulated policy interventions. *HealthAgeingMod* is a validated person-level system able to simultaneously account for diabetes and cardiovascular disease (CVD), with the possibility of extensions to other major chronic diseases.

Keywords: Common health risk factors, diabetes, cardiovascular disease, comorbidities, chronic disease onset and prevalences, nationally representative data sources, psychological distress, model building.

4.1. INTRODUCTION

Development of the chronic disease model system – *HealthAgeingMod* – started, in 2005, with only a relatively undeveloped outline for the planned project. The original proposal stated that the project would address the then Australian government goals of 'Promoting and Maintaining Good Health', improving

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

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'Preventive Health Care' and 'Ageing Well, Ageing Productively'. Several chronic disease models were to be developed which, when combined, would give a more accurate *overall* picture than what had been possible previously. The scientific knowledge base would be improved by researching the way demographic, socioeconomic, medical and lifestyle factors combined to produce Australia's high and increasing chronic diseases prevalences.

The difficult but important analytical issue of how to combine the outputs of several disease-based models into a nationwide framework that accounted for co-morbidities, would be addressed. Criticisms of the then generally adopted 'disease-by-disease' approach [22, 23] would be taken into account and thus decision-making tools would be improved. With the proposed model a more complete estimate of chronic disease costs and benefits of reform options could be obtained than had been possible previously. Such a global view was seen as particularly relevant in the case of chronic diseases, because they shared many common lifestyle-related risk factors (*e.g.,* obesity, high sugar level and blood pressure).

At that proposal stage the extent of model specification was uncertain and, as expected, lacked detail. So the first step after commencement of the project was to carry out pre-model-building research. The issues covered at that early project stage are discussed below.

4.2. PRE MODEL BUILDING RESEARCH

Impact of Chronic Diseases and Comorbidities on People's Lives

In Australia, as in most parts of the world, chronic diseases are now considered to be an epidemic of major proportions (Chapters 1, 2) [24]. While the most important chronic diseases – such as diabetes and cardiovascular conditions – have been extensively researched and analysed, knowledge of the impact of comorbidities – *i.e.,* the same individual acquiring several chronic diseases – is still very limited. This arose from difficulties of:

a) collecting comprehensive information at the person level, while still maintaining confidentiality;

b) nationally agreeing on the major chronic diseases that were to be studied as a group; and

c) finding methods to assess the combined impact of the comorbid diseases on the person's health and wellbeing.

Re (a), the Australian Bureau of Statistics (ABS) made de-identified unit record data available from its nationally representative health surveys (with age only released in 5-year groupings on its confidentialised unit record files). Nationally representative data allows analysts to estimate the nationwide costs and health benefits of the policy reform studied (rather than be limited only to sample survey participants). For Australian governments nationwide estimates are important because, if chosen, most of the health reforms they consider would be expected to be implemented nationally. Estimation of nationwide costs and benefits occurs through the person-level weights provided by the ABS (see section 5.1).

Re (b), initially the ABS's 'long term conditions' label was used, but that included conditions that had little impact on the lives of people (*e.g.,* myopia and the need to wear glasses). By 1996, a National Health Priority Areas (NHPA) list of four areas had been agreed to: Cardiovascular health, Cancer control, Injury prevention and control and Mental health. In following years four more were added: Diabetes mellitus (1997), Asthma (1999), Arthritis and musculoskeletal conditions (2002), Obesity (2008) and Dementia (2012) [25].

Fig. **2** shows that, in 2005: 32% of Australians aged 45 years or more had one condition from among the 12 chronic conditions listed below the chart. This compares with less than 20% in the 15-44 age group. Fig. **2** also shows the dominance of comorbidities among those aged 65+, with 27% having two such conditions, 15% three, 5% four and 3% having five or more such conditions. This clearly indicates that, as people age, they tend to acquire more and more chronic diseases.

Regarding comorbidities between CVD and diabetes, the two chronic diseases modeled in *HealthAgeingMod*, Fig. **3** shows that in 2005 a much greater

proportion of adults with *both* CVD and diabetes self-reported poor health (36%) than persons with only one of these diseases (24% for CVD and 17% for type-2 diabetes). By comparison, among all Australian adults only 5% reported poor health.

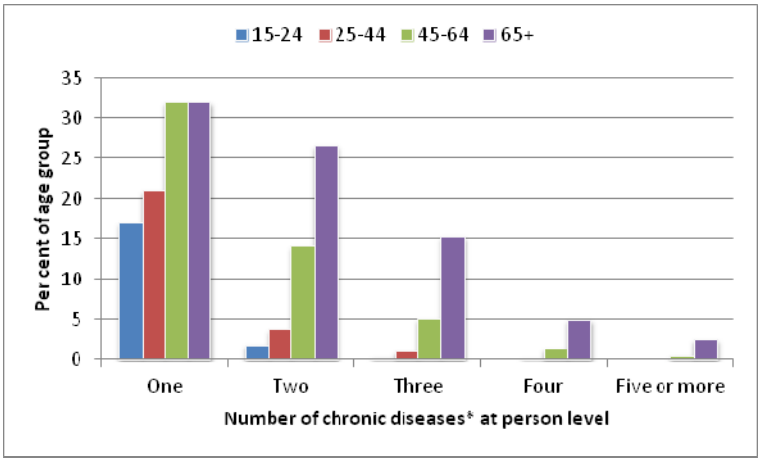

Figure 2: Distribution of 15+ year olds by number of chronic diseases, 2005.
***For 12 conditions:** Coronary heart disease; Stroke; Lung cancer; Colorectal cancer; Depression; Type 2 diabetes; Arthritis; Osteoporosis; Asthma; Chronic obstructive pulmonary disease; Chronic kidney disease; Oral disease.
Source: Figure based on Australian Institute of Health and Welfare study [26], using National Health Survey 2004-05 (NHS05).

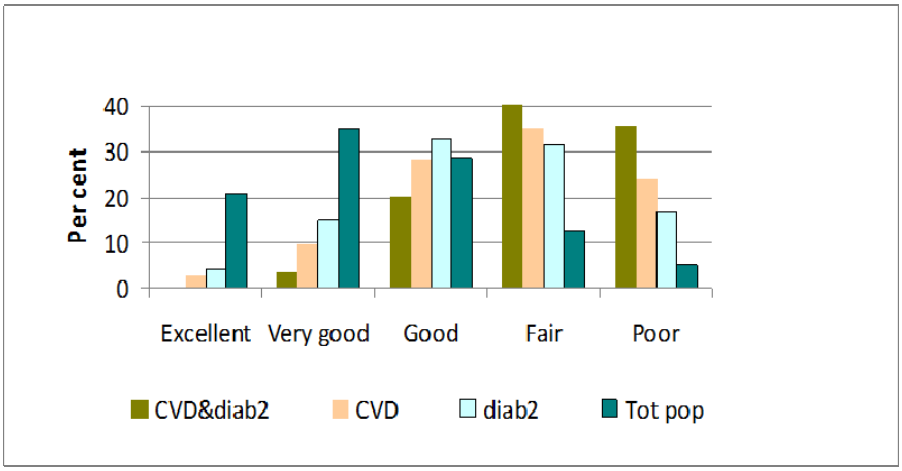

Figure 3: Proportion of 15+ year olds by disease and health state, 2005
Source: NHS05 CURF [47], – see Appendix A.

Considering the full adult population, a striking finding from Fig. **3** is that while over 80% of Australians self-assessed their health as Excellent, Very Good or Good, nearly 80% of those with both CVD and diabetes felt their health was Fair or Poor. So, although the estimation of comorbidities is difficult to handle analytically and to place in a nation-wide context, comorbidities – *i.e.,* the number of chronic diseases that each individual is likely to acquire with age – will be very important in this project. The difficulties arise in part from national health data collections tending to focus on single diseases, and in part from data on number of diseases at the person-level being scarce.

Re (c) above, how the number and sequence of chronic diseases affect that person's life is also an important research issue. For example, does having diabetes first and a heart attack next have a greater impact on a person's quality of life than the combined quality of life impact of two different persons only having one or the other disease (*e.g.* one with diabetes only, and the other with heart attack only).

In Australia, for the first time in 2001, a 'psychological distress' indicator became available in the ABS's National Health Survey (NHS01). This indicator was once again included in NHS12. However, at the time of preparing for this book the NHS12 unit record files have not as yet been released.

Using the ABS's 2001 'psychological distress' indicator, it was possible to chart the number of serious chronic diseases a 60+ year old person had against the extent of their self-reported 'psychological distress' [27].

Fig. **4** compares the distress of the group with 0-2 chronic conditions with the distress of those with three or more such conditions.

Fig. **4** shows that among those with three or more chronic conditions *33% less* said they were 'delighted' with their lives, and *160% more* said they felt 'terrible', than among 60+ year olds with only 0-2 such conditions.

The finding that those with three or more chronic conditions were so much less satisfied with their lives than those with 0-2 such condition is important. It provides evidence for what one would expect, that is that chronic diseases have

considerable negative impact on quality of life. Indeed, the more chronic diseases a person has, the faster the increase of that negative impact on quality of life.

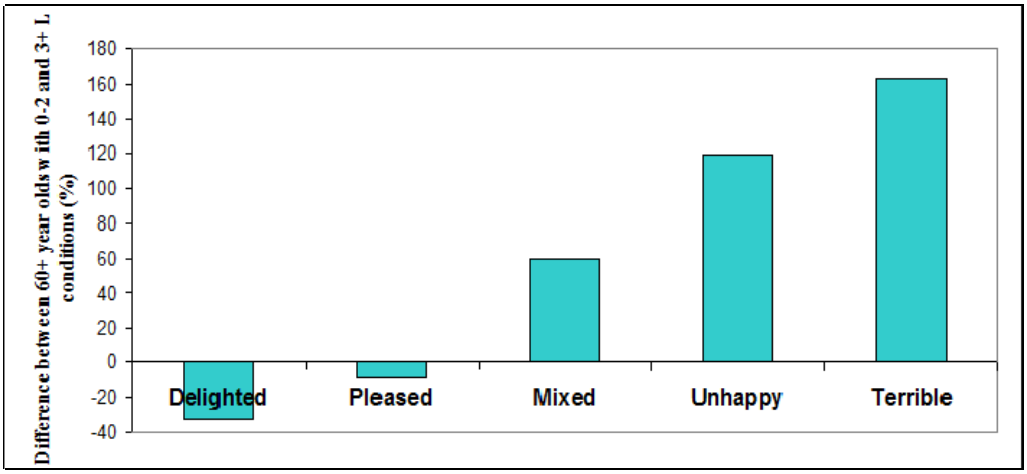

Figure 4: Difference between 60+ year olds with 0-2 and with 3+ long term conditions by quality of life indicator, 2001 (%).
*** The survey's 'psychological distress' categories were named: '**Delighted'; 'Pleased or mostly satisfied'; 'Mixed'; 'Mostly dissatisfied or unhappy'; and 'Terrible'.
***Source*:** 2001 National Health Survey (CURF) [27].

One implication for doctors, analysts and policy developers is that much greater attention should be paid to the *numbers of chronic diseases a person has*, rather than simply focus on the *total number of persons in Australia with each chronic disease*. Another implication is that greater focus on prevention – rather than on cure – could considerably improve the quality of life of older Australians.

Figs. **2, 3** and **4** indicate that avoiding or delaying the onset of major chronic diseases would be expected to significantly improve the quality of life of Australians. In that context quality of life refers to an individual's overall satisfaction with life and a general sense of personal wellbeing [36].

Why Choose Health Economics and Microsimulation for the Model?

Health economics, which many regard as having been founded by Kenneth Arrow's 1963 article in the American Economic Review [28], is by now a widely practiced analytical discipline. It is one of the disciplines appropriate for our

project, which aims to estimate the costs and benefits of policy relevant interventions in the chronic disease prevention and treatment fields. Because most health economics studies use grouped data, such as 'number of persons with diabetes' or 'number of persons with CVD', our project also needed another discipline which allowed us to use individual level data (*i.e.,* microdata). This is because comorbidities (*i.e.,* whether a person has diabetes alone, CVD alone or both), can only be adequately studied at the level of the individual. So for *HealthAgeingMod* we proposed – and used - microdata and microsimulation techniques.

Although over half a century had elapsed since Orcutt first proposed such techniques [29, 30], microsimulation has only relatively recently been used widely. Its popularity was underpinned by rapid advances in computer technology and in general availability of large microdatasets, such as – in Australia - the ABS's Census and sample surveys. In the late 1990s the OECD referred to microdata and microsimulation modeling as being among the few newer sophisticated techniques available to analysts in the health economics field [31]. Since then the technique has been increasingly applied worldwide by researchers in academia, government, and the private sector [32].

4.3. BUILDING HEALTHAGEINGMOD

The three major stages of building *HealthAgeingMod* have been documented in journal articles and research reports. The major stages were: Proposed Approach; [33, 34] the Prototype Model-System; [35] and the Final *HealthAgeingMod* [37, 38].

While the Prototype and the Final model system descriptions are broadly similar, the Final report also contains – apart from numerous literature updates – important revisions made to the prototype following initial test applications. It also contains a new comprehensive section that validates *HealthAgeingMod* against benchmarks from statistics published by external sources. The final model's validation is detailed in Chapter 5 of this book.

This section summarises the material in the earlier publications and re-arranges these so that the changes that took place between the proposed and final models

are highlighted, and the reasons for the changes explained. While in most projects changes to early proposals are common, the reasons for the changes have rarely been documented. Providing such documentation in this book is expected to not only help avoid potential pitfalls by data providers, modelers and policy developers, but also to be a learning tool for newcomers to modeling and to quantitative health policy analysts.

The section starts with an overview of the model-system including the methods used. It then mentions the key novel elements and possible model applications.

Overview of HealthAgeingMod

Already at the early proposals stage it was clear that no single data source and model could cover the broad-ranging factors, the complex interactions and the disease-level details required by *HealthAgeingMod*. To overcome this we proposed a model-system structure in two parts: [33, 34]

a) bringing together, in a coherent manner, individual-level cross-sectional data from several sources; and

b) using disease-specific longitudinal (or cross-sectional) data to model the incidence, progression and treatment costs of chronic diseases.

We proposed modeling (a) and (b) separately, and then linking the two parts, so that the 'big picture' as well as the 'detail' associated with the tracking of individuals' health can be simultaneously analysed. With such a strategy the policy interventions simulated could be assessed both in terms of broad population-wide variables (*e.g.,* worse or improved obesity patterns; population screening options), and in terms of disease or comorbidity specific medical treatment (*e.g.* surgery replaced by, or combined with new, improved - but more expensive – new pharmaceuticals).

Apart from validation (see Chapter 6), the initially foreseen modeling challenges included:

- development of new methods to adequately model comorbidities;

- allowing the model's datasets to be up-dated should later, better and more comprehensive data be released during the project period; and
- linking the elements of *HealthageingMod* [34].

Fig. **5** details the key elements of *HealthAgeingMod*: the "Base-year dataset", representative of the Australian population; "Progression modules" projecting into the future, "Chronic Disease models"; and the "Base-Scenario Outcomes" module that computes the net costs and benefits of simulated interventions.

HealthAgeingMod, programmed in the SAS language, may in future be extended to other chronic diseases, such as mental health, arthritis and cancer. The model-system is described below, with further details in Chapter 5.

Base-Year Population

In its final version, *HealthAgeingMod* represents the Australian population by a person-level nationally representative sample of individuals surveyed in 2005 by the Australian Bureau of Statistics. Fig. **5** shows that this representative sample of individuals makes up the model-system's Base-year population. The complete model-system allows for comorbidities, that is whether individuals have (or newly acquired) CVD only, diabetes only or both CVD and diabetes.

The Umbrella Model

A population-wide 'Umbrella model' of *HealthAgeingMod* processes the base-year data, which accounts for individuals' demographic, socioeconomic, health status and health-risk-factor characteristics. It progresses over time the age of these persons, and their health-risk-factors. Next, the 'Umbrella model' is linked to disease-specific sub-models for CVD and type 2 diabetes, which provide it with estimates of who will acquire diabetes and/or CVD in future. Finally, the 'Umbrella model' computes the associated costs – as health service expenditures – and the expected future changes in the quality of life of the individuals in the Base-year population.

Disease-Specific Sub-Models

Key reasons for initially choosing CVD and diabetes were that: they were major contributors to Australia's total burden of disease; [44] CVD and high mortality

from CVD tended to be a common complication of diabetes; and CVD and diabetes shared common risk factors (*e.g.,* physical inactivity, obesity and high blood pressure).

Surprisingly, there is not much difference between the initially proposed structure of the model-system and the one finally adopted in Fig. **5** [38]. Indeed, the final structure only differs from the initial proposal [34] by changes regarding the data to be used in the CVD and Diabetes sub-models.

For CVD, the initial proposal was to use the 1991 cardiovascular risk equations based on data from the US Framingham Heart and Framingham Offspring studies which covered the 1968 to 1975 period, including 12-year follow-ups [39]. Although dated and from a different country, in the late 2000s these 1991 estimates were still considered to be the best available for Australia. Indeed, the 2009 National Health and Research Council guidelines recommend – and still recommended in 2012 - using these equations for CVD [40, 41].

For the Diabetes sub-model, the initial data source proposed was from the United Kingdom Prospective Diabetes Study (UKPDS) [42], which was also from another country, but more up-to-date than the Framingham studies.

However, by the second year of the development of *HealthAgeingMod* it became clear that, compared with Australian aggregate benchmark statistics, both the US and UK data provided unexpectedly high incidence and prevalence over-estimates. Thus their use would have made it very difficult, if not impossible, to validate the final model-system. Luckily, from 2007 onwards data became available from Australia's longitudinal AusDiab study (1st wave in year 2000 and 2nd in 2005) [43].

While the Australian AusDiab data focused on diabetes, it also had valuable longitudinal information on CVD. For this project, person-level AusDiab diabetes data was made available in 2007, and CVD data in 2008. Thus, by 2008, for both the diabetes and CVD sub-models we could change the data sources in Fig. **5**

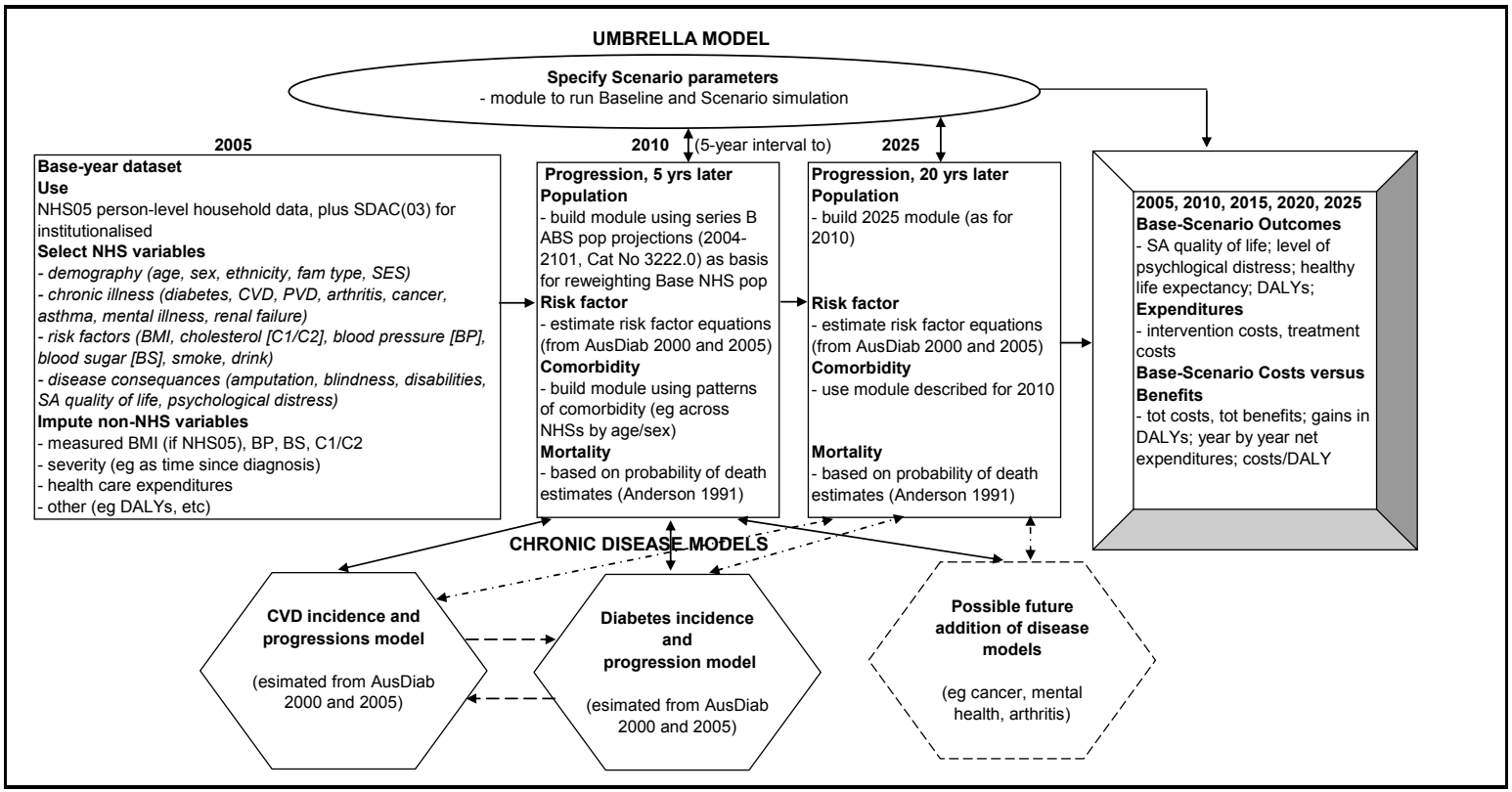

Figure 5: The chronic disease model-system.

from the US/UK sources initially proposed [39, 42], to AusDiab [43]. Although only comprising adults aged 25+ years or more, with a sample that is not nationally representative in wave 2, AusDiab is a considerably more appropriate source for Australia because it has data for this country, and is much more up-to-date than those available from US/UK sources.

Regarding the tasks to be carried out by the diabetes and CVD sub-models, we already knew what the chronic disease risk factors, and diabetes and CVD statuses were for each individual in the NHS05's nationally representative sample survey, and thus in the 2005 Base-year data of the Umbrella model. So the Base-year population of the Diabetes sub-model comprised persons who *did not* report in 2005 that a doctor or nurse told them that they had diabetes. Also, the Base-year population of the CVD sub-model comprised those who *did not* report in 2005 that a doctor or nurse told them that they had CVD.

The task of the sub-models is to project into the future the onset of diabetes and/or CVD for the sub-population who did not have these diseases at the start of the projection period. To estimate such future changes, we developed a set of equations estimating the probability of an individual acquiring diabetes or CVD during the projection period. Next, we used the Monte Carlo method to randomly select those who would actually acquire the disease in that period (Section 5.6).

Linking the Umbrella and the Disease Specific Modules

Information on people estimated to acquire diabetes and/or CVD by the two sub-model during the projection period being processed are then forwarded to the Umbrella model so that overall cost-benefit or cost-effectiveness indicators can be computed.

To Run the Model in Scenario Analyses

Fig. **5** shows that the model-system is designed to project the Base-year population's health progression over time. This can be done under a number of specific assumptions about the future characteristics of the health system, which the analyst can control in the 'Specify Scenario parameters' sub-model of Fig. **5**.

Typically, analysts will first run a model of this kind assuming 'no policy change' – *i.e.,* the 'Do Nothing' case. This will provide the *Baseline simulation* which estimates what could be expected in future if Australia's health system remained unchanged.

Next the analyst would run a model of this kind specifying that a particular policy reform would be implemented – the *Scenario simulation*. The model's output will then indicate what would be expected in future if Australia's health system had improved under the specified Scenario.

Finally, Fig. **5** shows that *HealthAgeingMod*'s 'Outcomes module' can compare the Baseline and Scenario simulation results in terms of:

- differences in Australian health outcomes - *e.g.,* Disability Adjusted Life Years (DALYs) or Years Lived with Disability (YLDs) avoided indicators. One DALY is one year lost of healthy life (section 5.5). The DALY is similar to the Quality Adjusted Life Years (QALY) indicator. In our *HealthAgeingMod* simulations we used either DALY or QALY, depending on for which of these we were able to obtain estimates appropriate for that application;
- differences in total health expenditures (at national and Scenario-specific levels);
- the net year-by-year benefits and costs arising from implementation of the Scenario; and
- indicators of the Scenario's cost effectiveness.

Novel Elements

While many individual-level population-based models had been, or are being, developed worldwide, most fall within the tax and social security fields. The few that account for health tend to be either of the large socioeconomic model type, which uses a broad indicator of health as a covariate within the larger picture, or of the disease-specific model type, designed to study treatment options so as to assess the cost effectiveness of either disease-specific or risk-factor-specific policy interventions [37, 45, 46].

Key novel elements of *HealthAgeingMod* are that they cover:

- both the broad socioeconomic and the detailed disease specific aspects;
- account for *several* chronic diseases and for comorbidities, the negative health impact of the latter having been shown in Section 4.2; and
- modeling the onset and progression of each, and linking these to their common risk factors.

Thus the model-system is able to assess the *full* benefits of interventions that target risk not only of factors *common* to several chronic diseases, but also of interventions related to these diseases. For example, *HealthAgeingMod* can simulate complex chronic disease policy reform proposals that combine medical treatment options – *e.g.,* a new drug being used for diabetes and/or new hospital procedures for stroke – with lifestyle changing options – *e.g.* diet and/or exercise – and with socio-economic reform options – *e.g.* improving the health of poorer population groups.

Overall, the novel elements in *HealthAgeingMod* are expected to encourage a re-focus of chronic disease policy initiatives toward multiple chronic diseases and away from single diseases. They are also expected to considerably improve the accuracy of the economic evaluations associated with the chronic diseases intervention proposal.

Possible Model Applications

Policy relevant intervention proposals that could be analysed using *HealthAgeingMod* include:

- simulating the impacts of various combined lifestyle and disease-specific treatment options, leading to their ranking through cost-benefit and cost effectiveness analyses;
- simulating the impact of various lifestyle interventions (*e.g.,* obesity/overweight, smoking, alcohol consumption) on health

outcomes and health care costs associated with single as well as multiple chronic diseases; and

- comparing such analyses across chronic diseases individually, and with the diseases combined - the aim being to identify key comorbidity patterns and the intervention points most likely to be effective.

Use of the model-system to inform decision makers can help identify the most effective policy interventions to reduce the prevalence and severity of chronic diseases. Following implementation of such policies, considerable benefits would occur to Australians in terms of better health, productivity and well-being. Health expenditures would be lower, the pool of skilled people entering or remaining in the workforce would be greater, and living independently would be a possibility for a greater number of the frail old.

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CHAPTER 5

Chronic Disease Model-System – Detailed Descriptions

Agnes E.G. Walker*

Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: This Chapter describes in detail the elements of *HealthAgeingMod*: the data sources and methods used, the assumptions underlying the model-system, the variables that needed to be modified, or imputed; the demographic and health characteristics of the Base-year dataset; the method of projecting into the future; and, for the diabetes and CVD sub-models, the data sources used and the incidence equations developed.

Keywords: Economic model building, cross-sectional and longitudinal data sources, microdata, methodologies, equations to predict risk factor and disease probabilities, microsimulation.

5.1. DATA

At the time this project was proposed, there were considerable gaps in the data available for use in a complex and novel model, such as *HealthAgeingMod* (Chapter 4). Although longitudinal data would have been preferred, much of the existing and expected future Australian data were cross-sectional. In addition, several key variables required for the model-sytem were either *not* part of the cross-sectional data, or they were *not* in the required form. Details of the various survey data used are in the Appendices, or in earlier publications [35, 37]. The main data sources chosen were as follows.

The Base-year person-level population was constructed from the Basic and Expanded CURFs (confidentialised unit record files) of the cross-sectional and nationally representative NHS05 of the Australian Bureau of Statistics [47, 48]. The NHS05 household sample survey comprises 25,906 person records, with some 1000 variables obtained by trained interviewers from survey respondents (Appendix A). Like all household surveys, the NHS05 excludes people residing in institutions (*e.g.,* in hospitals, hostels and nursing homes).

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

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While the responses were self-reported, the questions on diseases were asked so as to reflect diagnosis by health professionals (*e.g.*: were you told by a doctor or nurse that you had diabetes). Thus the 'have disease' responses could be cross checked with the 'whether used medication' question for that disease. Also, earlier studies have shown good agreement between self-reported illnesses and the related clinical diagnoses [49].

From among the 1000 or so survey variables, those used in *HealthAgeingMod* include: age, sex, socio-economic status, education level, health risk factors (blood pressure, cholesterol, blood glucose level, body mass index (BMI), whether smoking, and exercise level).

To each respondent record the ABS had attached a 'weight' variable to indicate the number of persons in the population estimated to be represented by that record. Application of these 'weights' to the Base-year population ensures that nation-wide estimates can be computed and that the estimates conform to an independently measured distribution of Australia's population by age, sex, state/territory and section of state [48].

When projecting the Base-year population into the future by sex and 5-year age group, we used the ABS's population projections for Australia from 2004 to 2101 [50].

The data sources for health expenditures were obtained from the Australian Institute of Health and Welfare (AIHW) [51, 52], the Federal Department of Health and Aged Care [53], and journal articles [42, 54]. Much of the available health expenditure statistics were aggregated from administrative data, such as State-run public hospitals. Thus, within our project timeframe, per person costs were scarce at the individual disease level, and close to non-existent at the level of persons with multiple comorbidities. Yet, while building *HealthAgeingMod* it was clear that estimates of such costs - *e.g.,* for persons with both diabetes and CVD - had to be an input data to the model-system.

At the time, one rare source of information on the costs of comorbidities was the Department of Health and Aged Care. As the first set of linked administrative data

became available, the Department published its 'one time only' estimates of the costs to government of chronic disease comorbidities. Table **1** summarises these and shows that there are significant additional costs associated with comorbidities.

Table 1: Health care costs for Australians with chronic diseases, 2000 prices

Description	**Average Cost Per Person Per Year** (Australian dollars, AUD)
Single disease	
Cardiovascular disease	4,006
Diabetes	1,289
Cancer	2,478
Asthma	1,502
Multiple diseases	
2 Cardiovascular disease and diabetes(2 diseases)	6,283
2 Cancer and cardiovascular disease(2 diseases)	8,526
2 Diabetes and mental illness(2 diseases)	2,738
3 Cancer, cardiovascular disease and mental illness(3 diseases)	10,090
4 NHPA conditions(4 diseases)	12,405
5 NHPA conditions(5 diseases)	14,337

Source: Department of Health and Aged Care [53].

Table **1** shows that the cost of treating individuals with chronic diseases increases with the number of diseases a person has, and that this increase is greater than the simple sum of the single-diseases involved. In Table **1**, for example, the single disease costs of AUD 4,006 per person per year for CVD and AUD 1,289 for diabetes sum to AUD 5295, which is less than the administrative data based estimate for treating a person with *both* CVD and diabetes that is AUD 6,283.

Thus the data in Table **1** indicates that, in 2000, the cost of treating a person with both diabetes and CVD was 19% higher than the cost of treating two Australians, one having diabetes only and the other CVD only. Since these findings are similar to those of a US study [55], the *higher* per person costs for people with *multiple* chronic diseases - than the sum for those with a single disease - is not unique to Australia.

To implement this cost pattern in *HealthAgeingMod*, we first added up in the CVD and diabetes sub-models the person-level costs as if they had applied to

people with a single disease only. Next, when linking the two sub-models to the Umbrella model, we identified persons with both diabetes and CVD, and then up-rated the initial simple summed-cost estimate by 20%.

Table **2** summarises the per person per year unit costs used in *HealthAgeingMod* as inputs under 'default' settings. For both diabetes and CVD, these estimates are based on the same Australian linked administrative data source [53, 54]. The research for CVD costs was carried out at a later date than that for diabetes, and thus we were able to examine a broader range of the cost items available in the linked administrative data.

Table 2: Diabetes and CVD 'default' per person per year input costs

	Total cost Per Person (Australian Dollars, AUD)	**Per Annum** (1999-2000 Dollars)
	Non-fatal	***Fatal***
Diabetes Without Complications	1,289*	-
CVD Events (at time of event)		
CHD (incl angina, heart failure)	13,000	10,000
Stroke	13,000	10,000
CVD Post Event (subsequent years)		-
CHD (incl angina, heart failure)	3,500	10,000
Stroke	3,500	10,000
Diabetes with CVD	20% above the sum of the single-disease costs*	-

* From Table **1** above, which showed that in 2000 the cost of treating a person with both diabetes and CVD was 19% higher than that of treating two persons, one with diabetes only and the other CVD only [53].
Source: CVD costs, Australia [54].

A new item was the separate estimation of fatal and non-fatal costs of CVD events, which we were able to make use of when developing *HealthAgeingMod.* Also important was examination of CVD events subsequent to the original event. When projecting 5-years ahead, we accounted for such 'post-event costs' (*i.e.,* AUD 3,500 in Table **2**). For example, if a stroke hospital event occurred in year 2 of a 5-year period, then we allowed for AUD 3,500 per person per year for the last three years of that period.

The main data source for the diabetes and CVD sub-models ended up being the longitudinal AusDiab study (1st wave in year 2000 and 2nd in 2005) [43]. As seen

in Appendix B, while AusDiab focused on diabetes, it also had valuable longitudinal information on CVD. As seen earlier, for this project AusDiab data was made available in 2007 and CVD data in 2008, allowing the use of up-to-date Australian data in *HealthAgeingMod* rather than rely on the initially proposed UK and US sources that did not line up with ABS aggregate benchmarks (section 4.3).

Wave 1 of AusDiab comprised 11,247 adults aged 25 years or more, with 6,500 of these same adults attending wave 2 (the 2004-05 update). Another 2000 of the original group who could not attend, provided self-reported information. Extensive data on diabetes, its risk factors, and its complications (especially CVD) were collected. Across the 2000 and 2005 waves, for diabetes only the data from the 6537 persons who actually had physical testing (*i.e.,* blood taken) could be used, while for CVD data from the 2000 in the original group who only provided self-reported information could be added to that 6537.

Because AusDiab is not nationally representative, the longitudinal nature of this data source could only be used as a basis for estimating the probability of disease incidence. For type-2 diabetes, we used data from the main AusDiab survey. For CVD incidence, we used its smaller CVD sub-survey data on hospital treatment of: stroke; coronary heart disease (CHD) and myocardial infarction; coronary artery bypass graft surgery; and percutaneous transluminal coronary artery angioplasty.

Once the building of these sub-models had commenced, serious inconsistencies emerged across the AusDiab estimates and benchmark estimates from other Australian sources. These are detailed in section 5.6, together with the ways the inconsistencies had been resolved.

5.2. METHODS

As the base-year population of *HealthAgeingMod* uses microdata based on the individual level – *i.e.,* not grouped – data, the Umbrella module mainly uses standard microsimulation methods. These are summarised below, with details in sections 5.4, 5.5 and 5.6.

The methods used when preparing the Base-year dataset included: selection of relevant NHS05 variables; checking these for adequate survey response rates;

modifying some variables to meet the requirements of the model-system; and imputing required variables that were not available in NHS05 (section 5.4). To carry out projections into the future, the method involved re-weighting of the 2005 base-year population to match published future population targets for 2010, 2015, *etc.* (section 5.5).

To project individuals' chronic disease risk factors into the future, we used longitudinal data to develop econometric equations able to estimate the risk of acquiring new diabetes or new CVD (sections 5.5 and 5.6). For people initially without diabetes and/or CVD, the diabetes and CVD sub-models then applied these equations and estimated the probability that the person under consideration would develop either of these diseases within the next five years. Then, applying the Monte Carlo method to each of these individual's diabetes and CVD risk-probability estimates, the two sub-models predicted who would actually become 'newly diagnosed' with diabetes and who will have at least one 'hospital CVD event' during the next five-year period.

The model-system accounts for across-disease linkages, such as whether CVD is a single chronic disease or is a complication of diabetes. It does so by keeping, for each person, a tally of whether they have diabetes only, CVD only or both diabetes and CVD. The initially projected numbers for each group are then aligned with their respective time trend targets. For the 'default' simulation these targets are assumed to be a continuation of past trends. For Scenario simulations the targets can be set by the user.

Finally, in its "Base-Scenario Outcomes module" (Fig. **5**). *HeathAgeingMod* makes use of standard cost-benefit and cost effectiveness methods [57, 58]. First, the model-system is run in 'default' mode (*i.e.,* no policy change). This provides the Baseline simulation. Next, it is run in 'Scenario' mode (*i.e.,* with the policy change specified by the analyst in the "Specify Scenario parameters" module in Fig. **5**). The "Base-Scenario Outcomes module" then compares the Baseline and Scenario health outcomes in terms of the Disability Adjusted Life Years (DALY) - or Quality Adjusted Life Years (QALY) - avoided, as well as the Base to Scenario differences in terms of monetary benefits and costs. This process for a diabetes prevention and care intervention, using an earlier model, has been

described in a refereed journal article [59]. In this book it will be described for *HeathAgeingMod* in Chapters 7 and 8.

Once the building of the model-system was completed, the outputs of *HealthAgeingMod* were validated against aggregated external and publicly available benchmark statistics (section 6.1).

5.3. ASSUMPTIONS

HealthAgeingMod was built under three main inter-woven assumptions:

1) observed cross-sectional health patterns, and trend changes in these, are an appropriate basis for projecting into the future;

2) comparing benefits *versus* costs across cross-sectional time series data is an appropriate basis for ranking/selecting intervention options. We chose this cross-section-based mode because the main alternative – *i.e.,* developing individual-level lifetime health profiles – has been shown to be much more complex, time consuming and costly; [60].

3) with improved population health and health service usage the related costs will decline. Because this assumption raises the question of whether Australians 'live longer because they are healthier', or 'are kept alive longer by ever improving medical technologies', we developed *HealthAgeingMod* so that users can alter this assumption.

Re continuity or otherwise of self reported diseases, we assumed that those who already had diabetes in 2005, and those predicted to acquire new diabetes, will continue to have the disease throughout the projection period. For diabetes this is a reasonable assumption given that, at this time, only obesity surgery can reverse diabetes. For CVD we assumed that *all persons* – whether with or without self-reported coronary diseases in 2005 - could have a major CVD event in the projection period.

Because for CVD hospitalised events were the best available predictors of incidence, we designed the model-system to only predict such new hospitalised

events. Thus CVD history in the base-year is not considered any further, except as a possible explanatory variable for the probability of a new CVD event in the projection period.

For CVD we also assumed 'recovery' for those who reported a history of CVD. Thus people with a CVD history were assumed not to require follow-up expenditures unless they have been predicted to have another CVD event in the projection period. This assumption is backed by external benchmark data which indicate that total CVD expenditures were *well below* those that would have occurred had a suggested annual follow-up cost of AUD 3,500 (Table **2**) applied to all those with CVD history.

When projecting new diabetes and new CVD over five years, we assumed random allocation of the new event occurring either in year 2 or in year 4 of the period. As there is a single per year unit cost for diabetes without complications (Table **2**), this cost is applied from the year of onset of the new diabetes and, for those with diabetes in the base-year, throughout the 5-year projection period. The situation is more complicated for CVD since for this disease there are three types of unit costs: two for the year in which the predicted event occurs (fatal and non-fatal) and one for the post-event years (*i.e.,* year 5 for events that took place in year 4 and years 3, 4 and 5 for events that took place in year 2).

The impacts of these assumptions on simulated Scenario outcomes can be examined through sensitivity testing. While alternative 'sensitivity' assumptions will change the magnitude of the costs and benefits associated with the Scenarios, in many cases they will not change the ranking of these Scenarios in terms of costs-benefit or cost-effectiveness yardsticks. The reason for this is that rankings compare options at the *marginal* level – that is at the level of *differences* between baseline and scenario, and thus not at the full cost/benefit level.

5.4. BUILDING THE BASE-YEAR DATASET

This section details the way the base-year dataset was developed. The box "Base-year dataset" in Fig. **5** shows how this task fits into *HealthAgeingMod*'s overall framework.

The accuracy of the model-system will depend on the quality of data available for the modifications and the imputations. Having been granted access in 2007 and 2008 to the longitudinal AusDiab dataset meant that the modification and imputation were as accurate as the best data and state of the art imputation techniques permitted. AusDiab's CVD sub-sample provided us with longitudinal data for estimating the probability of future CVD events. Its full-sample provided data for the imputation of undiagnosed diabetes and prediabetes states as indicators of high risk for being diagnosed with diabetes in *HealthAgeingMod*'s projection years. Studies have shown that individuals do pass through a pre-diabetic state prior to developing diabetes [61].

Variables Extracted from NHS05

As seen in Chapter 4, the de-identified person-level base data for the Umbrella Model is made up of nearly all of the 25,906 individuals in the NHS05 confidentialised unit record file [47]. Being a household survey, the NHS05 population only comprised people residing in private dwellings. Thus people in non–private dwellings were excluded (*e.g.,* hotels, motels, hospitals, nursing homes and short-stay caravan parks). This meant that people who were likely to have the poorest health – *i.e.,* those in hospitals, hostels and nursing homes – had been excluded from *HealthAgeingMod*.

The key person-level variables extracted from NHS05 for the Umbrella model's Base-year population included:

- *Demographic:* Age (5-year groups), Sex; Country of birth;

- *Socio-Economic*: Income (Gross weekly equivalised household income), Income unit type (single or couple with or without children), Education **(**Highest post-school), Jobs (Hours usually worked per week in all jobs);

- *General Health:* **(**Excellent, Very good, Good, Fair, or Poor), Number of long-term conditions;

- *Risk Factors*: Body mass index group (15+ year olds), Regular smoker status (18+ year olds), Alcohol risk level (3 day average, 2000 guidelines), Exercise (total time spent in last 2 weeks);

- *Risk Factors* (medically assessed): Whether told by doctor or nurse that he/she had: High blood pressure, High cholesterol, High sugar level;

- *Chronic Diseases* (medically assessed): Whether told by doctor or nurse that he/she had: Diabetes (type1, type2, gestational), Angina, IHD (Ischaemic Heart Disease), Stroke, Cancer, Arthritis, Depression (Feeling depressed);

- *Whether Used Medication* for blood pressure, sugar level, cholesterol, mental wellbeing.

Variables Modified

While the variables extracted from NHS05 for the Base-year dataset are quite comprehensive, their forms do not always line up with the requirements of *HealthAgeingMod.* So some NHS05 variables needed to be modified. Also, not all variables required are available in the NHS, so these needed to be imputed.

The NHS05 Basic CURF variables that had been modified are as follows.

- *Age* (available in 5-year age groups then 85+) was converted to 'single years' to match the 'single years' data of the AusDiab-based Diabetes and CVD sub-models, and of the population targets (used for reweighting when projecting into the future). For this modification we used the much more restricted NHS05 Expanded CURF which has age as 'single-years' and observed the single year age distributions within each 5-year age-sex group of the Basic CURF. We found that in general the single years were equally distributed within the 5-year age-sex group – *e.g.,* in the 70-75 age group for men each of the single years (*i.e.,* 70, 71, 72, 73 and 74) accounted for 20% of the total population in that group. Based on this finding we randomly allocated a single age to each person in a particular 5-year-sex group until the population for each single year within that group reached 20% of the total 5-year population.

- *Country of Birth* was needed in the early stages of the project when we planned to use the British UKPDS model (section 4.3) which required an Ethnic group variable (White; Afro-Caribbean; Asian-Indian). From the Basic NHS05's 'Country of birth' variable we created the broadly matching groups of 'White' and 'Asian-Indian-other'. A few other matches were achieved with UKPDS variables, but neither these nor the Country of birth variable were used in the applications reported in Chapters 7 and 8.

- *Body Mass Index* (BMI) was available in eight self-reported BMI bands for 15+ year olds in the Basic NHS05 CURF. First we converted these into three broad BMI groups, matching the AusDiab-based Diabetes and CVD sub-models. The BMI groupings were: thin/normal < 25 kg/m^2; overweight 25 to 29.99 kg/m^2; and obese >= 30 kg/m^2. We later used these as basis for the continuous BMI value imputations (see sub-section below).

Variables Imputed

The main imputations were: continuous values for BMI within the NHS05 BMI-bands; continuous values for each of the (0,1) NHS05 risk factor variables for high blood pressure, cholesterol and blood sugar levels; estimation of the (0,1) health states of undiagnosed diabetes and prediabetes: Impaired Fasting Glycaemia (IFG) and Impaired Glucose Tolerance (IGT).

The reason why we needed to impute continuous BMI values onto the Umbrella model's base dataset was that the Basic NHS05 CURF only provided self-reported BMI in 'bands'. This is not acceptable for the diabetes and CVD sub-models, which require continuous BMI (and other risk factor) values - preferably measured, rather than self-reported. The data choices for the imputation were: the NHS05 Expanded CURF (25,906 individuals surveyed) which had self-reported individual-level weight and height information for people aged 15+ years; and AusDiab_2000 (11,247 surveyed) which had individual-level measured BMI values for those aged 25+ years. It is not clear which of these sources is the more appropriate, because NHS05 is for 2005, the year of the base-year dataset, with a

larger sample size but with self-reported data, while data in AusDiab_2000 is measured, but it is for 2000 and has a smaller sample size.

To assist with the choice of data source, we ran the same regressions with both datasets for each of the thin/normal, overweight and obese 'broad BMI groups' (see sub-section above). Regression equation (1) was of the form:

$$BMI = c + a*Age + b*SEX + c*Diab + d*Smoke + e*Exerce \quad \textbf{(1)}$$

with BMI: continuous BMI value

Age: in groups (25-34; 35-44; 45-54; 55-64; 65-74; 75+)

Sex: 0=male; 1=female

Diab: 1=has been told has/had diabetes; 0=never told

SMOK: 1=current or ex regular smoker; 0=non-smoker

Exerce: 1= sufficient (>150 mns per week); 0=insufficient

To estimate the coefficients of equation (1) we used the general-purpose PROC REG function of the SAS programming language. The results were weighted. When testing equation (1) with various age, sex, *etc.* values, it became clear that the estimated continuous BMI values tended to be heavily concentrated around the mean of the 'band' and thus the continuous BMI estimates did not cover anything like the full range between the band limits. As an example, BMI estimates using the AusDiab equation for the 25 to 29.9kg/m^2 'Overweight band' (with Exerce not statistically significant):

$$BMI=27.04247 +0.0034*Age - 0.15677 *SEX + 0.16292 *Diab + 0.14651*SMOK$$

was found to only cover a value range between 27.1 and 27.5 across individuals with extreme combinations of the explanatory variables. This concentration of values around the mean was considered unsatisfactory for providing continuous BMI values in *HealthAgeingMod*, since it was likely to create clustering of disease onsets in the projection years.

In view of the above, for *HealthAgeingMod* we decided to keep the eight original BMI bands in the basic NHS05 Basic CURF, and impute BMI values randomly within the limits of each of its original eight BMI 'bands': thin1: <16.00; thin2: 16.00–16.99; thin3: 17.00–18.49; normal1: 18.50–19.99; normal2: 20.00–24.99; overweight1: 25.00–29.99; overweight2: 30.00–39.99; and overweight3: 40 or more.

Advantages of this imputation method were that: we could use 2005 data (rather than 2000); cover the population aged 15+ years (not only 25+); and end up with continuous imputed BMI values within the eight bands specified for each *NHS05 individual* (rather than imputed values that tightly clustered around the means of only three 'bands').

To impute other continuous risk factor values for 15+ year olds in the Umbrella model's base-year dataset we used the detailed, measured and continuous value information from AusDiab_2000 for 25+ year olds. The risk factors considered were blood pressure, cholesterol and blood sugar level. For these we assumed that the patterns for 25+ year olds would also apply to the Umbrella model's 15-24 year olds.

In NHS05, high/low risk is only indicated by (0,1) variables in response to the question: 'Ever told has condition, which is still current and long-term'. If these NHS05 variables were equal to 1, then they indicated the person having high blood pressure, high sugar level or high cholesterol. For high sugar level the question specified "diabetes or high sugar level", so in the 'high sugar' group we needed to include both people with diabetes and prediabetes.

To impute continuous values for these risk factors we estimated separate regression equations for the 'high' and 'low' risk groups in the Umbrella model's base-year population using the multiple regressions PROC REG command of SAS on 11,247 AusDiab participants. The equations for each of blood pressure, sugar level and cholesterol were of the general form:

Risk factor value = constant + a*AGE + b*SEX + c*BMI + d*SMOKING + d*EDUCATION + e*EXERCISE

with the explanatory variables being in line with those found important in earlier research [62]. The detailed equations are described in an earlier publication [38].

To impute undiagnosed diabetes and prediabetes states (IFG or IGT) onto the 'free-of-diabetes' population in the Umbrella model's base-year dataset, we first estimated corresponding equations from AusDiab_2000. The population base for the regressions included respondents with both types 1 and 2 diabetes, the latter accounting for 92% of those with diagnosed diabetes.

For the undiagnosed regressions we modeled the 'newly diagnosed' in the 'diabetes free' AusDiab population. For the prediabetes regressions we modeled the groups with IFG and IGT in the population without diagnosed or undiagnosed diabetes.

For the undiagnosed and prediabetes groups we estimated logistic regression equations using the SAS LOGISTIC procedure which performs regression analyses for dichotomous outcomes, and fits the proportional odds model and the generalised logit model by the method of maximum likelihood. It estimates the probability 'p' that an individual of given characteristics has undiagnosed diabetes or prediabetes. Details of the equations are in an earlier publication [38].

An important finding from these AusDiab data based equations was that blood sugar level was by far the most important explanatory variable of the probability of undiagnosed diabetes. With a normal blood sugar level this probability was very low (p=0.02261). However, with the mean sugar level of people with diabetes, this probability was very high (p=0.97899). In other words an undiagnosed person with a blood sugar level equal to the mean of those with diabetes was near certain to have (undiagnosed) diabetes.

To impute risk factor and undiagnosed/prediabetes states onto the Umbrella model's 15+ year old population, we used the above mentioned equations in conjunction with the Monte Carlo method. This process generally resulted in a slight underestimate of the related benchmark prevalences in AusDiab_2000. To correct for this we used an appropriate scaling factor to align the model-system prevalences with the AusDiab_2000 targets.

Demographic and Health Characteristics of the Base-Year Dataset

Table **3** summarises the demographic and health characteristics of the NHS05-based 25+ population in the Umbrella model's Base-year dataset. We chose the 25+ population for this summary Table partly because it allowed comparisons with the full population of AusDiab (*i.e.,* 25+ year olds), and partly because the chronic diseases and comorbidities of interest mainly affect older people.

Table **3** shows that the model-system's base-year population aged 25 years or more was 13 million in 2005, estimated from the NHS05 sample of 17,688 persons. Among these 9.7 million had neither diabetes, nor prediabetes or CVD (the 'healthy' group). Around 629,000 had CVD without diabetes, 708,000 had IFG and 1.3 million IGT; 511,000 had undiagnosed diabetes and 576,000 diagnosed diabetes. In addition, around 125,000 had both CVD and diabetes (diagnosed and undiagnosed), with 58,000 of these reporting to have been diagnosed by a doctor or nurse with diabetes.

The average age of the total 25+ year olds population was 50.5 years, compared with 47.2 years for the 'healthy' sub-group; between 55 and 60 years for those with prediabetes; around 65 years for those with diabetes (diagnosed and undiagnosed); and 70.6 years for those with CVD without diabetes. This pattern clearly shows the impact of ageing on people's health.

An indicator of the extent of comorbidities among the 25+ population is the distribution of the average number of long term conditions within each of the sub-population groups.

This average is 2.7 long term conditions for the 'healthy' population, compared with between 3.1 and 3.5 such conditions for those with prediabetes; between 3.9 and 4.4 for those with diabetes and 4.7 for the group with CVD without diabetes.

The comparisons of self-reported health within these groups shows a similar pattern, 85.3% of the 'healthy' group having reported their health to be good, very good or excellent, compared with between 70 and 75% of those with prediabetes or undiagnosed diabetes, 52% of those with diagnosed diabetes and only 38% of those with CVD.

Table 3: Demographic and health characteristics, Umbrella model's Base-year dataset, 25+ year olds, 2005

	All	**Healthy**[5] no diabetes, prediab,CVD	**CVD**[4] no diabetes	**IFG**	**IGT**	**Undiag'd diabetes**	**Diagnosed diabetes**
N - unweighted - weighted[1]	17688 13068	12814 (69.6) 9687 (71.6)	959 (5.4) 629 (4.8)	945 (5.3) 708 (5.4)	1849 (10.5) 1292 (9.9)	780 (4.4) 511 (3.9)	844 (4.8) 576 (4.4)
Male - unweighted - weighted[1]	8039 (45.5) 6401 (49.0)	5530 (68.8) 4509 (70.4)	233 (2.9) 170 (2.7)	662 (8.2) 507 (7.9)	794 (9.9) 607 (9.5)	389 (4.8) 280 (4.4)	431 (5.4) 328 (5.1)
Age (year) - unweighted	50.5 (16.2)	47.2 (14.8)	70.6 (12.0)	54.8 (15.7)	59.9 (15.7)	65.8 (15.0)	64.6 (12.8)
No of long term conditions[2] - unwght'd	3.0 (1.7)	2.7 (1.7)	4.7 (0.7)	3.1 (1.7)	3.5 (1.6)	3.9 (1.4)	4.4 (1.0)
Good-excellent 'health'[3] - unweighted - weighted[1]	14299 (80.8) 10734 (82.1)	11902 (83.9) 9089 (85.3)	182 (39.9) 111 (38.0)	720 (76.2) 540 (76.3)	1387 (75.0) 960 (74.4)	549 (70.4) 361 (70.6)	434 (51.4) 299 (51.9)
CVD[4] **with diabetes** - unwght'd - weighted[1]	199 (23.58) 125 (21.74)	-	-	-	-	-	97 (in 844) 58 (in 576)

Data are 'number of persons' (% of total in category) or 'mean' (SD).
1: '000 persons (nationally representative estimates).
2: up to 5 conditions which respondents had at interview and which had lasted, or they expected to last, for six months or more.
3: assessed own health as good, very good or excellent.
4: ever told by nurse or doctor that had angina or heart attack, or stroke.
5: without prediabetes, diabetes or CVD.
Source: *HealthAgeingMod*'s base-year dataset.

Of importance for interpreting simulations with *HeathAgeingMod* will be that, on average, Australians with prediabetes and undiagnosed diabetes are 5 to 10 years younger, have less comorbidities and have better perceived health than those with diagnosed diabetes. In turn, people who have ever been diagnosed with CVD (but without diabetes) are on average around 5 years older, have more comorbidities and worse perceived health than people with diagnosed diabetes (but without CVD).

5.5. THE UMBRELLA MODEL

The various functions of the Umbrella model are:

- projecting the Base-year population and individuals' health characteristics into the future (the "Progression" boxes in Fig. **5**);
- projecting values of the key chronic disease risk factors (blood pressure, cholesterol, and blood sugar);
- linking the Umbrella model to the CVD and Diabetes sub-models; and
- the 'pulling-it-all-together', so that Scenario and Baseline outcomes can be estimated and compared (the "Base-Scenario Outcomes" box in Fig. **5**).

Projecting the HealthAgeingMod Population into the Future

Official projections of Australia's ageing and increasing population give some indication of the health impacts of future population changes, given that age has been shown to be one of the key determinants of health. As noted in section 1.3, health expenditures are already of concern in Australia. So an ageing and increasing population is most likely to add to today's cost pressures. Health service demand and the related expenditures will continue to be of concern, so estimating population changes over time is an important task of the Umbrella model.

A standard way of ageing survey-based populations in microsimulation models is to readjust the weights attached to survey individuals so that re-weighted populations match the desired official 'targets'. Below we first describe the population 'targets' chosen, then explain how we carried out the re-weighting task against these targets.

The 'targets' chosen for population projections were those published by the Australian Bureau of Statistics [50]. Between 2005 and 2025, estimates were provided under three sets of assumptions: a 32% increase in Australia's population under series A, a 25% increase under series B and a 19% increase under series C. For our 'default' simulations we chose the age (5-year age group) by sex estimates of the 'middle projection' - series B - with series A and C available for sensitivity testing.

Fig. **6** charts, by age, the population changes between that estimated in NHS05 for 2005 and that in the series B projection for 2025. It shows that the overall 25% population increase predicted in that period mainly occurs within the '30 years or over' age group, with little change in the numbers of children and younger adults.

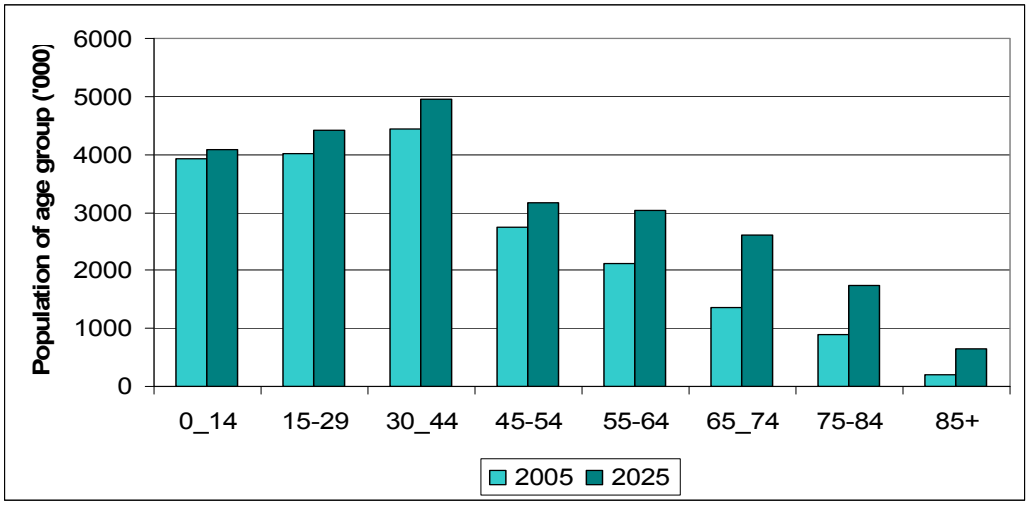

Figure 6: Changes in Australia's population distribution by age, 2005 and 2025.
Sources: for 2005 [47]; for 2025[50], series B projections.

Clearly, the series B projection of a near *doubling* of the number of 65-74 year olds (a 94% increase), and a more than *trebling* of the number of 85+ year olds (a 236% increase) is expected to have a considerable impact on health outcomes and expenditures.

To re-weight the Umbrella model's Base-year population**,** we obtained permission from the ABS to use its Generalised Regression (GREGWT) estimator program.

GREGWT carries out calibrations, modifying the initial survey-weights to closely match externally provided benchmarks [63]. When requesting multiple runs, GREGWT will adjust successive initial weights in line with the distance function specified until convergence to the set 'max distance error' is reached.

Thus, in *HealthAgeingMod* the 2005 individual-level weights are those provided in the NHS05 CURF and the projection year weights by GREGWT, so that the subsequent population sizes closely match the official published 'targets' for each age-sex population group. Most of our simulations to date projected 5 years into the future, between 2005 and 2010. Once the 2005-2010 period computations are obtained, the process can be repeated for the following 5-year period, and so on.

The ABS's population projections are estimates of Australia's live population that is deaths had already been accounted for in the population targets set for *HealthAgeingMod*. This raises special issues for modeling those diseases that are major causes of death, such as CVD (section 5.6).

Projecting the Key Health Risk Factors into the Future

We chose the longitudinal AusDiab survey for developing equations to project chronic disease risk factors 5-years ahead, because AusDiab had *measured* risk factor values for the *same* persons over the 2000 to 2005 period, compared with the NHSs having self-reported values across two cross-sectional surveys (and thus the data cannot be tracked for the same person).

Because we were modeling the progression of risk factor values over time, only the 6537 AusDiab participants who had been subjected in both waves to measurements could be included. For these we constructed a 'single dataset' in which each participant had both their 2000 and 2005 measured risk factor values on the same data record. First we used that dataset to examine the risk factor trends over the period, and next we used it to develop risk factor projection equations.

Risk Factor Trends, 2000 to 2005

Using the above 'single dataset', we estimated for both 2000 and 2005 and by age-group the *mean* values for blood sugar (HbA1c), BMI and systolic blood

pressure (BP), as well as the proportions of participants with high cholesterol and with insufficient exercise. Because the AusDiab sample is not nationally representative, the estimates were unweighted.

We expected the risk factor *means* to be higher in 2005 than in 2000 because AusDiab participants were 5 years older in wave 2 than in wave 1. Our findings lined up with this expectation for blood sugar levels and for body mass indexes, with these showing increases across all age groups over the period (overall, a 5.32% increase for blood sugar and 2.92% for BMI).

These higher blood sugar and BMI levels occurred despite more people in 2005 exercising sufficiently (*i.e.,* at least 150 minutes per week) than in 2000. The proportions with sufficient exercise increased in nearly all age groups, by 6.08% in total. A finding of particular concern was that, despite a higher proportion of 25-44 year olds exercising sufficiently, this age group experienced the greatest BMI increases over the period (close to 5%).

The surprising findings were the declines in mean BP and in the proportions with high total cholesterol (*i.e.,* at or above 5.5 mmol/l). For the full 25+ age group the mean BP decreased by 3.91%, and the proportion with high cholesterol by 29.43%. These improvements may have arisen through greater prevention focus by medical practitioners, and/or AusDiab participants themselves changing their lifestyles (*e.g.,* due to the greater awareness they gained at their wave 1 measurement session).

Risk Factor Projection Equations

For the chronic disease risk factor projection equations we initially used the same set of variables as for the risk factor imputations described earlier in this section for 2010 (time t) and 2005 (time t-1). However, as the variables EDUCATION and EXERCISE were not statistically significant at the 0.01 level in any of the 'Risk factor value' equations, they were removed from the projection equations.We used, in stepwise mode, the multiple regression PROC REG command of SAS.

The order in which the risk factor values were processed mattered, as it allowed in some cases to consider certain explanatory variables at time t, instead of t-1. The equations were of the form:

Risk Factor Value(t) = constant + a* SEX + b*AGE + c*SMOK + other relevant risk factors.

The detailed equations for each risk factor are in Table **4**.

Table 4: Coefficients of equations that project risk factors 5-years ahead

	HbA1c(t)	BP(t)	CholValue(t)	BMI(t)
constant	1.54472	23.55074	3.21823	3.22536
SEX	-	-2.70273	0.17244	0.12904
SMOK	-	-	-0.06564	-
AGE(t)	0.00225	0.20143	-0.00339	-0.02100
AGE(t-1)	-	-	-	-
HbA1c(t)	-	-	-	-
HbA1c(t-1)	0.69137	-	-0.10872	-0.13473
BP(t)	-	-	-	-
BP(t-1)	-	0.61758	-0.00175	-0.00480
CholValue(t)	-	-	-	-
CholValue(t-1)	-	-	0.55037	-0.14665
BMI(t)	-	-	-	-
BMI(t-1)	0.00830	0.43721	-0.00685	0.99955

Data Source: AusDiab waves 1 and 2.

Umbrella Model Links with the Disease Specific Sub-Models

Once the above population and chronic disease risk factor projections are completed, the Umbrella model's "Progression" module links with the health state transitions predicted by the Diabetes and CVD sub-models, including indication of whether a person has both diabetes and CVD (section 5.6). Finally, it computes summaries of the changes predicted and transfers these to the "Base-Scenario Outcomes" module.

A flowchart of the "Progression" module is presented in Fig. **7**.

Estimating Costs and Health Benefits

It is in the Umbrella model's "Base-Scenario Outcomes" module (Fig. **5**) that the health benefits and costs of the Baseline and Scenario simulations are computed, and then compared to obtain the net costs and benefits. From these cost

effectiveness and/or cost benefit ratios can be estimated to provide indicators of the 'value for money' of the intervention (*i.e.,* Scenario) compared to other possible interventions.

The unit costs embedded in the Umbrella model were described in section 5.1 and summarised in Table **2**. Based on these, total costs are computed from the (weighted) numbers of persons with diabetes only, fatal or non-fatal CVD only, and with both diabetes and CVD.

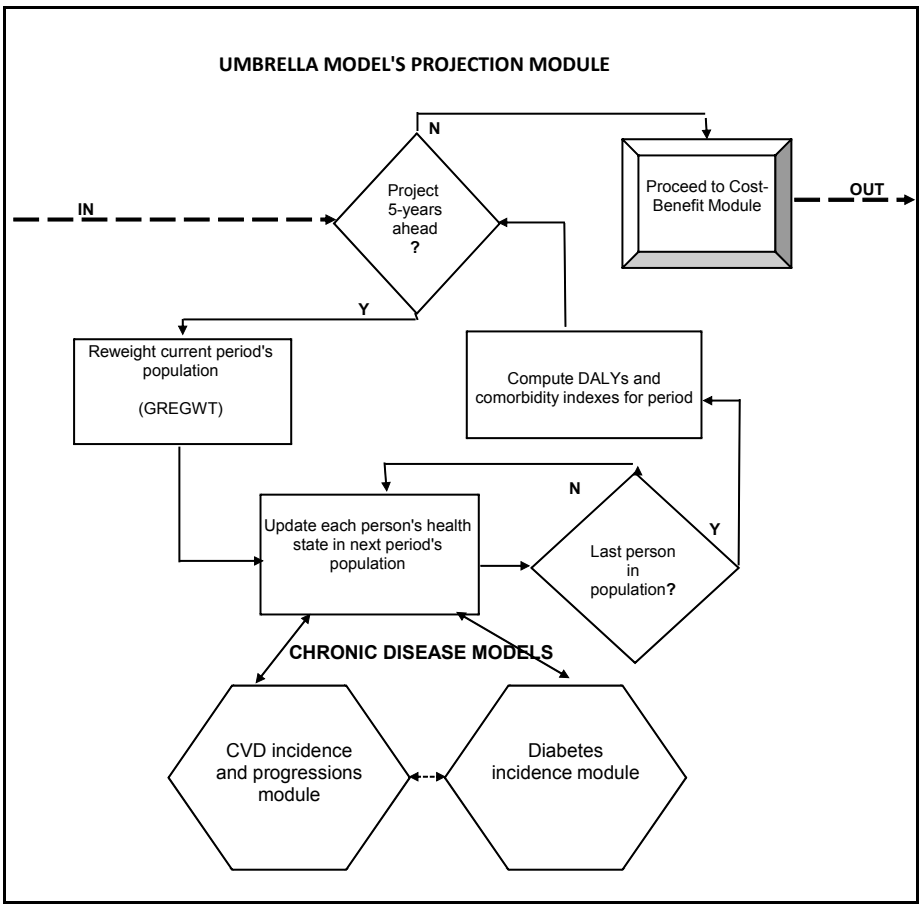

Figure 7: Umbrella model's projection module.

However, to be able to rank various interventions, monetary considerations – such as the costs of the Scenario – need to be offset by the additional health benefits

expected to arise from implementation of the intervention. Considerable human benefits would arise from less people developing - or die from – heart disease or stroke, and/or fewer people suffering from the end-stage complications of diabetes, such as CVD, blindness or kidney failure.

In *HealthAgeingMod* we accounted for non-monetary benefits by computing the Disability Adjusted Life Years (DALY) summary statistic, based on the model-system's disease-related outputs. Briefly, 'one DALY is one year lost of healthy life' [64]. It is made up of two components: years of life lost through premature death (YLL); and years lived with a disability (YLD). Thus:

$$DALY=YLL+YLD$$

In *HealthAgeingMod* the 5-year YLL and YLD components and the DALY were derived as:

$$YLL = (N * F * LE)$$

where N is the total number of Australians who died from the disease over the five-year period, F is the proportion of population-wide deaths due to the disease, and LE is the average life expectancy at the midpoint of the age-gender group under consideration.

$$YLD = (I * L * D)$$

where I is the number of incident cases over a five-year period, L is the average duration of the disease (in years) at that age and D is the disability weight (reflecting the severity of the condition).

For the YLD estimate we used already published Australian disability weights for diabetes and for CVD [65]. From these we selected the following 5-year disability weights:

- DiabDisabFactor=**0.10** for people with new (or old) type 2 diabetes but without CVD.
- HeartDisabFactor=**0.44** for people with new heart event, but without diabetes.

- StrokeDisabFactor=**0.92** for people with new stroke event but without CVD.

As noted in section 5.1, for people with both diabetes and CVD, *HealthAgeingMod* applies the comorbidity factor set by the user (20% as 'default').

Estimation of DALYs – a hard to quantify indicator of the disability adjusted life years gained – uses 'dollars', the single measure of both costs and health benefits. Thus the statistics computed in the "Base-Scenario Outcomes" box (Fig. **5**) are the result of complementing the cost-benefit approach with cost-utility analysis. Details of the actual processes carried out within that box are in section 5.2.

5.6. DIABETES AND CVD SUB-MODELS

Data Sources, Comparisons and Choices

The accuracy of *HealthAgeingMod*'s Diabetes and CVD Incidence Moduels critically depend on the quality of the data available in Australia. As was noted in section 5.1, AusDiab was generally the preferred data source for both the Diabetes and the CVD sub-models. This was due to the longitudinal nature of AusDiab allowing estimation of the incidence of these diseases, which was not possible with the cross-sectional NHSs that only measure prevalence at the time of the survey. However, the NHSs could provide trends in prevalences over a much longer time period than the two waves of AusDiab.

While our initial 'overall' choice was generally correct for both diabetes and CVD, once we started to build these sub-models several data source inconsistencies emerged. How these were resolved is described below, first for diabetes and then for CVD.

For the Diabetes sub-model the already mentioned data sources considered were the ABS's National Health Surveys and AusDiab's wave 1 and 2 (section 5.1). As a benchmark we could also use the National Diabetes Services Scheme (NDSS) which had incidence data for one year, 2003, in the form of the 43,100 new registrants it had recorded Australia wide as having 'new diabetes' [66]. For

diabetes this NDSS information indicated an incidence estimate of ***0.33%*** in 2003, assuming that all those newly registered were aged 25 years or more.

The question to be investigated was which of the sample survey based data sources indicated an incidence closest to the 0.33% per annum that had been recorded nationally.

Because AusDiab's longitudinal nature was best suited for studying incidence, and it also had 'measured' diabetes information in addition to self-reported data, initially AusDiab was chosen as the main data source for the Diabetes sub-model (section 5.1). However, AusDiab was a one-off survey, while the NHSs were well established over the longer term and were nationally representative.

Before carrying out comparisons across the sample surveys, it was important to find out which of the three AusDiab diabetes status variables should be used in the Diabetes sub-model. The possible AusDiab variables were:

- *DiagnosedDiab*: self-reported diabetes as response to the same 'have you been told by doctor or nurse that you have diabetes' question as in the National Health Surveys;

- *KnownDiab*: a subset of the Diagnosed Diab group in which survey respondents not only self-reported but also had blood glucose values in the diabetic range in the AusDiab tests; and

- *UndiagnosedDiab*: another sub-group in which respondents said they had *not* been told they had diabetes, but in the AusDiab tests their blood glucose values were in the diabetic range.

The patterns across AusDiab's 2000 and 2005 waves allowed estimation of the incidence of diabetes (*i.e.,* those *without* diabetes in 2000 who were *with* diabetes in 2005). Also, because the AusDiab sample was not nationally representative, the related analyses needed to be based on that survey's unweighted wave1 and wave2 populations.

Table **5** summarises our prevalence and incidence estimates using the *DiagnosedDiab* and *KnownDiab* variables of AusDiab, the cross-sectional NHSs

of 1995, 2001 and 2005, and the NDSS registrations in 2003. The Table shows that the NHSs indicated a steady increase in the prevalence of type 2 diabetes from 1995 to 2005 (2.72% in 1995; 3.47% in 2001 and 4.41 in 2005).

Our analyses support earlier findings by other researchers that, among Australians, there were as many undiagnosed persons as diagnosed persons. In Table **5** this is indicated by the prevalences of the *KnownDiab* and of the *UndiagnosedDiab* groups, both being 4.2% in 2000 among Australians aged 25 years or more.

Table **5** also shows some surprising findings. A major one is that, contrary to expectations, the responses to the *same* question of "Have you ever been told by a doctor or nurse that you have diabetes?" resulted in very different prevalence estimates in AusDiab and in the corresponding NHSs. Also, the AusDiab *self-reported* data relating to this common question provided not only quite different prevalence estimates from the NHSs, but also highly unstable estimates. For example, to the 2001 NHS prevalence estimate of 3.47% corresponds a higher 5.0% estimate in AusDiab's wave 1 and, to the 2005 NHS estimate of 4.41% corresponds a much higher 8.4% in wave 2 of AusDiab. This suggests a nearly doubling of diabetes prevalence in just five years which, if accurate, would be well above the increase estimated by NHSs over the ten year period to 2005. As will be seen below when discussing incidence rates, the AIHW had similar concerns about the accuracy of the AusDiab findings across waves 1 and wave 2.

A likely reason for the very high AusDiab estimate in 2005 could be that those found to be 'undiagnosed' in the AusDiab initial sample by the blood glucose test were more likely to have visited their doctor between 2000 and 2005 and then be declared 'diagnosed' with diabetes. Thus in wave 2 of AusDiab a higher proportion of the sample was likely to self-report as 'diagnosed' than in the random cross-sectional sample of NHS05. Another reason may have been the relatively low wave 2 attendance rate (6,500 persons compared with 11,247 in wave 1). Another 2000 of the original group who could not attend but provided self-reported information did not undergo a follow-up blood glucose test, and thus do not have a *KnownDiab* record in wave 2.

Table 5: Comparison of diabetes prevalence and incidence estimates, 25+ year olds

	TYPE 2	**DIABETES**	
	1995	***2000-01***	***2005***
		Prevalence	
ABS_NHSs (%)	2.72	3.47	4.41
AusDiab *(%)*			
- *DiagnosedDiab*		5.0*	8.4*
- *KnownDiab*		4.2	5.8
- *UndiagnosedDiab*		4.2	
		Incidence	***2000-2005***
AusDiab *(%)*			
- *DiagnosedDiab*			4.0* (0.77% pa)
- *KnownDiab*			2.4 (0.46% pa)
National Diabetes Services Scheme (for the year 2003)			0.33% pa

***** for responses to the question "Have you ever been told by a doctor or nurse that you have diabetes?".
Sources: AusDiab; [43] NHSs; [47, 67] and NDSS [66].

The *KnownDiab* self-reported and blood sugar tested estimates at 4.2% in 2000 and 5.8% in 2005 were closer to the NHS estimates, but they still showed a time trend above the cross-sectional NHS estimates. Likely overall explanations for the NHS-AusDiab discrepancies are that, unlike the NHS, AusDiab is not nationally representative, and the AusDiab sample size – especially wave 2 - is much smaller than the sizes of the NHS surveys.

For incidence, the AusDiab *KnownDiab* variable (at 0.46% a year) comes much closer to the external NDSS benchmark for 2003 (at 33%) than the estimate based on the *DiagnosedDiab* variable (at 0.77% a year). This 0.77% estimate is similar to that published by other researchers using AusDiab data [43, 62], at around 0.8%. When quoting the estimate of 0.8% by [43], the AIHW found that it was equivalent to 275 people developing the disease each day, or around 100,000 per year [66]. Noting that the National Diabetes Services Scheme recorded 43,100 new registrants in 2003, the AIHW concluded that it was unlikely that 100,000 25+ year old Australians would have been diagnosed with diabetes per year in the 2000 to 2005 period. Thus, the AIHW's conclusions support the Table **5** finding that AusDiab's self-reported diabetes data is unreliable, especially in wave 2.

Based on the above findings, for diabetes prevalence alignments we used NHS data (section 6.1). When developing diabetes incidence equations we used the AusDiab's *KnownDiab* variable.

For the CVD sub-model we initially also intended to use overseas longitudinal data. However, as the project progressed Australian data (AusDiab) became available which had longitudinal information on CVD as well as on diabetes (section 4.2).

Among Australian sources of CVD data – mainly the cross-sectional NHSs and the longitudinal AusDiab – there were considerable differences in the definition of CVD. This made it difficult to compare them so that the more accurate source could be identified and chosen for *HealthAgeingMod.*

For NHS05 CVD was defined as Angina, IHD (Ischemic Heart Disease) and Stroke. For each of these diseases respondents were asked 'whether told by doctor or nurse that they had the disease' (section 5.4). For AusDiab CVD comprised: stroke; myocardial infarction; as well certain CVD related hospital operations (section 5.1). As for diabetes, AusDiab had greater detail in the CVD related questions asked and whenever possible it also developed medically verified (*i.e.,* 'adjudicated') records.

Re the self-reported responses, out of the 10,788 AusDiab participants eligible for re-testing in 2004-05, the CVD sub-sample comprised those 8,802 (81.6%) persons who completed an interviewer-administered questionnaire about previous CVD. In the 2004-05 CVD questionnaire they were asked whether they had ever been told by a doctor or nurse that they had a heart attack (myocardial infarction), a stroke, a heart bypass operation or an angioplasty or stent for their heart. Out of the 8,802 sub-sample respondents 653 self-reported one or more non-fatal CVD event, 323 occurring prior to wave 1 and 330 in the five years between AusDiab waves 1 and 2. Contrary to expectations, based on high mortality rates due to CVD, only a very few AusDiab participants died over the 1999-00 to 2004-05 period.

Re medically verified records, CVD sub-sample participants who answered 'yes' to any of the above self-reported questions were asked to provide the date and hospital admission details for each CVD event. They were also asked to provide consent (or no consent) to have their medical records reviewed by the AusDiab group.

If consent had been granted, then two independent physicians ascertained whether the self-reported events could be 'adjudicated', *i.e.,* whether they complied with the modified World Health Organisation/MONICA criteria for myocardial infarction (MI) or with the WHO criteria for stroke and for Coronary artery bypass graft surgery (CABG) and Percutaneous transluminal coronary artery angioplasty (PTCA) operations.

Among the self-reported 330 events in the five years between waves 1 and 2, only 191 could be medically verified (58%). The inability to adjudicate was mainly due to an incomplete consent form or the event having taken place in an overseas hospital. Given that only 58% of the self-reported CVD events could be medically verified, the question arose as to which of the AusDiab CVD variables should be used in *HealthAgeingMod*.

Comparing AusDiab with NHS05 and external benchmarks, CVD *prevalence* in AusDiab_2000 was close to the NHS05-based 3.85% prevalence estimate embedded in the model-system's base-year dataset. Re *incidence*, the AusDiab self-reported data suggest a CVD incidence of 3.75% over five years, or 0.75% per annum. However, using the 'adjudicated' data, the incidence estimate is 2.17% over five years, or 0.43% a year.

As incidence cannot be estimated from the NHSs, we searched for *external benchmarks* that could be used to validate one or the other of these AusDiab estimates. From among the scant statistics on CVD incidence we used information from an AIHW publication from which it was possible to obtain a ballpark estimate [68]. This publication stated that in 2001-02 there were 48,700 new coronary heart disease (CHD) events among Australia's 40–90-year olds, with 26,300 of these (54%) non-fatal and 22,402 fatal. It also stated that, based on local registers in Melbourne and Perth, incident stroke events nationally ranged between 40,000-48,000 each year.

By assuming a similar fatal/non-fatal split as for CHD (*i.e.,* 54%), we estimated the incidence of non-fatal events to be around 26,300. For Australia's 8.9 million 40-90 year olds in 2001-02, we estimated CVD incidence to have been around 0.3% in 2001-02, based on these external data sources. So we adopted ***0.3% a year*** as our ***external benchmark for CVD*** incidence rate.

Thus, the AusDiab based CVD incidence estimates mentioned earlier (*i.e.,* 0.75% a year using self-reported data and 0.43% using medically verified data, are well above this 0.3% external benchmark. Because AusDiab's 0.43% estimate is the closest, *we chose the AusDiab medically verified CVD variable regression equations to predict future hospitalized CVD events.*

Re CVD deaths**,** we noted in section 5.5 that the ABS's population projections were estimates of Australia's live population that is deaths had already been accounted for in the population targets set for *HealthAgeingMod*. We also noted that this raised special issues for modeling those diseases that were major causes of death, such as CVD. This was partly because simply reweighting the 2005 base population would have kept alive, throughout the simulation period, all persons in the model system's base-year dataset, whether they had CVD or not. Clearly, we needed to allow some people with severe CVD to die in *HealthAgeingMod.* However, we also needed to bear in mind that the NHS05 survey sample only had a relatively small number of records for persons with CVD and losing a large proportion of these through deaths could significantly distort the characteristics of the original full survey sample.

Regarding available data on CVD deaths, we first hoped that the AusDiab participants who had died between 2000 and 2005 could provide the CVD related mortality data required by *HealthAgeingMod.* However, because only very few in the original AusDiab CVD sample died by 2005, the weighted AusDiab CVD death statistic was well below the ABS published 39,000 Australians who died in 2000 with ischemic heart disease or stroke as main cause of death. So AusDiab data could not be used in regression equations predicting CVD deaths.

We decided that, for CVD deaths, we would stay with the initial proposal [34] to use the US data based CVD death equation [39] to predict CVD deaths in *HealthAgeingMod.* This was acceptable since these US equations were still considered internationally to provide best estimates for CVD. However, to bring the prediction close to Australian statistics, we also decided to align the model predictions with ABS-published CVD deaths and time trends.

In summary, the data sources and variables chosen for estimating the diabetes and CVD sub-models' projection equations were:

- AusDiab's *KnownDiab* variable for diabetes; [56, 43]
- AusDiab's medically verified CVD variables for predicting future hospitalised CVD events (stroke, myocardial infarction; coronary artery bypass graft surgery; and percutaneous transluminal coronary artery angioplasty); [56, 43] and
- The US data based equations for CVD deaths [39].

Diabetes and CVD Sub-model Equations

To estimate the probability of new diabetes and new CVD events we used the PROC LOGISTIC command of SAS, based on the Fisher's scoring optimisation technique. Initially we used all available variables shown in the literature to impact on diabetes and/or CVD status, however not all proved to be statistically significant. In particular, exercise, high cholesterol and having (measured) prediabetes – although initially included - were found to be not significant statistically.

Considering both the diabetes and CVD equations, the variables available in AusDiab [43] and in the US-based source [39] that were found to be statistically significant were:

female	0 for males; 1 for females
Age	single years
Sugar level (hbA1c)	measured hbA1c (%)
Blood pressure (SBP)	systolic blood pressure (mmHg)
Cigarettes (SMOK)	1 if current or ex regular smoker; 0 otherwise
Body mass index (BMI)	measured weight/height^2 (kg/m^2)
total-C/HDL_C	total/HDL cholesterol (mmol/l)
Diabetes	1 if self-reported type 2 diabetes (told by doctor/nurse); 0 otherwise

CVDhistory 1 if any CVD event prior to 2000 (told by doctor/nurse); 0 otherwise

EdLevel 1 if has University or other further education; 0 otherwise

Table **6** reproduces the *HealthAgeingMod* coefficients for the diabetes/CVD incidence and CVD death equations within the Diabetes and CVD sub-models.

For the probability p_i of a coronary heart disease (**CHD**), **stroke** or **diabetes** event the estimated logistic regression equations were of the form:

$p_i = \exp(\eta)/(1+ \exp(\eta))$ where

η = constant + a*female + b*age + c* hbA1c + d*SBP + e*SMOK + f*BMI + … + h*EdLevel

For the probability p_i of **CVD death** over the next 5 years, the equation [39], was:

$p_i = 1- \exp(-\exp(\eta)$ with η computed as:

$\mu = \beta_0 + a*female + b*\log(age) + c*(\log(age))^2 + \ldots.+$ diabetes*female

$sig = \theta_0+\theta_1* \mu$

sigma = exp(sig)

$\eta = (\log(5) - \mu)/sigma$

Once these p_i had been estimated, we applied the Monte Carlo method by drawing a random number, z, from a uniform distribution over the interval [0, 1] and comparing it with the relevant p_i. That is, we allocated an *actual* event to the person being considered if his/her p_i was greater than z.

Next, as part of the *HealthAgeingMod*'s alignment process, the above event allocation process was carried out until the alignment variable – that is the external data source based limit of the number of new events in that group – had been reached (section 6.1).

Table 6: Probability of CVD death# and diabetes/CVD incidence** - coefficients

CVD Death Variables	**CVD Death**	***CVD/Diabetes Incidence Variables***	**CHD**	**Stroke**	**Diabetes (Type 2)**
θ_0	0.8207				
θ_1	–0.4346				
β_0	–5.0385	Constant	-10.0208	-9.5504	- 23.1995
female	0.2243	female	- 1.0312	–	0.8345
log(Age)	8.2370	Age	0.0456	0.0498	- 0.0199
$(\log(Age))^2$	–1.2109				
log(Age)* female	–				
$(\log(Age))^2$ *female	–	sugar level (hbA1c)	–	–	3.3440
log (Blood pressure)	–0.8383	blood pressure (SBP)	0.0163	–	0.0112
cigarettes (Y/N)	–0.1618	cigarettes_current/ex (SMOK)	–	–	0.4030
log(total-C/HDL_C)	–0.3493	Body mass index (BMI)	0.0507	0.0271	0.0405
diabetes	–0.0833	CVDhist	- 0.4775	–	–
diabetes * female	–0.2067	EDlevel	0.3456	–	–
ECG-LVH^	–0.2946	Concordant	82.1%	56.1%	83.1%.

Sources: # [39]; ** authors' estimates from AusDiab data, all variables significant at 0.05 level or less; ^ not used.

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CHAPTER 6

Model Validation, Generalisability and Limitations

Agnes E.G. Walker*

Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: To be credible, a model such as *HealthAgeingMod* needs to be validated against external benchmarks, its limitations need to be identified, and the extent of its generalisability needs to be explained. To the extent possible, credibility should be widely established among, for example, potential users, researchers, medical practitioners, policy developers and health administrators. This Chapter summarises work carried out to establish credibility, in addition to the work that had been reported in a peer reviewed Journal [37].

Keywords: Model validation, alignment against benchmark statistics, base-year and projection period output validations, model generalisability, limitattions, credibility of results, potential users.

6.1. VALIDATION AND ALIGNMENT AGAINST EXTERNAL BENCHMARKS

As seen in section 5.6, topic-specific checks against external benchmarks had already been carried out when developing the diabetes and CVD sub-models. This Chapter reports on the overall validation of *HealthAgeingMod*, which was carried out in three stages:

1. checks of the summary statistics embedded in the model-system's 2005 base-year dataset against external benchmarks (Table **7**);

2. checks of the model-system's 2005 to 2010 projections against changes observed in cross-sectional NHSs - mainly NHS05 and NHS08 [47, 69], (Table **8**); and

3. a peer review of *HealthAgeingMod* and its validation, through publication in a peer reviewed Journal [37].

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

Agnes E.G. Walker, James R.G. Butler and Stephen Colagiuri (Eds.)

For the *base-year,* 2005, Table **7** shows a good match with external benchmarks. That year the weighted number of Australians diagnosed with type 2 diabetes was 579,249 in *HealthAgeingMod*, which is close to the AIHW's published estimate of 581,000 for the total number of persons in 2005 with diabetes types 1 and 2 [66]. The higher estimate in the benchmark arises from it accounting for both types 1 and 2 diabetes. The closeness of the model and benchmark estimates is due to the proportion with type 1 only accounting in NHS05 for 13% of the total.

The model-system's estimate of the costs associated with diabetes and its complications (AUD 1,584 million, 2000 dollars) was close to the AIHW's published estimate of AUD 1,664 million [52]. Such a close match is remarkable, given that the model-system's base data is survey based while the AIHW data are full-population based. The difference between *HealthAgeingMod* and benchmark estimates may be due to the model system's AUD 1,584 being an underestimate. This is because NHS05 is a household survey and thus excludes the very sick in hospitals or nursing homes (section 5.1).

Table 7: Validation of *HealthAgeingMod*- Baseline characteristics, 2005

	HealthAgeingMod	**Benchmark**	**Source of Benchmark**
Total population - 2005	19,681,539	20,328,600	ABS 2006 [70]
Diagnosed type2 diabetes – without CVD – with CVD **Total**	528,928 50,321 **579,249**	581,000 (types 1 and 2)	AIHW 2008 [66]
Diab treatment costs (AUD million, 2000) - without CVD - with CVD **Total**	 746 838 **1,584**	1,664	AIHW 2005 [52]
CVD^ - without diabetes2 (Persons)	242,958	242,958	ABS 2006 [47]
CVD treatment costs (AUD million, 2000)	3,209 (without diabetes)	3,944 (with diabetes)	AIHW 2005 [52] **

^ Ischaemic Heart Disease (incl angina) and stroke; *MI, stroke, CABG and PTCA.
+ Coronary Heart Disease, stroke, heart failure.
** AIHW [52] Table **5**, recurrent expenditures for NHPA defined CVD pharmaceutical and hospital events^^ Heart. Stroke and Vascular Disease.
Source: Baseline simulations.

The exact match in the number of Australians who have CVD without type 2 diabetes – 242,958 persons – arises from the benchmark being the *same* as the data on which *HealthAgeingMod'*s base-year population is based [47]. In this case we had to also use the NHS05 CURF as benchmark because it was the only 2005 source-data from which the numbers with CVD, but without type 2 diabetes, could be estimated.

The model system's 2005 CVD treatment cost estimate of AUD 3,209 million was below the benchmark of AUD 3,944 million. This is as expected, since *HealthAgeingMod* models a smaller subset of CVD conditions than does the benchmark. The latter covers the broader CVD group. Also, it involves all hospital and pharmaceutical expenditures, as defined in Australia's National Health Priority Area documents.

Validation of the model-system's *projections from 2005 to 2010* proved considerably more difficult (Table **8**). Availability in late 2009 of person-level data from the 2007-08 NHS only gave us some indication of likely benchmarks for 2010. Where a relevant benchmark could be constructed, we pro-rated these from 2007-08 to 2010 in a linear fashion.

Table **8** shows that *HealthAgeingMod*'s 2010 population of 20.2 million was somewhat less than the corresponding ABS projection of 21 million. This difference is due to the model-system's 2010 population being based on a reweighted NHS05 survey population. Thus, it is not exactly the same as the ABS's Census-based projections.

The diabetes and CVD projections in Table **8** reflect the AusDiab-based incidences embedded in *HealthAgeingMod*. These estimated 429,198 persons to become *newly diagnosed with type 2 diabetes* between 2005 and 2010. Unfortunately, for this incidence statistic we could not find a nationally representative external benchmark.

For the total number *with type 2* diabetes in 2010 the model-system's estimate was 974,719 persons. Because the data sources for diabetes prevalence provided quite different estimates of the number of cases in Australia, the question arose as to which source should provide the benchmark for this *HealthAgeingMod* estimate.

Table 8: Validation of *HealthAgeingMod*– Projections: 2005 to 2010 (5yr period)

	HealthAgeingMod	**Benchmark**	**Source of benchmark**
Total population - 2010	20,181,395	21,472,282	ABS 2005 [50]
New diabetes type2: (No) using AusDiab data	429,198		
All diabetes type2: (No) – without CVD – with CVD **Total**	924,851 50,068 **974,719**	813,860 (with or without CVD)	ABS 2009 [71], growth_2005 to 2008 pro-rated to 2010
– treatment costs (diabetes2) – no CVD – with CVD Total	3,753 1,134 **4,887**		
CVD, fatal: using US data (Best predictor internationally) in *HealthAgeingMod* (No)	200,831 (over 5 years)	156,060 (over 5 years)	ABS 2008 [72] (CVD deaths in 2006*5)
CVD* event, non-fatal, using AusDiab data in *HealthAgeingMod* (No)	289,140 (over 5 years, - without diabetes)	238,485 (hospitalisations in 2006-07+ - with diabetes)	AIHW 2009 [73],
Decline in total numbers with CVD^^ 2005 to 2010 (No)	100,907	0.3% lower prevalence in 2008 than in 2005 (0.5% lower over 5 years, pro-rata)	ABS 2009 [74], advice re change in CVD classes
CVD treatment costs (AUD million) : fatal hospitalised CVD event : non-fatal CVD event without diabetes : treatment_ CVD history only **Total**	 1,317 5,856 4,142 **11,315** (over 5 years, or AUD 2,263 pa)	 3,944 (with diabetes)	AIHW 2005 [52],**

^ Ischemic Heart Disease (incl angina) and stroke; *MI, stroke, CABG and PTCA.
+ CHD, stroke, heart failure; ** AIHW 2005, Table **5**, recurrent expenditures for NHPA defined CVD pharmaceutical and hospital events; ^^ Heart. Stroke and Vascular Disease
Source: *HealthAgeingMod* simulations

The issue being of nationwide concern, in 2009 the National Centre for Monitoring Diabetes assessed five data sources that provided national estimates of diagnosed diabetes prevalence: AusDiab, the NHSs, the administrative NDSS, and the Medicare and PBS databases. The findings were published by the AIHW [75]. The conclusion of the Centre was that, in Australia, the best available sources for diagnosed diabetes prevalence data were the NHS surveys and the NDSS.

We chose NHS08 [69, 71] as benchmark to compare with the model system's 2010 estimate of 974,719 persons with type 2 diabetes. By pro-rating the numbers in NHS08 to 2010 this benchmark became 813,860 person, which is 20% above the model-system's projection. To align *HealthAgeingMod* with this benchmark, we randomly selected persons with (AusDiab-based) new diabetes, and kept changing their diabetes status from 'with' to 'without diabetes' until the weighted total of those with diabetes in the model-system closely matched the NHS08 benchmark.

Validating the CVD related projections proved to be considerably more difficult, as benchmark data was not only harder to find than for diabetes, but it also covered a broader range of cardiovascular categories than those embedded in *HealthAgeingMod*. Thus we had difficulty extracting from the broadly defined CVD benchmark those with the major hospitalised CVD events that were considered in *HealthAgeingMod*. However, there was some compensation for this when computing post-event CVD costs, as in this case we could use the NHS05's question on whether a person has had a history of CVD.

When validating the CVD projections we first checked whether the model-system projections were in line with the CVD prevalence time-trends indicated in the NHSs for 'Heart, Stroke and Vascular Disease', that is 4.1% in 2001; 3.8% in 2005; and 5.2% in 2008 [71]. However, in NHS08 the ABS changed its method of processing CVD statistics. As a result, the 5.2% in 2008 was not comparable with the earlier prevalences. We approached the ABS re this issue and the ABS provided comparable CVD prevalences for these three NHSs. To achieve comparability, it used the NHS08 processes for each of the earlier surveys [74]. The comparable CVD prevalences were: 5.8% in 2001; 5.5% in 2005; and 5.2% in 2008.This suggests a 0.3% decline in prevalence between 2005 and 2008. When pro-rated to 2010, this decline became 0.5% over the five years to 2010. The resulting *HealthAgeingMod* estimate was 100,907 less persons with Heart, Stroke and Vascular Disease in 2010 than in 2005 (Table **8**).

After aligning *HealthAgeingMod*'s CVD projections to this declining time-trend, the cost estimate for CVD treatment became AUD 11,315 million over the 2005 to 2010 period, or an average of AUD 2,263 million per annum. This annualised estimate seems plausible, since it is not too far from the AIHW's benchmark estimate of AUD 3,944 million for its broader CVD grouping [52].

Overall, while for diabetes the available benchmarks gave us an indication of the accuracy of *HealthAgeingMod*'s projections, this was less so for CVD due to the benchmark data covering a broader CVD group than that of the model-system.

There are a few general comments that can be made about the Tables **7** and **8** results. First, because external benchmark data was only slowly becoming available during the model construction phase, the validations are most robust for the base-year dataset (Table **7**). The checks on the 2005 to 2010 projections are less certain. The available benchmarks rely on NHS05 to NHS08 differences, and these two datasets only have information on prevalences (rather than incidences) of type 2 diabetes and CVD. In addition, the definition of CVD changed in NHS08 compared with its definition in earlier NHSs, and the benchmark data in NHS05 and NHS08 were only available at a higher level of aggregation than what we were able to incorporate into *HealthAgeingMod*.

As more comprehensive data become available, in future it might be possible to better align projections by *HealthAgeingMod* to benchmark data, especially for certain specific applications. Also, as usual with microsimulation models similar to *HealthAgeingMod*, fully completing the alignment process is likely to take time, as experience continues to be gained with additional policy relevant simulations.

Overall, despite the data limitations, we were able to carry out a comprehensive set of validations. These indicate that *HealthAgeingMod* is already a credible analytical tool for scenario assessment and ranking.

6.2. GENERALISABILITY

A common issue in relation of complex models, such a *HealthAgeingMod*, is their generalisability. The question is how broad is their range of applicability to policy relevant studies.

Internationally, the methods used, the health issues covered and the data difficulties encountered are likely to be very similar in most developed countries and in several developing countries. Indeed, our accounts of data difficulties and

analytical pitfalls can be very useful to researchers new to this field, whether in developed or developing countries.

So, internationally, many of the lessons learnt from this book are generalisable. However, for each country *HealthAgeingMod's* base-year dataset would need to be re-based using person-level and nationally representative data from that country. In doing that, the set of variables included in the model will of necessity be somewhat different, reflecting the characteristics of that country's health databases. Because chronic disease patterns tend to be similar around the world, the differences are not expected to be large.

Within Australia the model-system is generalisable, as it could be used in a wide range of policy relevant applications without any need to re-specify its base-year dataset. For example, a generalisation from the 60+ focus of this book would be to consider younger age groups as well in the analyses, *e.g.* when studying interventions that aim to reduce obesity rates nationwide. Another example would be to extract statistics on the 25 to 60 age group from *HealthAgeingMod*'s extensive outputs, since its base-year dataset covers persons from age 15, and that of the diabetes and CVD sub-models from age 25.

For other applications, it is posssible that some of the required risk factor and disease variables may not currently be in the model-system's base-year dataset. In such cases additional variables could either be added to the base-year dataset from NHS05 or, if not available in that survey, imputed using another data source.

Studying additional chronic diseases – such as arthritis, depression, *etc.* – would be possible once equations of the probability of acquiring such diseases had been developed. *HealthAgeingMod* could then estimate the number of persons with these diseases while simulating the 'Do nothing' and the 'Scenario' options. Once the relevant findings had been extracted from *HealthAgeingMod's* output files, studies of costs, benefits, cost effectiveness, *etc.* could be obtained while working outside the model (for example through use of an EXCEL spreadsheet).

Finally, it is important to note that 'generalisability' of *HealthAgeingMod* for particular applications would need to be carried out by analysts with considerable

data and modeling experience, and that such tasks are likely to take some time to complete.

6.3. LIMITATIONS

As with most models and statistical collections, an important limitation of the model-system is its inability to fully replicate the real world. Despite this, *HeathAgeingMod* can handle considerable complexity and detail. Because it accounts at the level of the individual for the many variables identified in the literature as key drivers of disease incidence, prevalence and health expenditures, and because it models their inter-relationships, simulations with *HealthAgeingMod* are likely to provide decision makers with valuable insights over and above what is already known.

One limitation specific to *HealthAgeingMod* is that currently it only accounts for two major chronic diseases, diabetes and CVD. In this respect section 4.2 described how additional diseases – such as arthritis and/or dementia – could in future be accounted for, subject to suitable disease-specific data being available. A related limitation concerns *HealthAgeingMod*'s estimates of life years gained. This limitation arises because it is not only possible, but also in many cases likely, that severe disability (or death) simulated to have been avoided through implementation of the Scenario, may in reality occur through other disease(s) not accounted for in the model-system. Indeed, many older people have several potentially fatal conditions, but in most cases only one of these is officially recorded as 'cause of death'.

Another limitation is one that arises from the choice of a household survey to provide the model's base-year dataset. As seen in section 5.4, the NHS05 only covers people living in households. This means that Australians who were likely to have the poorest health – *i.e.* those in hospitals, hostels and nursing homes at the time of the survey – had been excluded from *HealthAgeingMod*. The consequence of this is that the model findings will be under-estimates compared with simulations which were also able to include the institutionalised.

An often reported technical limitation of models arises from use of the Monte Carlo method (section 5.6), since this method introduces randomness into the

models' outputs. Different runs of the model, with identical parameters, but using different random number seeds, are generally expected to produce different outputs. To assess the extent of the stochastic variation due to use of the Monte Carlo method, researchers often execute several runs until the results 'converge'. They compute the means of the imputed variables across the repeated runs, and continue the process until the difference in the means at the margin is below a set target. However, with microsimulation models such as *HealthAgeingMod,* the number of repetitions required to achieve 'convergence' was generally found to be small – for example four runs in UK studies [76, 77], and six runs in Australian publications [78, 79].

The general limitation that *HealthAgeingMod* shares with other health models is that the income and technological-progress related increases in health expenditures are not accounted for. Because, in economic terms, health is a 'luxury good', every 1% increase in national income is expected to result in a more than 1% rise in national health expenditures. This means that, although Australians' health is generally better today than it had been in the past, future improvements in prevention may in reality not result in a decline in health expenditures.

As noted in Chapter 1, technological advancements have been major contributors to the rapid rises in health care costs that are of major concern globally. In Australia, health expenditures rose by close to 20% between 2000 and 2005, and the extent of this increase was similar across sub-classes of health costs, including drug prescriptions and outside hospitals medical costs [80].

Key reasons for not accounting for technological advances in models are uncertainties about which medical research will lead to breakthroughs and when; whether these breakthroughs could be commercialised; whether their take ups would affect large or small populations; and whether or not unforeseen adverse secondary effects would lead to their eventual withdrawal.

Despite these uncertainties there have been attempts to quantify the impact of better medical technologies. One example is a study that found that, in the US, newer drugs improved length and quality of life compared with use of older drugs

[81]. People using new drugs were more likely to survive, reported better perceived health, and experienced fewer activity, social, and physical limitations. Such findings are likely to apply to Australia as well, since new drugs are only listed on the PBS if pharmaceutical companies can demonstrate that the new drug is more effective than existing ones (Chapter 3).

In some applications, limitations arising from uncertainties associated with advancements in technology could be alleviated in models such as *HealthAgeingMod*. One example is when simulating policy proposals, such as use of new PBS drugs, the analyst could add to *HealrhAgeingMod* a software sub-routine that accounts for the expected impacts of the technological advances considered. Also, a wide range of likely impacts could be assessed through 'sensitivity tests'.

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CHAPTER 7

Illustrative Simulations Using *HealthAgeingMod*

Agnes E.G. Walker[1,*], James R.G. Butler[2] and Stephen Colagiuri[3]

[1]Australian Centre for Economic Research on Health, Australian National University, Australia; [2]Australian Centre for Economic Research on Health, Australian National University, Australia and [3]The Boden Institute of Obesity, Nutrition, Exercise & Eating Disorders, University of Sydney, Australia

Abstract: In this chapter two relatively simple applications of *HealthAgeingMod* illustrate the type of findings that can be expected from the model-system. The first addresses the question of what the benefits and costs might be of Australia's obese adults reducing their weight by 10%, through themselves adopting healthier lifestyles. The second is about the likely health and health expenditure impact of the projected ageing of Australia's population. The aim is to provide readers with an initial idea of the type of issues the model-system can handle, as well as the routine outputs it can produce. A much more complex and policy relevant application is presented in Chapter 8.

Keywords: Illustrative model applications, lower obesity rates, population ageing, projections, chronic diseases, diabetes, cardiovascular disease, comorbidities, health benefits per dollar spent.

The two illustrative examples described below summarise earlier work by the authors of this Chapter [37, 83]. They were chosen partly because they concerned topical issues, and partly because their simulation with *HealthAgeingMod* required minimal input data preparation. While their findings suggest an order of magnitude of the likely health and expenditure impacts of the intervention Scenarios simulated, the examples are only meant to serve illustrative purposes. For a more complex and realistic policy relevant application see Chapter 8.

7.1. IMPACT OF LOWER OBESITY RATES AMONG ADULTS ON CHRONIC DISEASES

As seen in Chapters 1 and 2, rapid rises in obesity (BMI 30 or more) are of

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

Agnes E.G. Walker, James R.G. Butler and Stephen Colagiuri (Eds.)

growing concern not only in Australia, but also in most other countries. In this section's illustrative 'obesity' example, that we first presented at a world congress in Paris [83], Australia's 2.5 million obese adults in 2005 were assumed to have changed their lifestyle so that by 2010 each had reduced his/her weight (and thus BMI) by 10%.

Measured across NHS01 and NHS05, ABS statistics indicated an upward trend in obesity rates. The proportion of Australians with self-reported obesity increased from around 25% in 2001 to 28% by 2005. Thus in *HealthAgeingMod's* base-year dataset the nationwide obesity rate was 28%, with the official statistics indicating an upward trend for that rate over the previous five years.

In this 'obesity' example *HealthAgeingMod* first projects the baseline (*i.e.* the 'No intervention' case) to 2010 and assesses the changes in individuals' chronic disease risk factors, as well as in the onsets of diabetes, or CVD, or both. In this baseline simulation 'No intervention' means that that there will be no change in the lifestyle patterns of Australia's obese adults over the 2005 to 2010 period. Next *HealthAgeingMod* projects the Scenario to 2010, assuming that in 2005 Australia's obese adults changed their lifestyle patterns so that, by the end of that year, they all managed to reduce their weight by 10%. Once again, the output of the H*ealthAgeingMod* simulation will be the changes in individuals' chronic disease risk factors and in the onsets of diabetes, or CVD, or both. In both simulations, *HealthAgeingMod* will also estimate the related health expenditures.

Table **9** presents the model-system's key outputs. It compares projections from 2005 to 2010 across three simulation runs:

- Baseline (S1), in which *HealthAgeingMod's* 2005 base-year population was up-rated to 2010, ensuring that age-by-sex totals matched the official 2010 forecasts by the ABS. Outputs include numbers of people with diabetes, CVD and/or both, as well as well as related expenditures;

- Scenario 2 (S2), that is similar to S1, except that each of Australia's 2.5 million obese adults had managed, in 2005, to lower their body weight by 10%; and

- Scenario 3 (S3), that is similar to S2, except that the risk-factor-benefits of lower weight among the obese had also been accounted for. For this S3 simulation we assumed that the positive risk-factor-impacts of reduced obesity were 10% lower blood pressure, sugar level, and cholesterol.

Table 9: Impact of 10% lower weight among Australia's obese adults on diabetes and CVD, 2005-2010 (numbers and costs)

	Baseline S1 2010 population structure*	**Scenario S2** S1 with 10% lower weight for obese** adults	**Scenario S3** S2 with 10% lower blood pressure, sugar level, cholesterol
Persons in 2010 *(numbers)*			
- Diabetes only	951,706	894,480	893,762
- Diabetes+CVD event	50,749	43,387	4,492
- CVD event only (non-fatal)	285,222	277,016	274,437
ALL WITH DIABETES AND CVD	**1,287,677**	**1,214,883**	**1,208,691**
difference from S1		**- 72,794**	**-78,968**
Expenditures *(AUD million)*			
- Diabetes only	4,816	4,629	4,630
- Diabetes+CVD event	1,128	981	934
- non-fatal CVD event only	5,767	5,594	5,532
- fatal CVD event only	1,317	1,317	1,303
TOTAL CVD plus DIABETES COSTS	**13,028**	**12,521**	**12,399**
difference from S1		**- 507**	**-629**

* *HealthAgeingMod* estimates aligned to Australian Bureau of Statistics projections [50]: a population in 2010 ** Body Mass Index of 30 or more.
Source: *HealthAgeingMod* simulations and [82]

In these baseline and Scenario simulations we were able to *separately* identify persons with diabetes only (pre-existing as well as new diabetes), with non-fatal CVD hospital event only, and with both diabetes and CVD. Table **9** shows that the estimated benefit of the '10% lower weight' Scenario (S2) was 72,794 less Australians with diabetes and/or CVD over the five years. The corresponding cost savings were estimated at AUD 507 million. Adding to S2 the downstream risk-factor benefits arising from 10% lower blood pressure, sugar and cholesterol (S3),

the estimates over five years became 78,968 less Australians with diabetes and/or CVD, and a saving of AUD 629 million.

Overall, because we assumed that the 10% weight decline were purely due to changes in individuals' lifestyle choices, in this example there were no publicly financed intervention costs. However, though illustrative only, the above estimates broadly indicate the magnitude of the benefits that could be obtained through lowering the prevalence of obesity in Australia – and thus the costs that could be expended to achieve similar weight changes through a policy intervention.

7.2. IMPACT OF POPULATION AGEING ON CHRONIC DISEASES

This illustrative simulation was first reported in an earlier publication by the authors of this Chapter [37]. It concerns the health and health cost impacts of population ageing in Australia.

Table **10** compares projections from 2005 to 2010 across two simulation runs:

- Baseline (S1), in which *HealthAgeingMod's* 2005 base-year population was up-rated to 2010. The up-rating process ensured that the model's 'age-by-sex' totals matched the published 2010 population projections by the ABS [50];

- Scenario 2 (S2), which simulated what health and health costs would have been if in 2010 Australia had the population forecast by the ABS for 2025 [50]. In this Scenario re-basing the population from S1 to S2 resulted in the proportion of Australia's 60+ year olds to increase from 17% of the total population to 26% – a situation similar to Japan's 60+ proportion in recent years (around 27%).

Table **10** shows that in these simulations we were able to *separately* identify persons with:

- *diabetes only*, estimating 618,294 more persons under Scenario S2 with type 2 diabetes than under S1. The additional treatment costs over the 2005-2010 period were estimated at AUD 3,350 million;

- *diabetes as well as a CVD hospital event*, estimating 59,033 more persons having both these conditions in S2 than in S1, with an additional treatment cost estimate of AUD 1,297 million over five years. Of particular interest is that, with the older population of S2, the numbers in this comorbidity group more than doubled, from 50,749 in S1 to 109,782 in S2;

- *non-fatal CVD hospitals event only,* with 216,448 more persons with CVD only in S2 than in S1. The additional treatment costs over the five years were estimated at AUD 4,344 million.

- *deaths* in hospital as a result of a CVD event. The additional cost was estimated at AUD 2,068 million over five years.

Table 10: Population ageing in Australia: impact on diabetes and CVD, 2005-2010 (numbers and costs)

	Scenario S1 2010 population structure*	**Scenario S2** S1 with 2025 population structure*	**Difference** S2 to S1
Persons *(numbers)*			
- Diabetes only	951,706	1,570,000	+618,294
- Diabetes+CVD event	50,749	109,782	+59,033
- CVD event only (non-fatal)	285,222	501,670	+216,448
ALL WITH DIABETES AND CVD	**1,287,677**	**2,181,452**	**+893,775**
Expenditures *(AUD million)*			
- Diabetes only	4,816	8,166	+3,350
- Diabetes+CVD event	1,128	2,425	+1,297
- non-fatal CVD event only	5,767	10,111	+4,344
- fatal CVD event only	1,317	3,385	+2,068
TOTAL CVD plus DIABETES COSTS	**13,028**	**24,087**	**+11,059**

* *HealthAgeingMod* estimates aligned to Australian Bureau of Statistics projections [50]: a population of 21.5 million in 2010 and 24.7 million in 2025
Source: *HealthAgeingMod* simulations and [83]

In summary, the additional costs for diabetes and CVD hospital events arising from ageing – that is 26% rather than 17% of the population being aged 60+ years – have

been estimated at AUD 11,059 million over five years. With *HealthAgeingMod*'s complex unit record based system we were also able to decompose this total cost into 39% for non-fatal CVD events only, 30% for diabetes only, 19% for fatal CVD events and 12% for persons with both CVD and diabetes.

In this illustrative example we only accounted for change in one factor, the age structure of the Australian population. However, it is important to note that population ageing has been shown *not* to be the main reason for the very rapid increases in health expenditures [7]. Key drivers of health cost increases were found to be above GDP growth rises in health costs arising from factors such as breakthroughs in medical technology, and Australians' expectations to have subsidised access to the most advanced pharmaceuticals and medical techniques (section 9.3).

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CHAPTER 8

Simulating a Policy Relevant Reform Option with *HealthAgeingMod*

Agnes E.G. Walker[1,*], James R.G. Butler[2], Stephen Colagiuri[3] and Crystal Man Ying Lee[4]

[1]Australian Centre for Economic Research on Health, Australian National University, Australia; [2]Australian Centre for Economic Research on Health, Australian National University, Australia; [3]The Boden Institute of Obesity, Nutrition, Exercise & Eating Disorders, University of Sydney, Australia and [4]The Boden Institute of Obesity, Nutrition, Exercise & Eating Disorders, University of Sydney, Australia

Abstract: In this chapter the policy relevant scenario simulated with *HealthAgeingMod* concerns the health benefits and costs of an integrated diabetes and cardiovascular disease screening, prevention and management intervention among 40-74 year old Australians. The Scenario was proposed by a group of Australian health policy developers at a time of studies reporting that a significant proportion of Australians were missing out on prevention and recommended treatment. The Scenario reflects Australian practices, costs and medical guidelines.

The screening tests for CVD, diabetes and their risk factors, and high-risk status or diagnosis, is followed by several possible medically identified treatment and prevention paths. Within *HealthAgeingMod* both single and combined diseases are identified, and account is taken of the non-linear nature of comorbidities.

This policy relevant application compares, over the 2005-2010 period, the outcomes of the scenario simulation with that of the Baseline simulation in terms of extra life years lived and health costs saved. We found that implementing the scenario would result in a net cost to government of around AUD 7,000 per Quality Adjusted Life Years gained. Sensitivity tests indicated a range from AUD 3,000 to AUD 14,000.

Because this range is within what is usually considered to be cost-effective in Australia, an intervention of this kind is worth consideration for public funding.

Keywords: Vascular risk assessment, health modeling, economic analysis, policy relevant simulation, screening, risk scores, medical advice or treatment, cost effectiveness, sensitivity analyses.

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

Agnes E.G. Walker, James R.G. Butler and Stephen Colagiuri (Eds.)

8.1. INTRODUCTION

In Australia, the vascular conditions of heart disease, stroke and diabetes, which often lead to disability and premature death, account for over AUD 6 billion health expenditures per year [80]. Although with early diagnosis these conditions are preventable, or can be delayed, recent studies indicate that many Australians at high risk are missing out on risk assessment, and that high-risk cardiovascular patients are under-treated in general practice [84, 85]. These developments may have arisen from service providers' focus on individual risk factors, rather than on overall vascular risk which simultaneously takes account of several common risk factors [84].

Because major risk factors for diabetes and CVD – such as unhealthy diets, insufficient physical activity and excessive tobacco consumption – arise from individuals' lifestyle choices [86], chronic disease prevention and treatment are not only of medical concern, but also of social, family-level, personal and government policy interest [87, 88, 89].

This is important for policy studies that simultaneously consider several chronic diseases acquired by the same person, *i.e.,* comorbidities [1, 90]. Among other things, quality of life has been shown by studies to decline and health expenditures to increase with comorbidities [27, 91]. Such studies are however rare in the literature, despite the well documented fact that many chronic diseases share common lifestyle risk factors and underlying health conditions [43]. So the *HealthAgeingMod* model-system, which simultaneously considers at the person level several vascular conditions and risk factors (Chapters 4 and 5), is particularly appropriate for analyses of vascular risk and treatment interventions, such as the scenario reported below.

8.2. SCENARIO: AN INTEGRATED VASCULAR RISK ASSESSMENT AND MANAGEMENT INTERVENTION

To ensure that the *HealthAgeingMod* application in this Chapter was generally seen as policy relevant, we selected the Vascular Risk Assessment Scenario proposed by a group of Australian health policy developers.

The Scenario concerns the economic evaluation of an Australia-wide vascular risk intervention program that assesses its impact on patients' quality of life and on the prevalence and treatment costs of CVD and type 2 diabetes. In specifying the details of

the Scenario we ensured that it reflected Australian practices, costs and medical guidelines.

In choosing this intervention we aimed to account for the gradual recognition that preventive chronic disease policies should be developed within an 'overall' context (Chapter 4), rather than within the traditional disease-by-disease approaches. Because chronic diseases tend to have many common risk factors – such as ageing; high glucose, blood pressure and cholesterol levels; obesity; smoking – treatment of one or more of these risk factors will impact on several chronic diseases. Compared with studies adopting an 'overall' approach, single-disease studies underestimate the benefits of reforms that modify one or more common risk factors. This has considerable policy relevance, since the greater (and more accurate) the benefits from an 'overall' approach, the lower the related cost per Quality Adjusted Life Years (QALY) gained will be.

Briefly, the intervention studied starts with vascular checks (screening), followed by medical assessment of the vascular risks of the individuals screened. Next, those assessed are offered treatment(s) and/or lifestyle advice. Finally, *HealthAgeingMod* assesses the costs and benefits of this intervention over the 2005-2010 period (Fig. **8**). Reasons for choosing a 5-year projection period are detailed in section 8.5.

HealthAgeingMod estimates the lower numbers likely to become diagnosed with diabetes and/or CVD under the 'intervention' than under the 'no intervention' option. Next it estimates the marginal net costs, as well as gross costs, over the 5-year projection period. Net costs are gross costs minus the savings achieved through less people acquiring diabetes and/or CVD, resulting in lower hospitalisation rates and treatment costs. Although indirect cost savings, such as disease-related absenteeism or loss of job, are not accounted for in this study, they could be estimated outside the model-system if required.

8.3. THE SCREENING PROCESS

Key elements of the *screening process* itself are:

Target Population: all 40-74 year old Australians without CVD and/or diabetes. The intervention starts with a one-off Vascular Risk Assessment screening program offered in 2005.

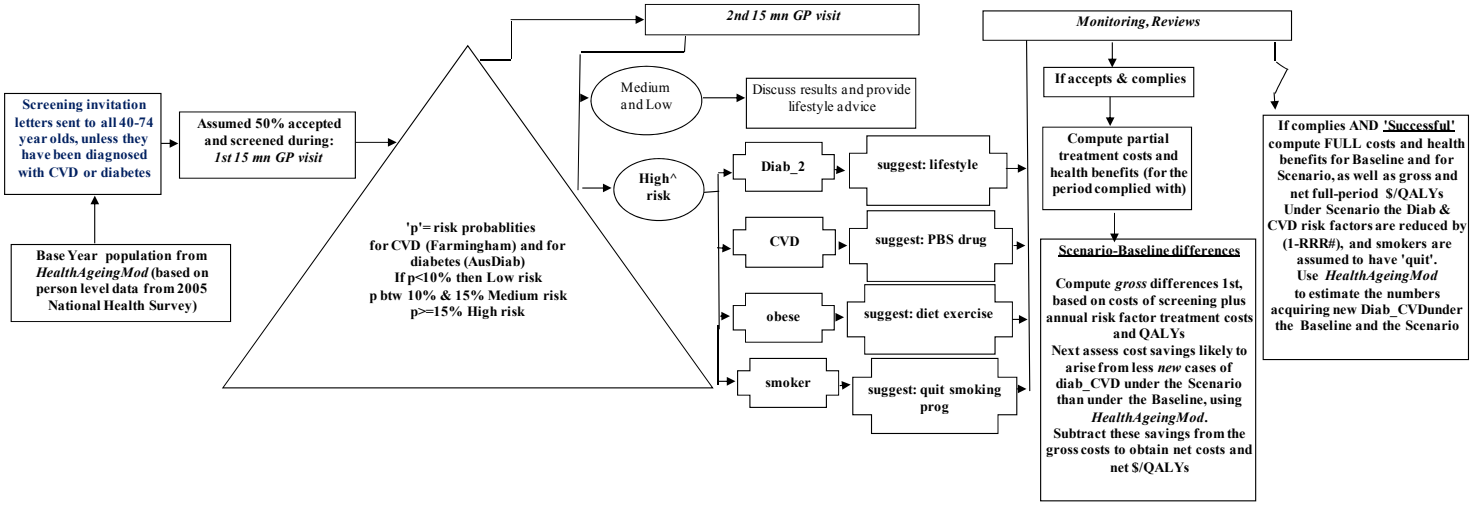


Figure 8: Elements of 'Vascular Risk Assessment' Intervention, 40-74 yer olds.

Invitations: all 40-74 year olds in the 2005 base population of *HealthAgeingMod* to receive a letter from the government about the new program of free Vascular Risk Assessment.

In the letter, individuals would be asked whether they are currently being treated for diabetes and/or CVD. If yes, they would be asked to ignore the invitation. All others would be invited to book a 15 minute vascular check session with their general practitioner (GP). This would be followed by a risk assessment and a second 15 minute GP visit. During the latter those assessed at high risk would be offered treatment, and those at medium or low risk some lifestyle advice. The screening, assessments and offers of treatment or advice were to occur at the start of 2005.

We chose to include *all* 40-74 year olds, rather than persons already assessed by their GP as being at 'high risk'. We did this so as to allow the Vascular Risk Assessment to also capture people who had the diseases but were as yet undiagnosed, or were unaware of their 'high risk' status. The undiagnosed and the unaware are often persons who are generally reluctant to visit a GP. Studies, as well as our research, have shown that about half of Australians with diabetes were undiagnosed (Chapter 5) [43], and a similar situation may also exist for CVD. Although more costly than contacting only persons already medically identified as 'at high risk', covering *all* 40-74 year olds had the important advantage of addressing 'prevention', in addition to 'treatment'.

Take up rates: Australian take-up rates for cancer screening have varied between 40 and 60% : 57% for breast cancer [92], 61% for cervical cancer [93], and 38-45% for bowel cancer [94]. Taking these statistics as a guide for our Scenario, we chose 50% as *HealthAgeingMod*'s 'default' take-up rate for the Vascular Risk Assessment intervention.

8.4. DATA MODIFICATIONS

Prior to simulating the Scenario, some modifications of *HealthAgeingMod'*s base-year data needed to be carried out. First, we needed to identify who self-reported in NHS05 that they had been told by a doctor or nurse that they had diabetes and/or CVD. These persons did not qualify for the Vascular Program, so their records had been deleted from *HealthAgeingMod'*s base-year dataset.

Risk factor values needed for the Scenario were proxied through use of the vascular conditions data already in *HealthAgeingMod*. These included systolic blood pressure (SBP), body mass index (BMI, with 30+ kg/m^2 indicating obesity), and whether the person was a current regular smoker. As seen in section 5.4, in *HealthAgeingMod* the related NHS05 values had been converted into continuous 'measured values' for use in the diabetes and CVD sub-model equations.

8.5. RISK ASSESSMENT

Cardiovascular Disease

The CVD-related National Health and Medical Research Council guidelines [41] recommend that, to assess CVD risk, GPs in Australia should use the Framingham Risk Equation [39]. To meet this guideline when estimating CVD risk following the Vascular Checks, we replaced *HealthAgeingMod*'s AusDiab-based CVD probability equation with the Framingham CVD equation. The Council's guidelines state that: "Absolute cardiovascular risk assessment, using the Framingham Risk Equation to predict risk of a cardiovascular event over the next 5 years, should be performed for all adults aged 45–74 years who are not known to have CVD or to be at increased risk of CVD."

Because of the 5-year scope of this guideline, and the 5-year coverage of waves 1 and 2 of the AusDiab data used in *HealthAgeingMod*, we chose a 5-year projection time-frame for our Vascular Risk Assessment project. So, in this Chapter we use 5-year Framingham probabilities for our base-year CVD risk computations, and for predicting the numbers with new CVD and diabetes.

However, in interpreting our findings it is important to note that the Framingham Risk Equations have been shown to predict rates of new CVD episodes well above what had been observed in Australia and the UK (Chapters 4, 5) [37, 95]. One reason for this is that Framingham was based on a predominantly white US population in the 1970s, which had a much higher rate of CVD than is now common in countries like Australia and the UK.

Table **11** reproduces the Framingham equations [39].

Table 11: Coefficients of the Framingham CHD, stroke and CVD equations

Explanatory Variables	*CHD*	*Stroke*	*CVD*
θ_0	0.9145	–0.4312	0.6536
θ_1	–0.2784	–	–0.2402
β_0	15.5305	26.5116	18.8144
female	28.4441	0.2019	–1.2146
log(age)	–1.4792	–2.3741	–1.8443
$(\log(age))^2$	–	–	–
log(age)* female	–14.4588	–	0.3668
$(\log(age))^2$ * female	1.8515	–	–
log (SBP)	–0.9119	–2.4643	–1.4032
cigarettes (Y/N)	–0.2767	–0.3914	–0.3889
log (total-C/HDL_C)	–0.7181	–0.0229	–0.5390
diabetes	–0.1759	–0.3087	–0.3036
diabetes * female	–0.1999	–0.2627	–0.1697

Source: CVD equations recommended by the NHMRC for use by Australian GPs [39]

These equations are based on 5,573 persons, aged 30 to 74 years (Framingham Heart Study and Offspring Studies). The enrolment period was 1968 to 1975, with 12-year follow-ups of those enrolled. All persons in the study were initially free of CVD. The original 1991 article [39], discusses in some detail the validity of the coefficients reproduced in Table **11**.

Definition of *HealthAgeingMod* variables matching the ones in the Framingham equations are:

female	0 for males; 1 for females
age	single years
Blood glucose	measured HbA1c (%)
Blood pressure (SBP)	systolic blood pressure (mmHg)
Cigarettes (SMOK)	1 if current regular smoker; 0 otherwise

Body mass index (BMI)	measured weight/height^2 (kg/m^2))
total-C/HDL_C (chol)	total/HDL cholesterol (mmol/l)
Diabetes (Diab)	1 if self-reported type 2 (told by doctor/nurse); 0 otherwise

Using the CVD coefficients in Table **11**, we estimated the Vascular Risk Assessment related CVD risk scores as:

mu = 18.8144 –1.2146*Sex – 1.8443*log(Age) + 0.3668*log(Age)* Sex – 1.4032*log(SBP) –0.3889*SMOK –0.5390*log(Chol) –0.3036*Diab – 0.1697*Diab*Sex;

sig = 0.6536 – 0.2402*mu;

sigma = exp(sig);

mu5yrs = (log(5) - mu)/sigma; with probability of CVD in next 5 yrs being:

p_CVDbase=1 - exp(- exp(mu5yrs))

Overall, having replaced the original CVD equation in *HealthAgeingMod* with the one based on the Framingham study [39] ensured that the model-system's CVD risk assessments broadly matched the risk scores that Australian GPs would compute. The fact that the US Framingham equations predicted considerably greater numbers of new cases than did the AusDiab equations presented problems. However these could be resolved by *HealthAgeingMod's* alignment process that matched the total number of persons with new CVD with the relevant external benchmark (section 6.1).

Type 2 Diabetes

For consistency with the rest of *HealthAgeingMod*, for type 2 diabetes we used the original diabetes risk equation based on self-reported data in AusDiab. As in NHS05, the self-reported AusDiab question was whether respondents had been told by a doctor or nurse that they had been diagnosed with diabetes. This equation - drawn from self-reported AusDiab data - predicts considerably higher numbers with new diabetes than do the predictions based on the 'measured

diabetes' values in AusDiab [43]. However, due to the alignment processes described in section 6.1, the total number of persons with new diabetes will be adjusted by *HealthAgeingMod* to match the related external benchmark. The regression equation for predicting the probability (p) of type 2 diabetes was described in section 5.6.

Low, Medium and High Risk Score Groups

For developing Low, Medium and High risk scores for CVD, we once again followed the National Health and Medical Research Council guidelines [41]. These recommend risk score groups for the probability (p) of CVD as:

p<10%`	Low risk
p>10% to less than 15%	Medium risk
p ≥15%	High risk

For consistency, the same definitions were adopted for the diabetes risk groups.

8.6. FOLLOW-UP GP VISITS AND REFERRALS

After the first 15 minute GP visit, patients' vascular check results (for SBP, BMI, cholesterol, glucose concentration, *etc*.), were to be converted into related diabetes and CVD risk scores.

This process was proxied within *HealthAgeingMod* by computing the risk scores of those 40-74 year olds who were eligible for the vascular checks, and decided to attend the first GP visit on the basis of the set take-up rate (50% as 'default', see section 8.3). Eligible individuals in the model-system's base-year dataset were randomly selected for this first visit.

It was at the second 15 minute GP visit that these persons were told about their vascular checks results and their associated risk factors. At this visit the GP would also to recommend treatment for those at 'high risk', and provide advice on lifestyle changes for those at 'medium' or 'low' risk. For the *HealthAgeingMod* simulations we assumed that:

- those with high risk scores for CVD would be offered relevant treatments;
- those with high scores for diabetes would be offered attendance of the Commonwealth's Prevention of Type 2 Diabetes program;
- the obese (with BMI $\geq$ 30 kg/m^2) would be offered a weight management program; and
- those who self-reported to be 'current regular smokers' a quit-smoking program.

8.7. INPUT DATA FOR THE VASCULAR RISK ASSESSMENT SCENARIO

Default Settings in *HealthAgeingMod*

The default input data variables for the vascular checks are summarised in Table **12**. Analysts can change these when carrying out sensitivity tests.

Unit Costs of Screening and Follow-Up Treatment

As in many other countries, in Australia the costs of prevention, treatment and medical procedures are considerable. For example pacemaker implants, knee replacements and hip replacements cost around AUD 20,000 [96]. Thus using specific medical service costs was important in our case (rather than the generally available broad-group aggregates). So for this application we carried out research on medical costs that had been actually expended by Australian patients and governments for the relevant medical services and follow-up treatments.

We used the latest available cost information, because discovery of new medical procedures and drugs have been shown to be major contributors to the long-term upward trend in health costs. So our results, with latest available costs, are likely to be less favourable to introduction of Vascular Risk Assessments than they would have been had the costs of the previous five to ten years remained unchanged. Sources for our unit Australian government costs were statistics collected under Australia's Medicare Benefits Schedule (MBS) [99] and Pharmaceutical Benefits Scheme (PBS) [100].

Table 12: *HealthAgeingMod* default settings and assumptions, 40-74 year olds

DEFAULT SETTINGS	Per cent	Comment
Attendance	50.0	based on Australian data
Treatment if High risk, non-complying		1st year; assumes that ½ of those who agree to treatment/program, but quit, do so very early (cost=0), and that the other ½ do so at the end of Year 1.
Attribution*_CVDHigh Only	1.0	variable allows additional scaling of those complying and 'successful' with CVD treatment
Attribution*_DiabHigh Only	100.0	variable allows additional scaling of those complying and 'successful' with lifestyle program
CVDriskOnly_complies_successful	47.5	% based on UK study [95], *for SBP*: 40% accepting & 87% of these completing treatment. *For Chol*: mid-point between 85% and 70%. Assumed 2 related GP visits a year
Success^ DiabHigh_Only	47.1	% based on UK study [95], *for lifestyle prog*: 85% accepting & 90% of these completing treatment. *For Exercise:* mid-point between 77 and 23%. Assumed 2 GP visits a year
Success^ CVDandDiabHigh_Only	47.3	assumed average of above two
Success^ Obese_Only	58.0	% based on UK study [95], 85% accepting to start weight management program & 68% of these completing program. Assumed no yearly monitoring cost
Success^ Smoke_Only	3.0	based on UK study [95], 19% accepting to start on quit-program & 15% of these quitting smoking. Assumed no monitoring costs
Success^_ObeseSmok_Only	30.0	assumed average of above two
RRR for CVD	0.3	Relative Risk Reduction (RRR): the average for CVD in Appendix B of UK study [95].
RRR for smokers and for the obese	0.15	Assumed to be ½ of the RRR for CVD, see above
Discount rate	3.5	as per UK guidelines [95].

^ 'Success' refers to % of treatments expected to lead to the UK study's Relative Risk Reduction, or RRRs. 'Success' for those at HighRisk complying with treatment means: reductions by (1-RRR) in BMI for the obese, in HbA1c for the HighRiskDiab, and in SBP_Chol for the HighRiskCVD. For current regular smokers 'success' means 'quitting'. * 'Attribution' accounts in UK study [95] for some treatments over the 20 years having arisen from other than vascular checks. This does not apply in our study because we are only tracking people who attended the vascular Risk Assessment, and only over a 5-year period. Nevertheless these variables were included as they may be useful in allowing for additional scaling of the 'successful' High CVD/Diabetes risk groups.

The cost per drug-script to the Government was estimated as the 'PBS benefit' for the period January to December 2009, divided by the number of scripts over the same period. Total costs for drugs were also based on the statistics published by the PBS.

For GP services we estimated total costs based on bulk-billing rates and on examples of charges by GPs who do not currently bulk-bill. The most common GP practices, and the drugs they generally prescribe for high risk diabetes and/or CVD patients, were obtained from GPs currently practicing in Australia.

For the cost of 'completers' of the *Prevention of Type 2 Diabetes Program,* the source was General Practice, Victoria. For *Nutrition intervention* the Dietitians Association of Australia; and for the *Weight management program* a journal article [101]. For *Smoking cessation* we approached Quitline, Victoria, but this organisation was unable to provide the 'quit smoking' cost data we needed.

Table **13** summarises the unit costs used for government, and for both government and patients. It indicates that drug costs for those at high CVD risk are likely to make up a considerable proportion of total intervention-related costs. The main reason for this is that such drugs are taken monthly by those at high risk, rather than being a one-off irregular cost (as for example for lifestyle programs).

8.8. RESULTS

The results presented below involve comparisons between a 'no Intervention' (or Baseline) situation and the Scenario (that is implementation of the Vascular Risk Assessment Intervention). They are estimates of the marginal costs and benefits associated with implementation of the Scenario.

As seen in section 8.5, *HealthAgeingMod* estimates each vascular checks attendee's risk scores and groups these into Low, Medium and High risk categories.

Next, it estimates:

- the number of persons participating in the vascular screening program, as well as the related 5-year costs;

- the proportion at high risk complying with the follow-up treatments offered;

- the proportion successfully completing the treatment, as well as the related 5-year costs;

- the difference in the numbers acquiring new diabetes and/or new CVD over 5-years between the 'no Intervention' and Scenario simulations, as well as in the associated treatment costs.

Table 13: Unit cost data (government and total)

PER PERSON COSTS	**TotCost** AUD	**GovCost** AUD	**Comment**
GP visit_15 minutes (per visit)	41.9	34.9	assumed screening by GP, 2 visits
Dietician_initial visit for obese (1st year)	75	75	assumed 100% gov
Dietician_follow-up visit for obese (years 2 to 5, per year)	30	30	assumed 100% gov
Prevention of Type 2 diabetes program – if high glucose level (per year)	50	30	
Quit-Smoke program (per year)	50	30	assumed same as for Diabetes lifestyle program
Drugs – if high CVDrisk:_simvastatin 40mg (per month) for cholesterol	44.5	34.5	assumed to be taken monthly over the full projection period by those complying
Drugs – if high CVDrisk:_Irbesartan 150mg_(per month) for blood pressure	27.4	22.8	assumed to be taken monthly over the full projection period by those complying
Treatment cost – if *new* diabetes 2 (per year)	1,758	1,758	*HealthAgeingMod* data, assumed 100% government
Treatment cost – if *new* CVD (per event)	13,637	13,637	*HealthAgeingMod* data, assumed 100% government*.

* Definition of CVD [39] is: angina, heart attack (myocardial infarction, MI), stroke, congestive heart failure and peripheral vascular disease (PVD). Definition of CVD in *HealthAgeingMod:* hospitalised events of MI, Stroke, Coronary artery bypass graft surgery (CABG) and Percutaneous transluminal coronary artery angioplasty (PTCA)

Using the above *HealthAgeingMod* estimates, we computed the 5-year cost-effectiveness ratios for Australia as cost/QALY gained. For each treatment option considered, we used UK estimates of lifetime QALYs gained from illnesses and events avoided [95]. As the UK estimates cover a 20 year time frame, we pro-rated these to match our 5-year time horizon. Also, since full benefits from treatment are not expected until the second year, our lifetime QALY gains concern the period from beginning of year 2 to end of year 5.

Vascular Check Screening Invitees, Attendees and Costs

HealthAgeingMod estimated that 7,726,272 Australians aged 40-74 years would receive a letter advising of the availability of the Vascular Risk Assessment, leading to 7,131,774 being invited. Thus, under the 'default' option, one-half of these (3,566,000) would attend the vascular checks. The estimated screening cost (*i.e.,* the cost of the base-year Risk Assessments) amounted to AUD 249 million for government and AUD 299 million in total (*i.e.,* government and patients).

Numbers at High risk and Cost Effectiveness of Implementing the Scenario

The numbers at high risk in the Baseline and Scenario simulations and the cost effectiveness estimates of implementing the Scenario are presented in Tables **14**, **15** and **16**.

Table **14** shows that, between 2005 and 2010, less vascular checks attendees would have been at high risk under the Scenario than under the Baseline. It also shows that, under the Scenario, at the end of the 5-year period, there would be 47% less persons (82,783) at 'high risk of diabetes only'; 48% less at 'high risk of CVD only'; 58% less 'obese only'; and 3% less 'smoker only' than under the Baseline.

Table **15** indicates that 1,476,270 persons were identified by *HealthAgeingMod* to be at high risk among the 3,566,000 persons who attended the Vascular Risk Assessment. Within that high risk group 494,000 complied and thus successfully completed their 5-year treatment. The gross cost to government was estimated at AUD 769 million and the total gross cost AUD 947 million. On the benefits side, 32,132 'disability free' years would have been gained had the Scenario been implemented.

Table **16** summarises the savings arising from less cases of new diabetes and of new CVD under the Scenario than under the Baseline, that is: 35,110 less high risk persons acquiring type 2 diabetes, and 35,172 less having at least one hospitalised CVD event in the 5-year period. Because *HealthAgeingMod* operates at the level of the individual, persons with both diabetes and CVD could be identified prior to computing the related expenditures.

The savings in treatment and in hospitalization costs were estimated at AUD 634 million undiscounted (or AUD534 million if discounted at 3.5%). To obtain 'net costs', that is total expenditures less treatment cost savings, we subtracted this 'new diabetes-CVD-related' saving from the 'gross costs' reported in Table **15**. Thus the estimated 'net cost' is:

(947 – 634)=AUD 313 million.

Table 14: Changes in numbers at High Risk,* Scenario 2010 to baseline - Default settings (1st 5 years)

	At High Risk_Scenario	At High Risk_Baseline	Difference (No) Scenario-Base	Difference (%) Scenario/ Base
DiabHighRisk (if not HighRiskCVD)	73,707	156,490	82,783	47
CVDhighRisk (if not HighRisk Diab)	129,043	271,669	142,626	48
Diab&CVDhighRisk	6,872	14,529	7,657	47
Obese (if not HighRisk_Diab_CVD)^	253,756	437,511	183,754	58
Smoker (if not HighRisk_Diab_CVD)^	16,448	548,254	531,807	3
Obese and smoker only	14,584	47,817	33,233	31

* 'high risk' means: healthy 40-74 year olds assessed through the vascular check to be at 'high risk' of diabetes, or CVD, or both, and/or having a BMI of 30 or more (*i.e.,* obese), and/or being a current regular smoker. ^ Obese or smoker if not HighRisk Diab or CVD in Base-year

Sources: *HealthAgeingMod* runs for number of persons by 'high risk' category.

Time Profiles of Gross and Net Expenditures

While decision makers are interested in what the gross and net cost estimates of implementing the Scenario are likely to be, the yearly breakdown of these costs is also very important in the context of Annual budget preparations.

Table 15: Cost effectiveness* of treating high-risk** vascular check attendees (1st 5 years)

	Attendees ('000 persons)	**Complies &success** ('000 persons)	**TotCosts** (A$ million)	**GovCosts** (A$ million)	**UNIT QALY** gained	**TOT QALY** gained
DiabHighRisk (if not HighRiskCVD)	156	74	38	28	0.18	6,482
CVDhighRisk (if not HighRisk Diab)	272	129	557	445	0.26	17,024
Diab&CVDhighRisk	15	7	31	25	0.44	1,511
Obese (if not highRisk_Diab_CVD)^	438	254	47	47	0.05	5,739
Smoker (if not ighRisk_Diab_CVD)^	548	16	15	9	0.10	827
Obese and smoker	48	15	7	6	0.08	550
Total/average	**1,476**	**494**	**947**	**769**		**32,132**

* Costs and QALYs discounted at 3.5%; ^ Obese or smoker if not HighRisk Diab or CVD in Base-year ** 'high risk' means: healthy 40-74 year olds assessed through the vascular check to be at 'high risk' of diabetes, or CVD, or both, and/or having a BMI of 30 or more (*i.e.,* obese), and/or being a current regular smoker.

Sources: *HealthAgeingMod* simulations for number of persons by 'high risk' category.

Table 16: Less people with new diabetes & new CVD under the Scenario

DIFFERENCES IN (2005 to 2010)		**UNITS**
Numbers with New Diabetes	35,110	persons
Numbers with New CVD	35,172	persons
Sub-total	70,282	persons
Total Cost	534 634	AUD million, *discounted 3.5%* AUD million *undiscounted*

Source: *HealthAgeingMod* simulations

Using the 'default' settings in *HealthAgeingMod*, the yearly estimates of gross and net expenditures are charted in Fig. **9**. Results for different settings – that is the sensitivity tests - are presented in the next sub-section.

Fig. **9**(**a**) shows that, at AUD 532 million, gross expenditures are by far the greatest in Year 1, the year in which the vascular screenings take place. This total is made up of AUD 299 million as expenditure on the vascular screenings; of AUD 89 million as follow-up treatment cost for those at high risk who commenced treatment but did not continue or comply; and of AUD 144 million for those at high risk who complied and were successful with treatment. Because

these latter were assumed to continue treatment over the full 5-year period, Fig. **9**(**a**) also shows expenditures of AUD 144 million for each of years 2, 3, 4 and 5. When all these components are added up, the total gross cost over the 5-year period is AUD 1,108 million.

Fig. **9**(**b**) shows that once treatment cost savings arising from less 'high risk' persons acquiring diabetes and/or CVD under the Scenario are accounted for, the net costs are considerably lower than the gross costs. The Year 1 net cost is AUD 405 million (compared with AUD 532 million as gross cost), and the annual preventative treatment cost is AUD 17 million (compared with AUD 144 million). The full 5 year estimated total net cost is AUD 473 million (less than half of the gross estimate of AUD 1,108 million).

Sensitivity Simulations

As in most projects of this kind, there are uncertainties about the accuracy of, and likely changes in, the values of some of the 'default' parameters.

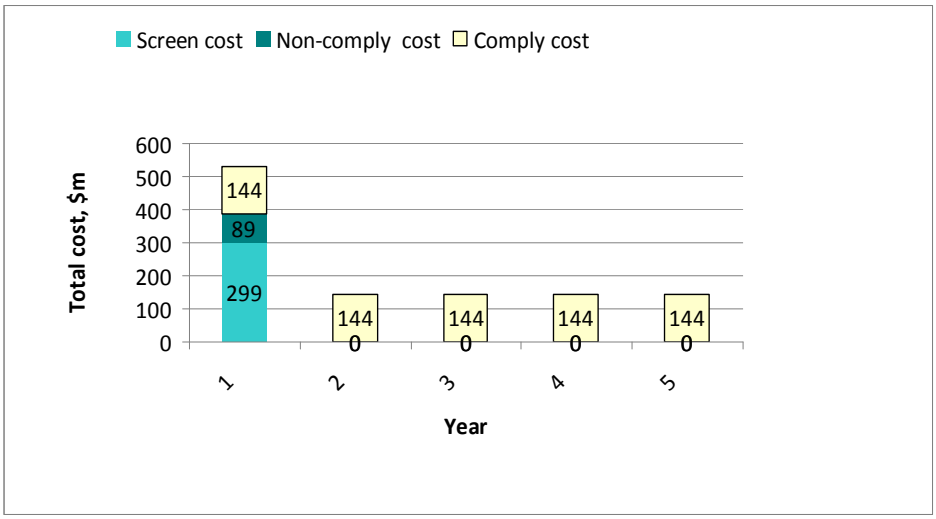
Although we carefully chose default values that closely reflected current Australian costs and practices, uncertainties still remain. For this reason we carried out sensitivity tests. For these we changed 'per unit costs' that were likely to have greatest impact on the results. Our sensitivity simulations involved:

- reducing GP visit costs by 50% (Fig. **10**). This indicates the likely impact of allowing practice nurses – rather than GPs as currently – to carry out most of the vascular checks. We assumed that the unit cost of a practice nurse providing a vascular check would be one-half that of a GP. This sensitivity test is relevant as use of practice nurses are already featuring in some recent Australian government health initiatives.

- lowering drug costs by 20% (Fig. **11**). The main reason for this sensitivity test is that the costs of similar drugs in the UK have been shown to be significantly lower than in Australia [97], and thus could decline in future in Australia.

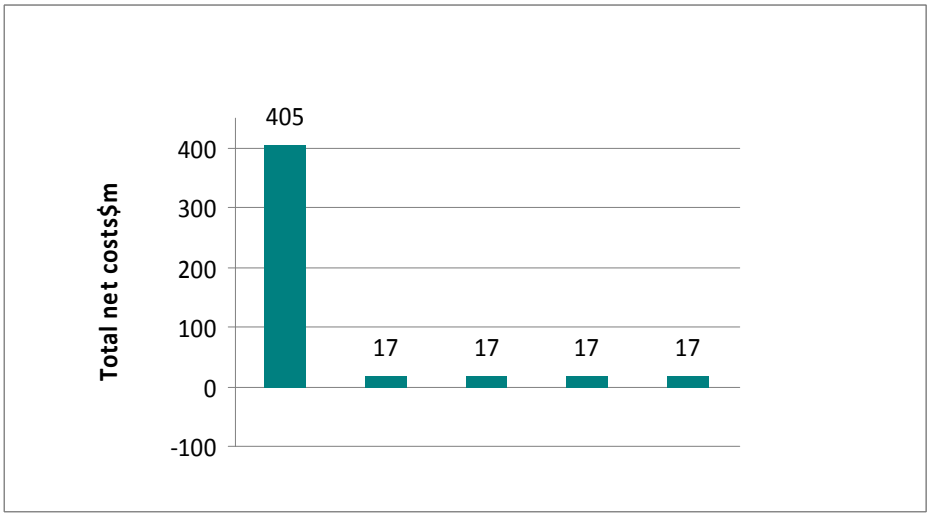
- increasing drug costs by 20% (Fig. **12**) to reflect a historically upward trend in the cost of the most often prescribed PBS drugs for blood pressure and cholesterol. We chose a 20% increase because, in the

five years to 2004-05, Australia's expenditure on prescribed drugs – as on medical care generally – rose by close to 20% [80].



Undiscounted 5yr Gross Total: AUD1,108 m (Year 1: AUD532 m; Years 2 to 5: AUD576 m)

(a) Total GROSS costs



Undiscounted 5yr Net Total: AUD473 million

(b) Total NET costs

Figure 9: Total gross and net costs – DEFAULTsettings (AUD million/year, undiscounted)
Source: *HealthAgeingMod simulations.*

- lowering the cost of new CVD events by 50%. The reason for this sensitivity test is that the Australian guideline specified CVD equations are based on US data [39] which cover a broader range of CVD events than NHS05 on which *HealthAgeingMod* is based. In this sensitivity test, the treatment cost per major CVD event becomes AUD 6,819. This is a plausible cost in Australia as it is close to an AIHW-based estimate of AUD 6,210 per hospital admission, with CVD as main cause [80].

The cost time profiles of the first three sensitivity tests are in Figs. **10, 11** and **12**. We found that the cost variations from 'default' (Fig. **9**) were particularly large for the 20% lower and 20% higher PBS costs cases – considerably greater than for the '50% lower GP cost' case.

Another interesting finding was that, with the '20% lower drug cost' simulation there were net cost savings of AUD 20 million in each year after the 1st year (when the screening costs dominated).

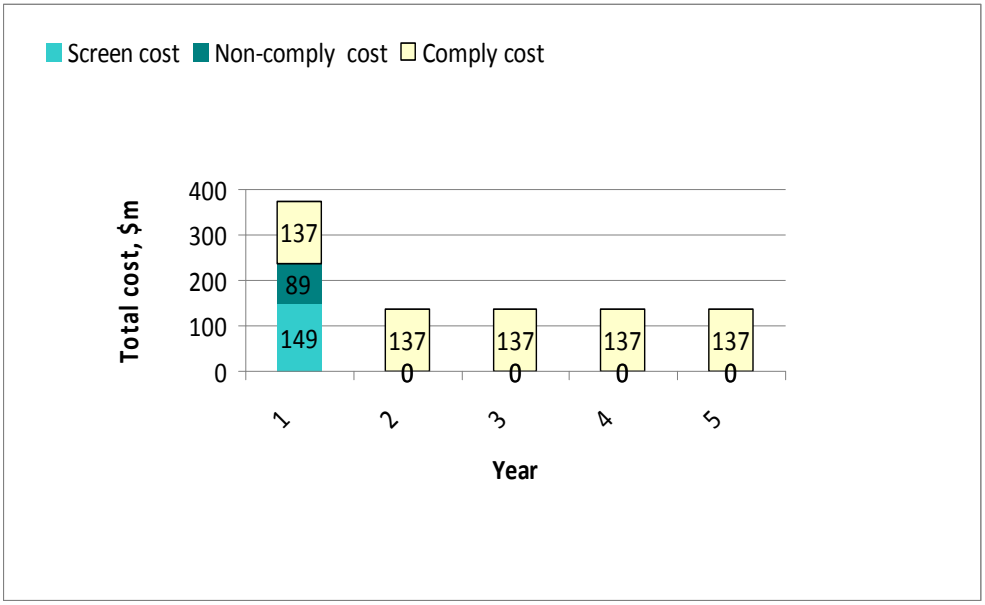
The fourth sensitivity simulation, 'lowering the cost of new CVD events by 50%', only affects the cost of treating people with new CVD, so in that case only the net costs would change from the 'default' option. Results for this simulation are included in Table **17**.

Range of Cost and Benefit Estimates, 'Default' and Sensitivity Simulations

Table **17** summarises and compares the results across the 'default' and all sensitivity simulations.

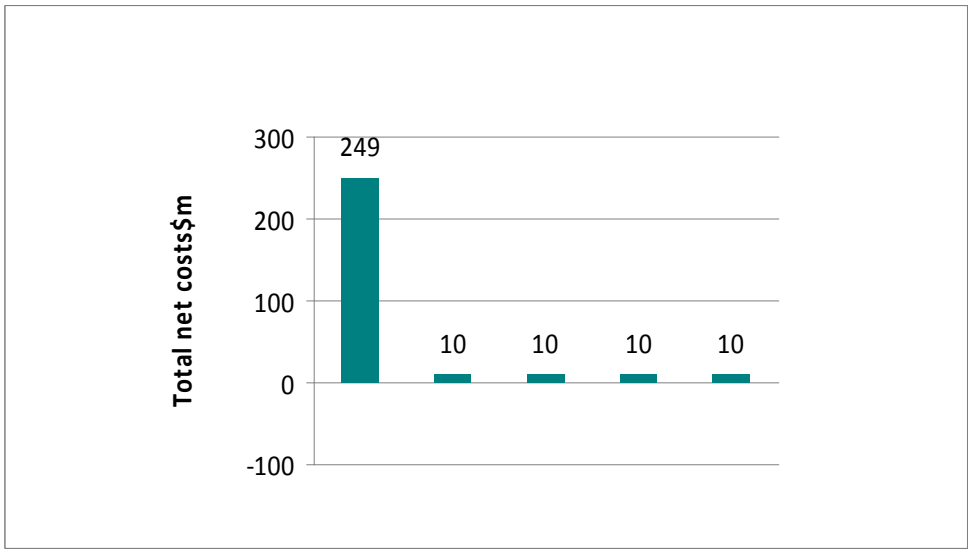
Table **17** shows that the estimates of *gross costs to government* range from AUD 639 million (50% lower GP costs) to AUD 856 million (20% higher drug costs). As expected, the 'default' amount (AUD 769 million) falls between these extremes.

The range for *net costs to government* is from AUD 106 million (50% lower GP costs) to AUD 437 million (50% lower treatment cost for new CVD events). Once again, the 'default' amount (AUD 769 million) falls between these extremes.



Undiscounted 5yr Gross Total: AUD 924 million (Year 1: AUD 376 m; Years 2-5: AUD548 m)

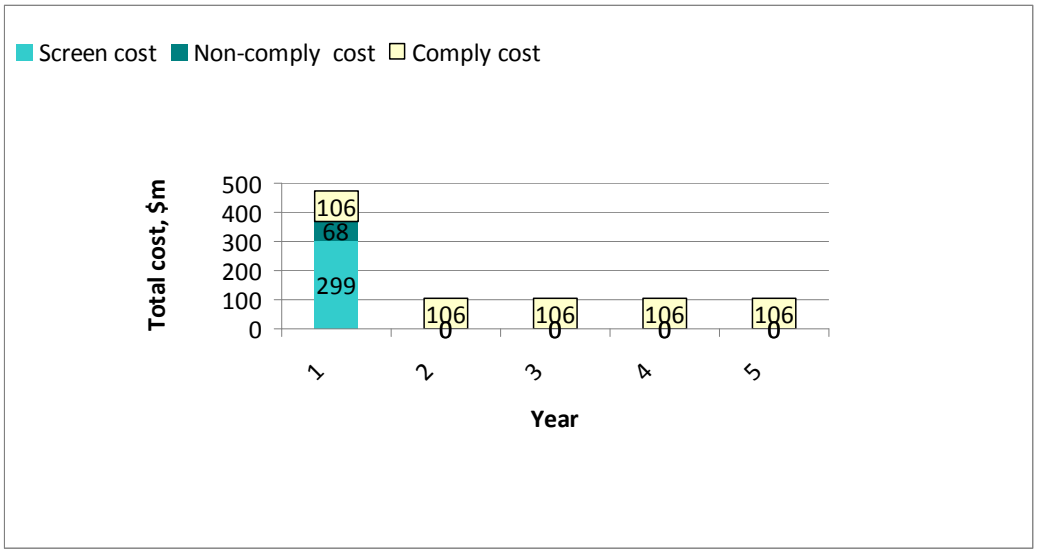
(a) Total GROSS costs, AUD million (undiscounted)



Undiscounted 5yr Net Total: AUD 289million

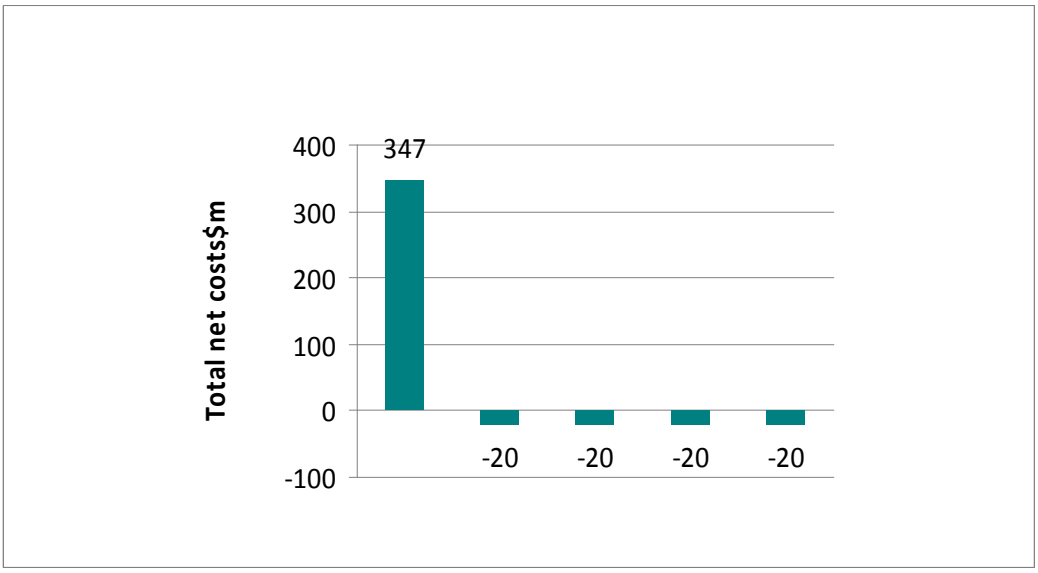
(b) Total NET costs, AUD million (undiscounted)

Figure 10: Lower GP Costs (50% of default, similar to practice nurse cost).
Source**:** *HealthAgeingMod* simulations.



Undiscounted 5yr Gross Total: AUD 899 million(Year 1: AUD473 m; Years 2-5: AUD 424 m).

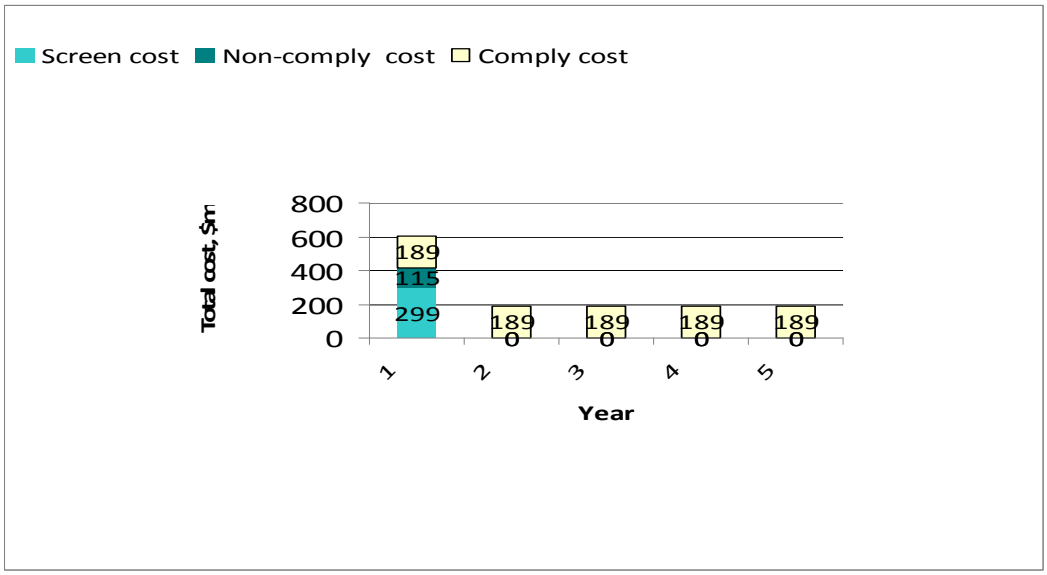
(a) Total GROSS costs, AUD million (undiscounted).



Undiscounted 5-year Net Total: AUD 267 million

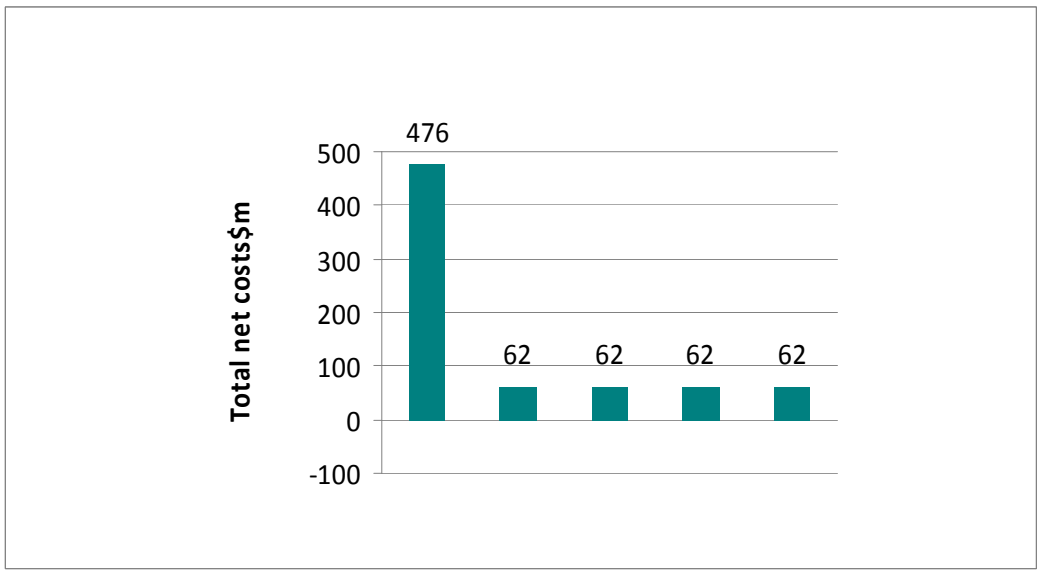
(b) Total NET costs, AUD million (undiscounted).

Figure 11*:* Lower PBS drug costs (20% lower: blood pressure and cholesterol drugs).
Source**:** *HealthAgeingMod* simulations.



Undiscounted 5yr Gross Total: AUD 1,358 m (Year 1: AUD602 m; Years 2-5: AUD 756 m)

(a) Total GROSS costs, AUD million (undiscounted)



Undiscounted 5yr Net Total: AUD 724 million.

(b) Total NET costs, AUD million (undiscounted).

Figure 12*:* Higher PBS drug costs (20% higher: blood pressure and cholesterol drugs).
Source**:** *HealthAgeingMod* simulations.

Table 17: Results: 'default' and Sensitivity Test simulations
(1st five years*; discount rate: 3.5%)

Simulation settings	**Gross costs** (AUD million)	**Net costs** (AUD million)	**Net AUD/QALY gained**
Default			
- government	*769*	*235*	*7,323*
- total	947	413	12,868
50% lower GP costs			
- government	*639*	*106*	*3,295*
- total	791	258	8,032
20% lower drug costs			
- government	*681*	*148*	*4,603*
- total	767	234	7,279
20% higher drug costs			
- government	*856*	*322*	*10,042*
- total	1,162	628	19,544
50% lower new CVD event cost			
- government	*769*	*437*	*13,607*
- total	947	615	*19,152*

* 2005 to 2010.
***Source**: HealthAgeingMod* simulations.

The range for *total gross costs* (*i.e.,* to government and patients) is from AUD 767 million (20% lower drug costs) to AUD 1,162 million (20% higher drug costs), with total gross costs being 11% to 26% higher than the governments' gross costs, depending on the simulation settings. Under 'default' settings, total gross costs were estimated at AUD 947 million.

Of particular interest are Table **17th** *net costs per QALY gained* estimates, as these are indicators of the worth of the Scenario in 'value for money' terms. The net government cost per QALY gained varied from AUD 3,295 (50% lower GP costs) to AUD 13,607 (50% lower treatment cost for new CVD events), and net total cost per QALY gained from AUD 7,279 (20% lower drug costs) to AUD 19,544 (20% higher drug costs).

Under 'default' settings, 'net total cost per QALY gained' was estimated at AUD 12,868 million and for 'net government cost per QALY gained' AUD 7,323 (Table **17**). These compare with additional *HealthAgeingMod* estimates of 'gross government cost/QALY gained' of AUD 23,934 and 'total gross cost/QALY gained' of AUD 29,479.

Because this range is well below what is usually considered to be cost-effective in Australia and in the UK (sub-section 8.9), an intervention of this kind is worth to be considered for public funding.

8.9. DISCUSSION AND CONCLUSIONS

The above findings regarding the Vascular Risk Assessment application of *HealthAgeingMod* indicate that, after implementation of the Scenario the related estimates would range from AUD 3,000-14,000 per QALY gained ('default' settings). Accounting for the limits set by the sensitivity tests, the 'net cost per QALY gained' was estimated to be AUD 14,000 or less for government, and AUD 20,000 or less in total (Table **17**).

Although before implementation a more comprehensive set of sensitivity tests could be carried out, the above findings suggest that the Scenario is likely to be well worth implementing. A recent analysis of recommendations from the Pharmaceutical Benefits Advisory Committee for listing of drugs on the PBS found that, based on data for an 11-year period, the incremental cost/QALY had a large and statistically significant effect on PBS listings [98]. The mean cost/QALY gained in that analysis was AUD 46,400, which is well above our upper-limit estimate of around AUD 20,000 for the Vascular Risk Assessment.

Regarding international comparisons, our result is similar to, but somewhat higher, than those of the earlier UK study considering similar vascular checks [97]. That UK study estimated the government cost/QALY for that intervention to be cost effective at £2,500-£3,000/QALY gained. Using the mid-2000s exchange rate of 2.5 AUD to the £, our 14,000/QALY gained are similar, translating to £5,600/QALY gained.

In conclusion, our findings show that the comprehensive Vascular Risk Assessment and Management Intervention reported in this Chapter is highly likely to be cost-effective in Australia. Thus, such an intervention is worth consideration for public funding. If implemented, vascular checks of this kind could ensure that many Australians at high risk would no longer miss out on prevention and/or recommended treatment.

PART III: ARE THERE LESSONS FOR THE FUTURE?

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CHAPTER 9

Issues for 21st Century Health Policy Concerning Chronic Diseases

Agnes E.G. Walker*

Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: Health care is a crucial policy issue worldwide and is forecast to continue to be so in future. Why do health care systems in many countries seem to be continuously undergoing reform planning and implementation? Why is the sustainability of Australia's health system of major concern, and what lessons can be learnt from recent health reform initiatives? In this Chapter we provide an overview of the major health policy areas of concern in the 21st century, including population ageing, health expenditure pressures and emerging major health threats likely to impact on chronic disease prevention and treatment. The focus will be on issues that can be resolved or influenced by individuals, governments, or the medical profession.

Keywords: Lessons from reform initiatives, sustainability of health systems, population ageing, obesity, 'super bugs', rising costs to patients, improved medical technologies.

9.1. LESSONS FROM RECENT REFORM INITIATIVES

Despite the global financial crisis, over the past seven years far more major government reforms had been initiated in Australia than in previous decades. Some reforms are currently at the initiation stage (*e.g.* partially or fully gone through federal Parliament); others have been funded in State and/or federal budget(s); and others are at various stages of the implementation phase. Among the latter are Australia's extensive health reforms which were initiated around 2009 and occurred during a rare period of a hung Australian Parliament (Chapter 3).

How did Australians respond to the health reforms and what lessons have emerged?

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +612 6125 9123; E-mail: agnes.walker@anu.edu.au

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First, although there were often lengthy delays before the reforms could be presented to Parliament, most were strongly supported by the public (*e.g.* health, education, disability, telecommunications), and their passages through Parliament were generally well received. So *one lesson* learnt was that very large reforms are possible even during unstable political periods.

However, passage through Parliament is only a first step, after which lengthy consultations with the many stake holders were needed before the details required for implementation could be finalised. Also, if elected late in 2013, the opposition planned to revoke some of the reforms. So after delays of one or more years, and the possibility of several reforms being revoked, Australians' awareness of the reforms seemed to evaporate as little had changed in their daily lives. *Another lesson* learnt was that announcement of a reform decision did not mean project implementation. Indeed, if revoked, reform implementation may not even be started, let alone completed.

A further unexpected problem was that, given the large number of reforms announced in health and other sectors, implementation of some of these had been poorly planned. In one case major loop-holes emerged in the certification of service providers, which followed several instances of unsafe practices and/or poor work quality. This leads to *another lesson* that is that reforms that had been successfully legislated can - during the implementation phase - end up being seen by the community as 'waste of money'.

Overall, announcement of major nationwide reforms with complex and inter-twined joint federal/State responsibilities, while necessary, is not sufficient to ensure that the reforms will actually happen, the expected health benefits will eventuate, and money will not be wasted.

9.2. HEALTH IMPLICATIONS OF POPULATION AGEING

In Australia, as in many other countries, the proportion of older persons in the population has been rising, and is expected to continue to do so in the decades to come. In this country population ageing was the result of sustained low levels of fertility and increasing life expectancies at birth [102]. A hundred or so years ago families tended to have five or more children of which only a few survived. Then, before dying, most people reached an age of less than 55 years. By comparison,

today families tend to have none, one or two children, and most of these are expected to survive to age 80 or above.

As life expectancies at birth increased dramatically, so did national health expenditures, and this caused concern to governments worldwide (section 1.3). However, as will be seen in section 9.3, population ageing has been shown not to be the major contributor to continued increases in health expenditures. One question is: can governments slow down the extent to which Australia's population ages?

While in past decades governments facilitated longer life expectancies – *e.g.* through improvements in sanitation; subsidising the pill; and fostering advances in medical technologies – such policies only tend to impact on health in the longer term. As a consequence, in the near future governments can do little to influence the extent to which Australia's population ages. This is because Australians who remain in this country will be getting older, year by year, until death (around 80 years on average). As a result, to date governments have not been considering population ageing to be a policy instrument and have accepted the ABS's population projections as a 'given'.

By 2025, the ABS predicts a 25% increase in Australia's population (Fig. **6** in Chapter 5). This increase is expected to mainly occur among the '30 years or over' age group, with little change in the numbers of children and younger adults. Among the retired, the number of 65-74 year olds is expected to nearly double, and that of 85+ year olds more than treble.

Given that modern medicine helps people to live longer with disability, the higher proportion of the aged in the population will not only have a considerable impact on health outcomes, but also on health expenditures. As a result, health costs per person have been rapidly increasing with age (Fig. **13**).

Advances in Technology are the Major Contributors to Increases in Health Costs

Several analyses have shown that population ageing *per se* is not the major driver of the increases in total health expenditures. For example, the Productivity

Commission estimated that population ageing, by itself, would only account for just over one third of the increases in total per person costs, and that advances in technology are far more important contributing factors [3].

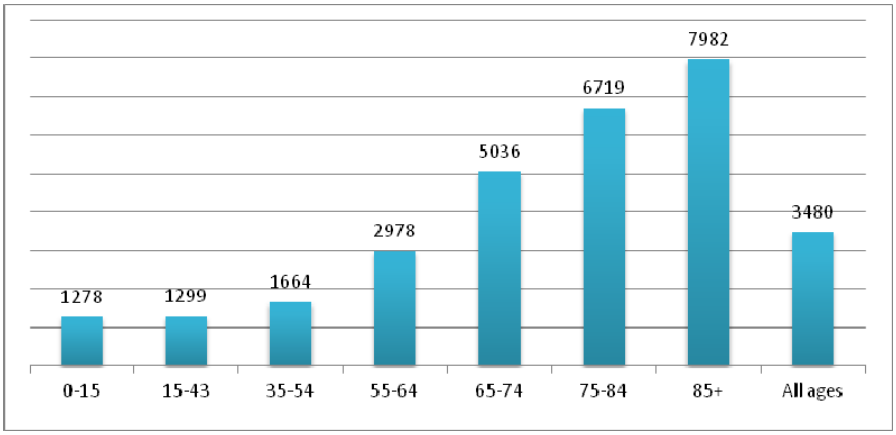

Figure 13: Per person health costs by age, in 2002-03 (AUD)
***Sources*:** Productivity Commission [3] for age distribution; AIHW [6] for All ages

Poorer and Older Australians find it harder to Part-Finance their Health Costs

In Australia, as in many other countries, governments have attempted to limit health cost rises by relying more on patient funding. For example, for doctor visits in Australia the Medicare rebate rises did not keep pace with the general level of doctor-fee increases, leaving some patients having to meet up to half of the cost of the visit. Also, by 2012, patient copayment for PBS listed drugs had increased to AUD 35.40 per script. For drugs costing more than that in total, patients now pay AUD 35.40, and for drugs costing below that amount they pay the full price.

In recent years Australians most in need - including the elderly - reported that they feared they might no longer be able to afford the services recommended by their health professional [8]. Also, a subsequent report found that people with major chronic diseases or disability were more likely to experience deep and persistent socioeconomic disadvantage than other Australians [103]. So, many Australians no longer see their country's health system as being of the 'universal' type, with government providing equal access and affordability to health care.

9.3. FISCAL PRESSURES ARE LIKELY TO BE TIGHTER IN FUTURE

Currently more than a quarter of Australian government spending is directed to health, age-related pensions and aged care. As seen in Chapters 1 and 2, during the past decade the most rapid increases in government spending were in health, and these patterns are forecast to worsen over the next four decades [7]. From around 2030, negative 'fiscal gaps' are projected to become the norm.

Sustainability of Australia's affordable and high quality health system has been reported to require future actions if governments are to curtail the growth of health expenditures [7].

Above GDP Growth in Health Expenditures Affects Affordability

As seen in section 1.3, it is the above GDP growth of health expenditures that puts pressure on budgets worldwide. That section also discussed the likely reasons why, in Australia and elsewhere, health expenditures have been increasing more rapidly than GDP. As seen in section 9.2, the related financial pressures made poorer and older Australians fear that they may no longer be able to afford the recommended health services.

This presents governments with a dilemma. On the one hand, simply accommodating future health cost pressures would, by itself, be a non-feasible option. On the other hand, financing by cutting back other budget items, such as education or aged care, is unlikely to be electorally acceptable. This leaves financing through tax increases, but such an action may not be possible at times of slow or negative GDP growth and/or increasing unemployment.

New Medical Technologies are the Main Drivers of Health Cost Increases

New medical technologies have been – and are projected to continue to be – the major drivers of the above mentioned GDP growth in health costs (section 9.2). However, due to the dynamic and complex nature of medical innovations, such discoveries are very difficult to predict and thus to include into economic analyses of proposed health reforms (section 6.3).

Complexities arise from the strong links between the creation of medical knowledge, the networks of invention, and the diffusion of innovation throughout the health sector. To arrive at a more comprehensive view of 'health' as a commodity than previously, a beyond 'pure market' perspective has recently been proposed combining neoclassical and evolutionary approaches [104].

Though contributing to health costs, future technological advances are expected to benefit many Australians by improving doctors' ability to detect or successfully treat diseases [105**].** One emerging new technology is genomics, which has the potential to provide revolutionary biological treatments, together with personalised targeting of medicine. Another is the 'bionic eye' which promises to restore at least some sight to those who are currently legally blind. Its prototype was unveiled in June 2013 [106]. Other examples include new developments in robotics. Already, Australian hospitals use remote control surgical machines which not only make procedures - such as coronary artery bypass surgery - considerably easier to perform, but also easier to recover from.

There are also emerging medical developments for diabetes, cardiovascular disease, cancer and neurological disease. While these are likely to greatly benefit Australians with major chronic diseases, they are also estimated to lead to significant cost increases compared with existing practices [105]. Main reasons quoted are the increased prevalences (through population ageing and improved treatments) and the higher unit costs associated with the new technologies. Additional cost increases could also arise through the advances requiring new workforce skills and new ways of delivering health care.

For the same reasons, other emerging technologies beneficial to patients are also likely to lead to cost increases, unless there are offsetting cost savings (for example with preventive measures, or with technologies that restore functionality, such as the bionic eye).

Overall, future cost increases arising from use of new technologies are likely to be significantly greater than the estimated cost savings [7, 90, 105**].** So for patients

and governments the sustainability of Australia's health system is likely to remain a longer term concern. It will be important to ensure that the health system responds well to innovation, provides 'value for money', and mainly funds cost-effective improvements to health care [7]. Indeed, these are the objectives of the *HealthAgeingMod* applications reported in Chapters 7 and 8.

9.4. EMERGING ISSUES IMPACTING ON CHRONIC DISEASE PREVENTION AND CARE

Threats to human health in the 21st century have been discussed in the literature and some actions have already been taken at the country or international levels. However, in most cases progress has been very slow. There is also considerable literature on many other important health areas that could be improved, including greater efficiency and focus on service deliveries [107].

In this Chapter we focus on major health threats that have implications for chronic diseases.

Obesity Epidemic and Non-Communicable Diseases

More than a decade ago, obesity has been identified as a major health threat globally. It was in the 1990s that the World Health Organisation (WHO) began sounding the alarm on an obesity epidemic [108]. In 2008, the WHO linked obesity to noncommunicable diseases – *e.g.* cardiovascular diseases, diabetes, cancers – noting that such diseases were largely preventable by modifying common risk factors, such as tobacco use, obesity (unhealthy diet, physical inactivity); and harmful use of alcohol [109]. The WHO considered that one of the major global challenges for the 21st century was the burden of non-communicable diseases, and initiated an action-based 'prevention and control' plan for such diseases. The plan was endorsed at the 2008 World Health Assembly [109].

Around that time, in Australia, a new longitudinal obesity study had commenced [110]. This study found that, in 2000, the prevalence of diabetes was more than

twice that in 1981 and has once again established associations between obesity and type 2 diabetes, cardiovascular disease, some cancers and arthritis.

Recognising that Australia had not invested enough in the prevention of chronic diseases, the federal government embarked in 2010 on a preventative health strategy targeting obesity (as well as tobacco, alcohol and illicit drugs) [111**].** We saw in Chapter 1 that obesity is already one of the most important risk factors for chronic diseases and that the proportion of Australians who are overweight or obese is expected to continue to rise.

As many other OECD countries, Australia has experimented with policies that aim to stem this 'epidemic', yet obesity rates continue to rise [112]. In a comprehensive international study, the OECD ranked broad level obesity related interventions (*e.g.* in schools, work places, primary care providers) across selected member countries [113]. It found that most of these interventions had very limited impact.

The above suggests that in general governments find it very hard to inspire individuals to abandon their obesity inducing lifestyle choices.

Antimicrobial Resistance *and 'Super Bugs*'

Another major global challenge for the 21st century is antimicrobial resistance [114]. In 2001 the WHO noted that a crisis had been building up, making common - yet life-threatening - infections difficult or even impossible to treat. In 2012 it reported that the hospital environment favoured the emergence and spread of resistant bacteria and that, once antimicrobial resistance had developed, it was either irreversible or very slow to reverse [115].

Several countries have voiced similar concerns. In Australia, a recent report by the Office of the Chief Scientist expressed concern about the misuse and over-use of antibiotics that have accelerated the development of antibiotic resistance. Examples quoted were using antibiotics as growth promoters in animals, and prescribing antibiotics for viral infections. While, until a few years ago, super

bugs in hospitals tended to involve the very sick or very frail, now even healthy people - in hospital just for a biopsy - may be attacked by super bugs [116].

A related concern is the collapse of the antibiotic discovery pipeline. This is because in the last 50 years only one antibiotic that worked in a novel way had been developed for use in humans. Unless many more new discoveries are attempted and discovered, things as common as strep throat infections or a scratched knee could once again kill [116]. Antimicrobial resistance is now seen as having the potential to become one of the world's biggest public health challenges [117].

In relation to the antibiotic discovery pipeline, pharmaceutical companies will, of necessity, focus on research that is most likely to be profitable, such as drugs that patients need to take over a long period (*e.g.* statins for cholesterol control). Because antibiotics are only used as 'one-offs' for infections, pharmaceutical companies had not focused on research for new antibiotics.

Clearly, not being able to control infections in hospitals, offices or homes is a life threatening set-back for today's treatments of chronic diseases. It is well known that there is a risk of infections with any operation. The risks related to major chronic diseases are particularly great because the operations are major and the patients are often very sick or frail. *Examples of chronic disease related operations include organ replacement, insertion of pace makers, and prostheses for joint replacements.*

As a full circle to the late 19th century's hygiene measures following the discovery of the 'innovative doctrine of antisepsis' [118], there are once again calls for greater surveillance of hospital protocols, such as cleanliness and hand hygiene. In today's world, additional protocols could concern antibiotic over-prescription by doctors, and patients not taking the full course of their prescribed antibiotics.

In Australia, the scant research relevant to antimicrobial resistance tends to be carried out by the public sector. One example concerns biofilms which are developed by micro-organisms that attach themselves to implanted medical devices, such as pacemakers. It has been known for a while that biofilms have

great importance for public health, as they can cause a *variety of device-related infections* [119]. Greater understanding of biofilm processes is seen as having the potential to lead to novel, effective strategies for biofilm control, and recent research has moved us closer to such an outcome [120].

However, research of this kind is time and skill consuming, and breakthroughs are rare. Unless, as the WHO suggests, more such research is encouraged and financed [115], people may have to soon face a future without effective antibiotics.

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CHAPTER 10

Could Health Modeling be Improved or Better Used?

Agnes E.G. Walker*

Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: In this Chapter we discuss some of the modeling improvements emerging from PART II that could possibly be addressed in the near-future. Next, we note that although for some health threats – *e.g.,* diabetes, antimicrobial resistance, system deficiencies – the best 'value for money' solutions have already been identified, so far funds for implementation had not been made available. We investigate why this may have occurred and suggest possible future alternative researcher approaches. Next we ask whether longer term modeling improvements are also needed to address the emerging chronic disease related health threats (Chapter 9). Finally, in view of the rapid changes in access to knowledge *via* the internet, and the need by decision makers and health professionals for more rapid and more readily accessible 'evidence-based' analyses, we ask whether some longer term modeling improvements could lead to web-based versions of the outputs produced by current models.

Overall, it seems uncertain that Australia can in future maintain its top health status internationally. However, we conclude that the ability to identify 'best value for money' in health investments will become even more important in future than it had been in previous decades.

Keywords: Modeling improvements; more coherent datasets; up-to-date guidelines; adaptable health structures; less system deficiencies; improved research to policy links; internet use.

Developing models such as *HealthAgeingMod* is both time and skill consuming. Also, at the time of applying for research grants there is no guarantee that the new data to be used and/or the novel methods adopted will end up delivering the expected outcomes. So it is important to ask whether continuing with the by now standard topic coverage and modeling methodologies is still the most appropriate.

Before answering this question it is worth examining why healthcare reform is

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

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currently such a pervasive global phenomenon, and why in recent decades policy makers seem to have been continually reforming their health systems. In Australia, the reforms arising from the major health reviews initiated by government around 2009 [16, 17, 107] are still in the pipeline. As seen in Chapter 3 and section 9.1, their coverage and completion have been much delayed by the political difficulties arising from an unstable minority government. So, a decade and a half after the reviews' initiation, the extent of their success still cannot be examined.

Since 2009 new health issues have emerged (Chapter 9) and already tight government budgets are expected to be even tighter in future (section 9.3). So, regardless of whether in Australia there is a change of government or not, a re-assessment of the reforms initiated around 2009 is highly likely.

These growing health challenges are making it more important to focus on 'best value for money' projects. If Australia is to continue to have a sustainable, up-to-date, cost-effective and well functioning health system, then decision making tools - such as those described in this book - are likely to be used more widely and more frequently in future.

Below we mention major improvements that could be carried out either in the near future, or in the longer term.

10.1. MODELING IMPROVEMENTS IN NEAR FUTURE

Some potential improvements were already mentioned in PART II. These concerned the design, building, and validation of *HealthAgeingMod,* and its Chapter 8 application to a policy relevant scenario (*i.e.,* the Integrated Vascular Risk Assessment and Management Intervention).

Recent research has also identified problem areas that had attracted less attention in the past, such as health systems, processes and waste elimination. These could in future better benefit from economic analyses using similar or complementary methodologies to *HealthAgeingMod*.

A selection of these potential shorter term improvements are discussed below.

Data Gaps, Inconsistencies

In this sub-section we mainly consider issues discovered while building *HealthAgeingMod* (Chapters 4, 5). Individual-based models of this kind are so highly data intensive that in most cases a single large survey-based dataset cannot provide all the variables required for policy relevant applications.

Two major survey datasets were used in building *HealthAgeingMo.* Its Base-year population was obtained from the cross-sectional 2005 National Health Survey (section 5.1), as were several of the benchmarks used to validate the model-system. Equations for predicting the probabity of acquiring diabetes and/or CVD were estimated from waves 1 and 2 of the longitudinal AusDiab database. In section 4.3 we mentioned that at the initial 2004 project proposal stage the above equations were planned to be estimated from US and UK data. However, once we started using these overseas data, it became apparent that they predicted incidence and prevalence estimates well above those published for Australia by the ABS.

This created a major problem as use of the US and/or UK data would have made it very difficult, if not impossible, to validate *HealthAgeingMod* against Australian benchmarks. Luckily, from 2007 AusDiab data became available, and we found that its aggregate prevalence estimates for wave 1 (year 2000) broadly matched the ABS benchmarks for the same year. Unfortunately wave 2 was not found to be nationally representative and indicated significant over-estimates for diabetes prevalence changes, compared with what had been observed from cross-sectional ABS data.

As this data issue became of nationwide concern, it was examined by the National Centre for Monitoring Diabetes (section 6.1). The conclusion was that, in Australia, the best available sources for diagnosed diabetes prevalence were the ABS's National Health Surveys [75].

Only after publication of the above assessment could we concentrate on validating *HealthAgeingMod*. In our case such mis-matches of prevalence estimates from different data sources – *i.e.,* across UK, US, ABS and AusDiab data – caused not only considerable delays, but also confusion as to which source was the one to use to ensure the credibility of *HealthAgeingMod*.

So a very important possible future improvement for data users would be the regular publication of comparative data assessments, similar to the one mentioned above. The AIHW might be one organisation considered for such a task.

Other Australian data related improvement could be more longitudinal databases and greater frequency of the ABS's cross-sectional Health Surveys. A related recent development in this respect concerns the 2011-13 Australian Health Survey which is said to have been much improved thanks to additional funding from the Department of Health and Ageing and the National Heart Foundation of Australia [121].

Regarding new data sources, the federal government's *eHealth* initiative seems a possibility (Chapter 3 and section 10.2). Other electronic possibilities could be the individual level devices that record people's or patients' activities or health events. One example is the *wireless activity tracker* (or pedometer) that measures how far the person wearing it ran, walked, or biked. It keeps a fitness log that, once transferred to the internet, can be compared with the logs of other users or user groups. Internet-based competition and support across groups (*e.g.,* by age and/or sex) has the potential to help people keep to their planned levels of physical activity and *could thus have a positive impact on the obesity threat.*

Other examples include devices such as *implanted pacemakers or cardioverter-defibrillators*. Because devices of this kind record the date, time and geographic location of the person suffering a health related event, new data sources could be created with permission of the device owners. The datasets thus obtained could then allow comparisons with other events happening at the same date, time and geographic location, such as a change in temperature or in air pollution. Through such comparisons researchers might be able to observe important statistical correlations.

Extending *Health Ageing Mod*

While currently *Health AgeingMod* only considers diabetes and CVD, it could in future be extended to other chronic diseases, such as arthritis, mental health, and cancer (Chapter 4).

Extensions to the types of results the model-system produces are also possible, given the 1000 or so variables available in NHS05. For example in Chapter 8 it

would have been possible to extend the Vascular Risk Assessment and Management Intervention application to estimate the impact of the related health improvements on patients' ability to work. Estimates of their likely incomes could follow, as well as the government expenditures associated with social security benefits. As an alternative for extending *Health AgeingMod* analyses to account for people's ability to work and to earn above poverty incomes, it would be possible to link *Health AgeingMod* to another model that focused on how disability status arising from chronic diseases impacted on employment [122, 123].

Modeling Methodologies

An emerging health issue identified by the WHO - and many countries, including Australia - is the threat of antimicrobial resistance (Chapter 9). Because to date the declining power of existing antibiotics had mainly affected very sick or frail hospital patients, this threat could be considered to be a complication of chronic diseases. As such, it would be important to cover this health threat in models such as *HealthAgeingMod*. However, because antimicrobial resistance is in the first instance a pandemic type of threat, different methodologies may be needed.

A more indirect way of considering antimicrobial resistance in chronic disease models would be to use sensitivity tests to assess their likely impact. For example, the length and cost of hospital stays could be increased for the proportion of hospital patients expected to be affected under 'upper limit' and 'lower limit' sensitivity tests.

While carrying out such tests, there will also be a need to alter the usual 'ceteris paribus' assumption – *i.e.,* 'all other things held constant' – that underlies many simulations. This is particularly so if the calls for a global effort to tackle antimicrobial resistance eventuates (section 10.2).

There are a number of other areas where methodological improvements or changes would be beneficial. For example, accounting for behavioural change may be important in simulations of initiatives that target obesity.

Systems, Processes and Cost Efficiency: Extensions to Topic Coverage

In Australia, and in many other countries, there have been calls for major health system changes in response to managing ever increasing health cost pressures (section 9.3). With the many government groups involved with health sector decisions – Prime Minister, Cabinet, Council of Australian Governments, State and territory Ministers, Parliament – and the numerous government Departments and central agencies providing advice to these, delivery of complex and as yet untried decisions about the 'big health issues' became very hard with the current structure of the health system. In 2011 a National Health Reform Agreement [20] had been secured with the aim to deliver funding to public hospitals with transparency, accountability, less waste and less waiting for patients (Chapter 3).

However, some questioned that this will be sufficient to maintain the sustainability of Australia's health system and suggested further actions. For example, Australia's Chief Scientist recently stated that there was a consistent view across stake holders on what future breakthrough actions should be. Such actions, by doing things differently, were expected to increase the chances of success [124].

Over the past decade or so there have been many suggestions for system-level changes to Australia's health sector (Chapter 3). Prior to gaining support from politicians, the few suggestions that were accepted had to undergo considerable modifications. During the related negotiations model-based economic analyses could have been used to rank the various amendments proposed against a generally agreed budgetary or health outcome indicator. In reality such an event did take place regarding tax area simulations by Treasury and the University of Canberra. The simulations supported political level negotiations prior to the introduction of Australia's Goods and Services Tax in 2000 [125]. With improved models, *such support could in future become more common in health, as well as in other sectors that are mainly government funded.*

Regarding the sustainability of health systems, the international literature argues that radical gains in efficiency and innovative practice would be required [126]. To meet this challenge the human resource function needs to be placed at the

forefront, given the importance of staff costs in health care expenditures. Another author [127] notes that the 'output' of the health industry is produced by disaggregated doctors, nurses, hospitals, pharmaceuticals and medical devices, and that somehow all this combines to adequately treat patients. However, there are few incentives in current health structures to ensure that these components are integrated into a coherent system in which provider incentives are aligned with the needs of patients for quality and affordable care. It has been argued that a form of market competition could in future provide such incentives, with competition taking place among systems of care that seek to serve value-conscious patients.

The importance of the above for economic analysts and modelers is that it would be well worth extending future study topics to a system level, and that more effort could be made to find and assess as yet untried incentives to achieve greater 'value for money'.

Similar system level structural changes were the main aims of the Australian reforms described in Chapter 3, although at this stage it is too early to assess their success or otherwise.

Health system under-performance in Australia is a worrying conclusion of recent studies. If in future such under-performance were better covered in economic studies, then it would be possible to rank the proposed scenarios and thus identify the 'best value for money' options.

One of the reasons for choosing in Chapter 8 the Vascular Risk Assessment and Management scenario was the emergence of the 2009 finding that many Australians at high risk were missing out on risk assessment, and that high-risk cardiovascular patients were under-treated in general practice [84, 85]. Under-performance may have arisen from service providers' focus on individual risk factors, rather than on overall vascular risk [84].

With early diagnosis CVD events could be prevented or delayed, so searching for solutions to health system under-performance is clearly worthwhile. Our vascular checks scenario (Chapter 8) focused on overall vascular risk, as it simultaneously took account of several risk factors. It involved doctors and nurses in managing

the combined risks, or in treating the related diseases. It was found to be a cost effective intervention. So implementation of the Vascular Risk Assessment and Management scenario could be a 'value for money' way of ensuring that many more high risk Australian patients would be appropriately treated in future.

There are many other health system and/or process problems. Indeed, a 2012 study suggests that under-performance extends well beyond the treatment of high-risk cardiovascular patients [128]. This research assessed the appropriateness of health care delivery in Australia and found that only 57% of the adults in the study-sample received appropriate care. The authors concluded that there was a *need for national agreement on clinical standards and for better structuring of medical records* to facilitate the delivery of more appropriate care.

Such an extensive under-performance of health care delivery in Australia seems surprising, given this country's top ranking in health among OECD countries (Chapter 2). One likely explanation may be that many of the risk factors for chronic diseases or ill health arise from individuals' lifestyle choices [86]. So the related prevention and treatment options are not only of medical concern, but also of social, family-level, personal and government policy interest [87, 88, 89].

This indicates that, while searching for possible solutions, it is very important to consider all key players - individuals, the medical profession, health administrators and governments.

Healthcare in hospitals is often mentioned in the literature and media as needing improvement. In Australia hospitals are often very large organisational systems. They are generally under great pressure to deliver quality services that are safe as well as cost-efficient. It has been suggested that a new approach, often called Lean Thinking, could provide hospitals with a structured approach to solve emerging problems [129]. Use of Lean Thinking would free up providers from focussing on system or process problems, and thus be able to re-focus on their patients.

Lean Thinking involves breaking down a process into parts, and then discussing with the relevant medical staff:

- which process parts are *not* providing value (*i.e.,* what is the 'problem');
- what solutions could lead to improvements;
- what monitoring would have a chance to ensure success in implementation; and
- what timelines, costs and benefits would be involved in resolving the 'problem'.

For anyone who recently visited a busy major city hospital in Australia, it is no surprise that hospital staff have neither the training nor the time to undertake LeanThinking practices. Indeed, hospital staffs often consider themselves lucky if they have sufficient time and energy to fully focus on their patients. And yet, Lean Thinking has the potential to improve service, reduce human errors and save scarce resources.

Although such system and process related tasks do not as yet seem to have been considered on a national scale, one possibility would be to set up a centre with teams of hospital staff, analysts, modellers and others (*e.g.,* group moderators). These could be called Lean Thinking teams. The models used would not be as complex as *HealthAgeingMod*, but the main threads of the analyses would be similar to the applications described in Chapters 7 and 8. If hospital staff wanted a 'value to patients' estimate from resolution of their process problem then use of microdata and/or microsimulation could be particularly useful. This is because individual-based data allows far more targeted 'patient value' estimates than do group data.

Such Lean Thinking teams could be made available to hospitals on demand, once a 'problem' needing help surfaced. Because the problems identified are likely to have similarities between them, the team(s) may gain expertise across hospitals and may be able to adapt earlier analyses to new requests.

Tobacco regulations are health areas in which Australia has achieved considerable success. The WHO declared tobacco use to be the leading cause of preventable

death worldwide, killing more than five million people each year [130]. In Australia a series of reforms have led to reductions in tobacco use, which by now is well below the world average in this country. Following a series of 'no smoking' regulations (*e.g.,* on public transport and in workplaces), by 2010 Australia's tobacco smoking prevalence rate for adults had declined to 16.7%, compared with 27% in the USA, 24.1% in China and 28.1% globally (WHO statistics). Further declines are expected following Australia's world first plain packaging legislation which became operational in December 2012 (Chapter 3) [131]. In August 2012 an Australian High Court challenge by the tobacco industry was ruled against. Tobacco companies are now continuing litigation in international trade courts. Many other countries - including Ireland and New Zealand - are currently considering similar legislation [132].

In view of the success of these policies, an economic assessment of the costs and benefits of the plain packaging reform would be of considerable interest in both Australia and globally, once sufficient statistics on tobacco consumption had been collected following the introduction of plain packaging on 1 December 2012.

Standards, Guidelines and Compliance

Recognising the importance of national standards, the National Health Reform Agreement [20**]** included new transparency measures in both hospital financing and health system reporting. The stated aim was to inform Australians about how health resources are used, and what results had been achieved re performance, including elective surgery waiting times and safety and quality issues such as hospital infection rates (Chapter 3).

Given the requirements of complex health systems, it is generally recognised that minimum standards and guidelines are needed if medical staff are to deliver quality services [1]. For example, guidelines are needed to help doctors to recognise particular diseases or to assess the risk for contracting these.

An example of using a risk assessment guideline has been described in sections 4.3 and 8.5. In these we made use of an NHMRC guideline that specifies how to quantitatively assess CVD risk using the US-based Framingham equations [41]. We found that for Australia these equations produced CVD incidence and

prevalence estimates that were well above the benchmarks published by the ABS. A likely reason for such high estimates was that the Framingham equations had been derived from US data covering the 1968 to 1975 period, and that advances in medical technology and practices had much improved since the 1970s. Because during our study the Australian 2000-2005 AusDiab data source became available [43], we chose for *HealthAgeingMod* the much more up-to-date Australian source.

However, when designing the Vascular Checks intervention (Chapter 8), the need to replace the AusDiab based equations in *HealthAgeingMod* with the Framingham equations emerged. This was because the Checks were to be carried out by Australian medical staff who were expected to follow the NHMRC guidelines that required use of the Framingham equations [41]. As we have not been able to find data on compliance rates, we assumed that Australian medical staff would fully comply with the NHMRC guidelines.

The above difficulties highlight the importance of having Australian guidelines as up-to-date as possible, and of having publicly available statistics on the extent to which practitioners comply with them.

10.2. MODELING IMPROVEMENTS IN THE LONGER TERM

Given that some health threats – such as obesity or antibiotic resistance – are a longer term phenomenon, improvements in researchers' way of estimating 'best value for money' solutions for these will also need longer term time horizons. This section focuses on possible long term modeling improvements.

Obesity and Diabetes

Regarding the 'obesity epidemic', knowledge to date suggests that a major turnaround cannot be achieved by government alone (section 9.4) [111, 113]. While the problem starts with the individual who practices unhealthy lifestyles, these patterns are often learnt within the family, and/or adopted within schools and work places. So combined efforts and commitment of all those involved may be needed.

As obesity has been shown to be a major risk factor for type 2 diabetes [112], it is not surprising that the number of Australians with type 2 diabetes is also

increasing. Between 2000–01 and 2008–09 spending on diabetes rose by 86% and, by 2011–12, close to a million Australians had diabetes - about 4.6% of the population. In 2008–09 spending on diabetes was around AUD 1.5 billion, or 2.3% of all allocated healthcare expenditure in Australia [112].

While Australian governments introduced several programs to control childhood and adult obesity rate rises, the above statistics suggest that their stated aims had not been met. One estimate of future patterns is that the financial burden of treating type 2 diabetes could quadruple by 2051, if obesity prevalence rates continue to rise [133].

Obesity is also a risk factor for many chronic diseases other than diabetes, such as CVD, arthritis, cancer and depression (section 9.4). *So in studies of obesity related interventions it is important to account for the costs and benefits of all major chronic diseases for which obesity is a risk factor*. While *HealthAgeingMod* has moved some way toward that goal, considerably more will be needed in future.

Antimicrobial Resistance

Already in 2001 the World Health Organisation had alerted nations to the emergence of antimicrobial resistance (section 9.4) [114]. In 2013 the WHO reported that the situation had worsened and that nations may soon have had to face a future without effective antibiotics [115]. Similar concerns were voiced in several WHO member countries, emphasising that a solution could only be found as a result of global effort.

In Australia, the issue was addressed in the 2012 National Health Reform Agreement [20**].** Its new transparency measures included reporting on issues such as hospital infection rates. However, these government agreements are limited to Australia, while the WHO called for a global effort.

A recent Australian report re-stated that nothing short of a global revival in antibiotics R&D was required, and expressed great concern about recent developments regarding super bugs in hospitals (section 9.4) [116] It raised the question of how could possible innovations by Australians be linked to a ‘global revival’, should such a revival eventuate.

To date grants for innovations of this kind have been provided by the National Health and Medical Research Council and, in recent media discussions, some wondered if the current structure of such grants were adequate, given the goal of avoiding a future without effective antibiotics. Also, the possibility of the federal government pooling Australia's research resources was raised.

Given the above, the question arises as to whether economic modeling studies could contribute to possible solutions to the pandemic style threat of antimicrobial resistance. Because *antimicrobial resistance* is already impacting negatively on frail populations – and is expected to continue to do so in future – it *could now be added in economic studies to the list of the conditions considered to be a complication of major and/or multiple chronic diseases*.

Until relevant innovative solutions emerge, models such as *HealthAgeingMod* could account for antimicrobial resistance within sensitivity tests, for example by increasing the time, cost and death rate associated with hospital stays. *The additional cost of the sensitivity scenario* (relative to the baseline simulation) *would provide an indication of the break-even funds that could be spent on developing 'new antibiotics'*. In such simulations the 'new antibiotics' would be those that were able to maintain the model's baseline level of antibiotic protection in hospitals.

When does 'Best Value for Money' Lead to Project Implementation?

Analysts and stake holders often wonder why so far there have been no funds allocated to many proposals that were consistently proven to be 'value for money'. A recent example is Australia's Chief Scientist asking why action had not been taken on many programs recommended in the past, despite discussions on these that began years ago were still continuing [134]. Some also wonder how, given budgetary health expenditure caps, projects are actually selected for funding from among the many proven to be 'value for money'.

Two key questions are: which economic studies are more likely to influence policy decisions, and which factors have influenced funding distributions in the past.

There seem to be no published nationwide statistics that may answer these questions. However, a few specific examples can be mentioned. In 2000, a case of direct policy influence concerned model simulations that supported the political negotiations prior to introduction of Australia's Goods and Services Tax (Chapter 10.1) [125]. Another example is the Victorian government's 2008 social policy action plan [135]. The related report refered to model simulations of a hypothetical Scenario in which the health of all Australians were assumed to be the same as that of the most affluent 20% of the population. The Victorian report noted that, as a result, health care costs were estimated to be AUD 3 billion lower (with one million less Australians being disabled, and a gain of around 180,000 life years) [122]. The report then stated that, for 2008, the Victorian government had allocated AUD 1 billion to health, including AUD 409 million to the new priority area of "Reducing health inequalities and promoting wellbeing" [135]. This is an *example where estimates of the net benefits of a hypothetical scenario had been interpreted by decision makers as an upper limit of the funds that would be worth allocating to a similar real life project*.

While such documented examples are encouraging, they are rare. Complexity of Australia's health system is a key reason why assessing the influence of 'value for money' findings on policy decisions is difficult. Because about 80% of Australia's health system is funded by federal and State governments (Chapter 1), the key funding decision maker is government. However, while the federal government shoulders a higher proportion of the total health budget, funds to be allocated tend to be determined in cooperation by both levels of government.

In addition, at government level resource allocation between health and other areas - such as education and public transport – often needs to be determined under tight budget constraints. As a result, many proven 'value for money' investments in all areas – and not just health - may end up not being funded at all, or may only be funded several years later. Also, for some investments governments may decide that the private sector would be the more efficient funder and implementer.

While governments consider 'value for money' a major criterion to be used when determining spending on health, many other criteria may be equally important.

For example the federal government also considers the national – or 'whole of Australia' – context. Budget decisions are made by politicians (*e.g.* Minister(s), State Premier(s)) after having received advice from their public servants. The role of the latter is limited to collecting and coordinating information and research findings, negotiating with stake holders, and preparing Ministerial advice.

So what does all this mean for researchers or stake holders keen to maximise the chances of their project being selected for funding? First**,** given that advice is prepared by public servants, it is important that researchers ensure that public servants are aware of their research findings. Also, this may need persevering over a number of years.

Second, remembering that 'a week is a long time in politics', most research projects would need to be planned, started and completed well ahead of when the results may be welcome by decision makers. The positive side of this is that many of the burning questions occupying politicians on a given day – *e.g.,* obesity, diabetes, CVD or hospital waiting lists - are likely to have been issues that had resurfaced again and again in the past.

So picking the timing for promoting current or earlier research findings is very important.

Third, projects most likely to be chosen for funding are those for which there is general support across most stake holders. Having a Minister who happens to 'champion' the project can also be a great help. A recent Australian example is the enactment of legislation on the National Disability Insurance Scheme that commenced on 1 July 2013 - a generally supported reform that had lost out on funding in previous years. This time it was championed by the Prime Minister and a federal Minister and had been allocated federal funds of AUD 19 billion over seven years. When fully operational, the reform expects to cover nearly half a million disabled Australians aged 65 years or less.

Internet, Social Media and the Health System

The advent of the internet and the rapid progress toward worldwide access to it is, in many fields, an as yet unexplored innovative opportunity. This is particularly so in

health, because through the internet individuals have access to free knowledge and advice from all parts of the world that previously they could only obtain from health professionals practicing in their locality. Information on the internet is available for prevention – *e.g.* on diet and exercise to maintain a healthy body weight – as well as on treatment options – *e.g.,* whether there are alternatives to an operation for angina. While there may be a need to check the credibility of the websites offered, the internet has the advantage of offering several sources of information from around the world that may complement people's efforts to obtain 2nd or 3rd medical opinions in their locality. The internet also offers a great deal more information than what a busy doctor is able to provide in one visit. Inevitably, the traditional doctor/patient relationship has already started to change. However, it may take many years before the transition to a new 'steady state' is complete.

Persons other than potential patients also benefit from the internet. For example, public servants working in the health sectors may find that use of the internet makes it easier for them to meet the short time frames set for preparing Ministerial advice.

In Australia, there are a few health related examples of internet usage. Two of these were mentioned in Chapter 3: *Telehealth* which gives Australians living in rural and remote locations TV-based subsidised consultations with GPs and specialists, and *eHealth* which aims to implement a centralised record system that makes the medical records of signed-on patients accessible to medical staff anywhere in Australia [136]. Such a centralised system is needed because currently the medical records of most Australians are only available within the practices they had visited. To date signing on to *eHealth* has been much slower than the government had expected, so whether the scheme will achieve its aims is not as yet clear. Many patients still seem unaware of the availability of *eHealth*, and some practices are concerned that the work required to rearrange patient data into a format acceptable to *eHealth* is not reimbursable by Medicare.

In the longer term, *eHealth* is expected to have major benefits. For example, it is expected to provide patients with the right treatment faster, safer and easier. Also,

subject to meeting confidentiality requirements, *it has the potential to provide a very useful new person level health data series for analysts and modelers*.

Another existing Australian electronic health project is *beyondblue* which, since 2000, has provided information and advice on the internet about depression and anxiety [137]. By 2009, around 87% of Australians were found to be aware of *beyondblue* and its work.

Because stigma is still attached to mental illness, *beyondblue* has proved to be an ideal vehicle for information provision and, eventually, for changing community attitudes. Depressed or anxious persons fearful of admitting their conditions even to health professionals were able to test their condition *via* the *beyondblue* depression checklist. They were also able to obtain information on programs and services available to them.

In future a great deal more internet based health-related applications may be discovered and implemented. In relation of model-based studies, in section 10.1 we described how electronic system usage could become a novel source for individual level health data.

Other possible *future internet applications could provide support for health investment decisions*. For example, an internet site could be established on which researchers could post their latest 'value for money' studies, giving details of the related publications, together with a brief and easily understood summary of the findings.

Also, *technically feasible, topic-specific web-based simulations could become very useful*, especially if non-modelers could alter a few key scenario parameters to assess the related change in the value and/or ranking of a proposed intervention.

Such web-based applications could help the general public to better understand the complexities of modern health systems and appreciate how evidence based quantitative analyses can lead to better health nationally, given limited resources.

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CHAPTER 11

Concluding Remarks

Agnes E.G. Walker

Australian Centre for Economic Research on Health, Australian National University, Australia

Abstract: This Chapter draws together the findings of PARTs I, II and III, in terms of the usefulness of the decision-making tools discussed in this book to the goal of maintaining Australia's current top health status internationally as its population ages.

This book started by noting that Australians' health has been among the best within the OECD, and that this had been achieved at expenditures as a proportion of GDP close to the OECD average (Chapters 1, 2). It also noted that chronic diseases were responsible for well over half of Australia's health costs; that there were considerable pressures on health expenditures; and that such pressures were likely to either continue or increase in future. The range of recent Australian health policy reforms initiated or implemented were also noted (Chapter 3).

An important question was whether Australia could in future maintain its top health status internationally, given existing and emerging health threats with likely impact on chronic disease prevention and care.

PART II described *HealthAgeingMod*, a chronic disease model system able to assess and rank various nationwide health reform options. A novel feature of the model is that it is able to consider a range of chronic diseases, as well as account for comorbidities, that is for the number of such diseases accumulated by an individual. Ability to account for comorbidities is important, because an individual's quality of life has been shown to decline rapidly as the number of chronic diseases she/he has increases (Chapters 4, 5, 6).

Examples of applications of *HealthAgeingMod* were provided for two illustrative scenarios re obesity and population ageing (Chapter 7), and one real-life policy

***Address correspondence to Agnes E. G. Walker:** Australian Centre for Economic Research on Health, Australian National University, Australia; Tel: +612 6125 0564; Fax: +61 2 6125 9123; E-mail: agnes.walker@anu.edu.au

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relevant scenario (Chapter 8). The latter concerned a Vascular Risk Assessment and Management Intervention for the prevention and/or treatment of obesity, smoking, diabetes, stroke and heart disease. This study found that the intervention was worthy of consideration for public funding in terms of the investment dollars needed to gain one additional quality adjusted life year (QALY). Because it indicates 'value for money', this 'dollar per QALY' indicator is very useful to decision makers. It is especially useful at times of tight government budgets, as it allows identification of the mix of reform options that are likely to provide the greatest health improvements given set health fund limits.

PART III asked if lessons could be learnt from the experiences of recently announced reforms within the context of emerging health issues impacting on chronic disease prevention and care (Chapter 9). A few possible modeling improvements were discussed that could ensure that emerging threats were also adequately assessed (sections 10.1, 10.2). The improvements mentioned included: wider range and more coherant data; improved methodologies; greater efficiency of the health system; and better use of the internet. Also addressed was the question important to researchers of when was a 'best value for money' project most likely to attract funding.

Overall, given existing and emerging threats it seems uncertain that this country can in future maintain its top health status internationally. However, if Australians wished to continue to have a sustainable, up-to-date, cost-effective and well functioning health system, then more frequent use of decision making tools – such as those described in this book – could well be an important step in that direction.

APPENDIX A

National Health Survey 2004-05

The Basic Confidential Unit Record Files (CURFs) of the Australian Bureau of Statistics' (ABS) *National Health Survey 2004-05* contain 25,906 respondent records (19, 501 adult and 6,405 child) [47]. The survey covered private dwellings from August 2004 to July 2005, only excluding the very remote areas of Australia. Non–private dwellings, such as hotels, motels, hospitals, nursing and convalescent homes and short–stay caravan parks were not covered. Within each selected household a random sub–sample of usual residents was selected for inclusion (one adult 18 years of age and over; and one child aged 0 to 17 years). Trained ABS interviewers conducted the personal interviews.

To allow for nationwide estimates to be obtained from the survey, the ABS CURF attached 'weights' to each survey person. This 'weight' variable indicated the number of persons in the population represented by each person-record in the sample dataset. Application of these weights ensures that the estimates conform to an independently estimated distribution of the population by age, sex, state/territory and section of state, rather than to the distributions within the sample itself [47].

The survey had a particular focus on the national health priority area conditions of: arthritis and osteoporosis; asthma; cancer; diabetes; heart and circulatory conditions; injury and mental health. The data on arthritis, asthma, cancer, conditions of the circulatory system, diabetes and osteoporosis had in most cases been medically diagnosed.

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APPENDIX B

Australian Diabetes, Obesity and Lifestyle Survey (AusDiab)

B.1. MAIN AusDiab STUDY

The AusDiab study fills in a data gap regarding the nature and extent of the many interactions that exist between chronic diseases, including their common risk factors. It is a longitudinal study of Australian adults aged 25 years or over [43].

In 1999-2000, a stratified clustered sample was drawn from 42 randomly selected census districts, six in each of the states and Northern Territory. This baseline AusDiab survey (wave 1) comprised 11,247 persons, with 6,500 of these attending the 2004-05 update (wave 2). Another 2000 of the original group (who could not attend) provided self-reported information.

Across the 2000 and 2005 waves, for diabetes only the data from the persons who actually had physical testing (*i.e.* blood taken) could be used, while for CVD data from the wave 1 group who provided self-reported information.

The 2000 baseline study provided benchmark national data on the number of people with diabetes, obesity, hypertension (increased blood pressure) and kidney disease. The 2005 follow-up study determined how many new cases of these diseases were occurring each year

B.2. CVD SUB-STUDY OF AusDiab

Out of the 10,788 AusDiab participants eligible for re-testing in 2004-05, the CVD sub-sample comprised those 8,802 (81.6%) participants who completed an interviewer-administered questionnaire about previous CVD. The AusDiab CVD data had both self-reported and medically verified components.

People responding to the 2004-05 CVD questionnaire were asked “have you ever been told by a doctor or nurse that you have had a heart attack (including ‘coronary’, ‘coronary occlusion’, ‘coronary thrombosis’ or ‘myocardial infarction’), a stroke, a heart bypass operation (including ‘coronary bypass’) or an

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angioplasty or stent for your heart (including 'coronary angioplasty', 'coronary stent' or 'balloon')?".

Participants who answered 'yes' to any of these questions were asked to provide the date and hospital admission details for each event. For these, medical information on the related hospital CVD events was sought by the AusDiab group, as well as an informed consent to participate in the study and to have their medical records reviewed.

Based on the above questionnaire, two independent physicians ascertained whether the self-reported events could be 'adjudicated', *i.e.* whether they complied with the modified World Health Organization/MONICA criteria for myocardial infarction (MI) or with the WHO criteria for stroke and for Coronary artery bypass graft surgery (CABG) and Percutaneous transluminal coronary artery angioplasty (PTCA) operation records.

Of the 8,802 participants who completed the questionnaire, 653 reported either MI, stroke, CABG or PTCA, with 323 of these having occurred prior to the baseline. 330 records remained with information on CVD events between 1999-00 and 2004-05. Among these only 191 events could be adjudicated (due to the event having taken place in an overseas hospital or incomplete consent form).

B.3. MORTALITY DATA IN AusDiab

Mortality data was obtained by linking all 11,247 participants from the AusDiab cohort to the National Death Index (NDI), which is maintained by the Australian Institute of Health and Welfare. The fields used to link the cohort included: name, sex, date of birth, state, date of last contact and date of death. People who were not matched to the NDI were assumed to be alive. Information was also obtained on 'Cause specific mortality'.

GLOSSARY

DEFINITIONS AND ABBREVIATIONS

ABS: Australian Bureau of Statistics.

AIHW: Australian Institute of Health and Welfare.

ANDIAB: Australian National Diabetes Information Audit and Benchmarking.

AUD: Australian dollars.

AusDiab: Australian Diabetes, Obesity and Lifestyle Study.

Baseline simulation: The model's estimate of what can be expected in future if Australia's health system remains unchanged.

BMI: Body mass index, computed as Weight(kg)/Height(m)$^{2.}$

CABG: Coronary Artery Bypass Graft (creates new routes around blocked arteries).

CHD: Coronary Heart Disease (Inc. angina), also known as IHD (Ischaemic Heart Disease).

Chronic diseases: Serious illnesses that had lasted or are expected to last for 6 months or more. Key examples are the seven diseases classified under the Australian government's National Health Priority Areas (NHPAs) – see further down this Box.

Commonwealth government: Australia's national government. At different times it is also referred to as federal government, and more recently Australian government.

Complications: Are diseases that are linked causally to the principal disease diagnosed.

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Comorbidities: Occur when a person has two or more chronic diseases which are not related causally to the principal disease diagnosed, but increase a patient's total burden of illness.

CURF: Confidentialised Unit Record Files available from various Australian Bureau of Statistics surveys.

CVD: Cardiovascular disease - IHD (incl. angina; oedema; heart failure) and stroke in model-system's Base Year.

DALYs: Are Disability Adjusted Life Years [36]. The DALY estimates the years of life lost due to premature death coupled with years of 'healthy' life lost due to disability.

DiagnosedDiab: Self-reported diabetes in AusDiab survey to the same 'have you ever been told by doctor or nurse that you have diabetes' question as in National Health Surveys.

Health: A state of complete physical, mental and social wellbeing - and not merely the absence of disease or infirmity.

Health status: Patients' subjective experience of their overall health [36].

HbA1c: Form of haemoglobin used to identify plasma glucose concentration.

HDL: High Density Lipoproteins, which carry cholesterol from body tissues to the liver. High HDL/Total cholesterol (5.5 mmol/l or more) has been shown to lower CVD risk.

IFG: Impaired Fasting Glycaemia, usually a first indicator of pre-diabetes.

IGT: Impaired Glucose Tolerance, a more advanced indicator of pre-diabetes than IFG.

IHD: Ischaemic Heart Disease (incl. angina) in the Base Year, also known as CHD (coronary heart disease).

K10: Is the Kessler Psychological Distress Score, usually grouped into 'low', 'moderate', 'high' and 'very high' psychological distress. It is a short dimensional measure of non-specific psychological distress in the anxiety-depression spectrum.

KnownDiab: Self-reported and measured diabetes in AusDiab survey.

Long term conditions: Self reported conditions which NHS05 respondents had and which had lasted, or are expected to last, for six months or more.

NDSS: National Diabetes Services Scheme.

NHPA *(National Health Priority Areas)**:*** Arthritis and musculoskeletal health; Asthma; Cancer; Cardiovascular health; Diabetes mellitus; Injury prevention/control; Mental health Mental health, Obesity and Dementia [25].

NHMRC *(National Health and Medical Research Council):* Australia's peak body for supporting health and medical research. Provides competitive research grants and publishes medical guidelines.

NHS05: The 2005 National Health Survey (by the Australian Bureau of Statistics).

MI: Myocardial Infarction (heart attack).

PBS: Australia's Pharmaceutical Benefits Scheme.

PTCA: Percutaneous transluminal coronary artery angioplasty (with or without stent).

Quality of Life: An individual's overall satisfaction with life and a general sense of personal wellbeing.

Scenario Simulation: The model's estimate of what can be expected in future if Australia's health system is undergoes reform after implementation of a Scenario.

UKPDS: United Kingdom Prospective Diabetes Study.

UndiagnosedDiab: Self reported in AusDiab survey; persons who had NOT been told by doctor or nurse that they had diabetes, BUT had blood glucose values in the diabetic range.

WHO: World Health Organisation.

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