

Economic Model System of Chronic Diseases in Australia: the Prototype

Agnes Walker and James Butler, Australian Centre for Economic Research on Health, Australian National University; and
Stephen Colagiuri, Institute of Obesity, Nutrition and Exercise, University of Sydney.*

* **Mailing address:** Australian Centre for Economic Research on Health, Australian National University CANBERRA ACT 0200, Australia

Email: Agnes.Walker@anu.edu.au

Tel: +61 2 6125 0564

Fax: +61 2 6125 9123

ABSTRACT

Chronic diseases - eg heart disease, cancer, diabetes - affect around 80% of older Australians, are the main causes of disability and premature death, and account for 70% of Australia's health expenditures. Individuals tend to acquire multiple chronic diseases (comorbidities) as they age. Older Australians with three or more such illnesses assess their quality of life as being much worse than people with two or less such illnesses. Also, research shows that treatment costs for persons with multiple conditions are well above what addition of the costs for persons with one major chronic disease only would suggest. Most existing chronic disease models cannot account for these important person-level effects due to their use of more readily available grouped data. By contrast our prototype model-system, developed under an Australian Research Council grant, is able to account for such effects. It combines microsimulation and person-level disease progression modeling techniques and accounts for individuals' demographic, socioeconomic and health-risk-factors, their comorbidities, quality of life and health-related expenditures. It projects 20 years ahead and estimates the costs versus benefits of policy interventions covering multiple chronic diseases.

We will describe the prototype model-system and its validation; the difficulties arising from poor match between disease specific data and nationally representative benchmarks; and present the findings of an illustrative policy relevant application.

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1 Background and Aims

1.1 Background

There is considerable agreement in the Australian literature that the prevalence of major chronic illnesses – such as the National Health Priority Area (NHPA) diseases of asthma, cancer, cardiovascular health, diabetes, injury prevention, mental health, arthritis and musculoskeletal conditions – is increasing. There is also agreement that population ageing and the ‘obesity epidemic’ are among the main forces driving these prevalence increases (Treasury 2007).

The rapid growth and by now epidemic proportions of these chronic diseases are major challenges for health policy, since they lower quality of life, restrict patients’ ability to remain in the workforce or live independently. They also account for a considerable proportion of public and private health expenditures – World Health Organisation (WHO) 2005a; Begg *et al* (2007); Lopez *et al* (2006). With further increases in life expectancies and more rapid population ageing driven by the retirement of ‘baby boomers’, the already strong pressures on health expenditures in Australia are predicted to be even stronger in future (Treasury 2007).

1.2 Aims

While most existing chronic disease models, based on readily available grouped data, cannot account for the important person-level health effects of the rising prevalence of chronic diseases, the more complex prototype model-system described in this paper, *HealthAgeingMod*, is able to do so.

The model-system, built under an Australian Research Council (ARC) grant, combines microsimulation and person-level disease progression modeling techniques and accounts for individuals’ demographic, socioeconomic and health-risk-factors, their comorbidities, quality of life and health-related expenditures. It projects 20 years ahead and is able to estimate the costs versus benefits of policy interventions covering multiple chronic diseases.

The main *aim of the ARC grant* is to build a state-of-the-art decision making tool that is better able to analyse and rank policy relevant interventions covering multiple chronic diseases than what was possible previously. An additional key aim is that *HealthAgeingMod* be capable of estimating nationally representative outcomes.

The *aims of this paper* are to:

- provide an overview of the prototype model-system;
- describe the difficulties encountered during the model-building phase – for example scant data in some crucial areas and poor match between disease specific data and nationally representative benchmarks; and
- present the findings of an illustrative policy relevant application which highlights important features of *HealthAgeingMod* that cannot adequately be included into traditional group-models.

At the current prototype stage, the model-system only projects five years ahead and only accounts for two major chronic diseases: cardiovascular disease and type 2 diabetes. However, the current structure of the Prototype allows *external* addition of other chronic diseases (eg cancer, arthritis, depression). It also allows for future

internal modifications so that additional chronic diseases can be accounted for within *HealthAgeingMod*.

2 Building the Prototype model-system

At the time of applying for the ARC grant we were aware of the considerable gaps that existed in the Australian data needed for a complex and novel model, such as *HealthAgeingMod*. We knew that some of these gaps would eventually be filled in from forthcoming data collections. Thus, up-dating the model-system's baseline data, once such new collections became publicly available, was part of the initial grant proposal.

However, much of the existing and expected future Australian data was cross-sectional, with many important gaps in disease specific longitudinal data not expected to be filled within the ARC grant's time frame. Our grant proposal in 2004 overcame this difficulty by proposing use of UK and US longitudinal disease specific databases. In view of similarities in chronic disease patterns across developed countries, this seemed a reasonable proposal at the time. However, new Australian longitudinal data released last year proved this quite incorrect.

This section first summarises the initial proposal. Next, it documents the data difficulties that led half way through the ARC project to abandonment of a major part of the initial proposal. Finally, it describes how these difficulties had been overcome in the current Prototype.

2.1 The initial planned approach

The initial approach is documented in Walker, Butler and Colagiuri (2009a, 2008a,b) and in Walker and Colagiuri (2009). Its focus is on designing a model-system that is able to simultaneously consider *several* person-level chronic diseases – ie comorbidities. This is important because, although quality of life had been shown to decline and health expenditures to increase with comorbidities (Shwartz *et al* 1996), such studies are rare in the literature (Walker 2007a). They are rare, despite the well documented fact that many chronic diseases share common lifestyle risk factors and common underlying health conditions.

The initial approach also included consideration of lifestyle patterns – eg unhealthy diets, lack of physical activity, excess alcohol and tobacco consumption. This was because these were major common risk factors for chronic diseases (Yach *et al* 2004). Thus chronic disease prevention and treatment could not be seen as only of concern to the medical profession. There was also a need to account for social, family-level and personal health behaviours and patterns (Seymour 2007; Griffiths *et al* 2007; Eckersley 2004).

The broad structure initially envisaged for *HealthAgeingMod* - and embedded in the Prototype – required the:

- (a) collection of a set of nationally representative person-level demographic, socioeconomic, lifestyle and health variables for the model-system's base-year dataset; and
- (b) projection into the future of both disease-specific incidences and prevalences, and of the progression of individual-level chronic diseases and comorbidities.

Part (a) involved the bringing together in a coherent manner of individual-level cross-sectional data from several sources. Part (b) required use of disease-specific longitudinal data to estimate the incidence and progression of chronic diseases over time.

We chose to model (a) and (b) separately, and then link the two parts, so that the ‘big picture’ as well as the ‘detail’ associated with the tracking of individuals’ health could be studied simultaneously. This two-part approach was essential, because no single data source, or single modeling technique, could cover the broad-ranging factors and complex disease-level interactions required by *HealthAgeingMod*.

Figure 1 shows that the initially proposed model-system considers a nationally representative sample of individuals in a microsimulation Umbrella model, and covers two chronic conditions, cardiovascular disease (CVD) and type 2 diabetes. The latter are analysed in disease-specific sub-models which are linked to the Umbrella model. It also shows that the planned model-system allowed for future extensions to other chronic diseases, such as cancer, mental health and arthritis.

There were three key reasons for initially choosing CVD and diabetes. First, they are major contributors to Australia’s total burden of disease (Begg *et al* 2007). Second CVD, and high mortality from CVD, tend to be common complications of diabetes. Finally, CVD and diabetes share common risk factors such as physical inactivity, obesity and high blood pressure.

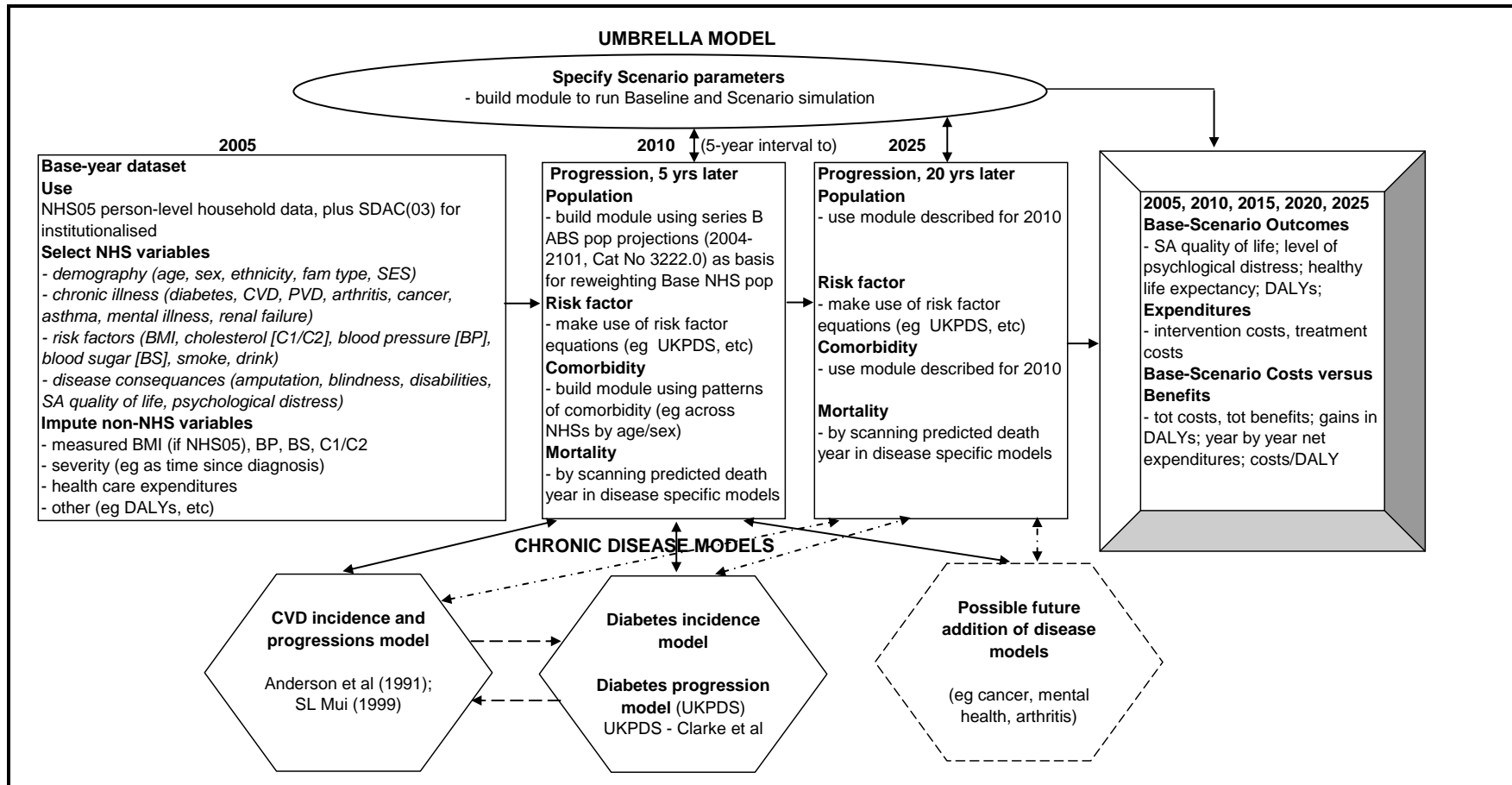
Figure 1 also shows that, for the CVD sub-model, we initially envisaged using the US-based Anderson *et al* (1991) cardiovascular risk equations, as at the time these were still considered to be the most appropriate equations for predicting CVD incidence in developed countries (Walker *et al* 2008a). The Anderson parametric statistical equations - based on Framingham Heart and Framingham Offspring data - separately predicted probabilities for: myocardial infarction (MI); coronary heart disease (CHD) - MI, angina; CHD death; stroke; stroke; congestive heart failure; peripheral vascular disease; and CVD death. The Framingham data covered the 1968 to 1975 period.

Figure 1 also indicates that while we were not able to specify a data source for diabetes incidence, *for people already diagnosed with diabetes* we planned to use the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes Model (Clarke *et al* 2004). This UK model projects the following complications of diabetes: myocardial infarction (MI), other ischaemic heart disease (IHD), stroke, heart failure (HF), amputation, renal failure, eye disease. It also estimates associated treatment costs and death. Using Australian dollar cost estimates in Clarke *et al* (2008) on diabetes, and on CVD as a complication of diabetes, we were able to change the Pound Sterling unit costs in the UKPDS Outcomes model with unit costs in Australian dollars. Walker *et al* (2008b) showed that there were considerable differences in these unit costs between Australia and the UK.

Other details of the planned model-system, including flowcharts for the CVD and diabetes sub-modules, are in Walker *et al* (2008a).

A major benefit of the model-system structure chosen for *HealthAgeingMod* is that the model is suitable for assessing policy proposals involving broad population-wide variables (eg worse or improved obesity patterns; choice of screening options; lesser health inequalities), as well as medical treatment choices (eg surgery replaced by new, improved - but costly - pharmaceuticals).

Figure 1: Chronic disease model-system



2.2 Considerable data difficulties

By the time the building of the planned model-system progressed to initial validation exercises, new data on diabetes became available from wave 1 of the Australian Diabetes, Obesity, and Lifestyle Study (AusDiab) longitudinal study (1999-00). Use of this new data allowed us to check the patterns in *HealthAgeingMod*'s basedata – which was based on the 25,906 individuals in the CURF (confidentialised unit record files) of the nationally representative 2005 National Health Survey (NHS05) - ABS (2006a,b,c,d).¹ For those with type 2 diabetes in that basedata set, UKPDS model simulations predicted complications of diabetes over time and their related treatment costs. We then compared our initial model-system simulations with external benchmarks for the:

- (a) 15 years or older baseline population in 2005; and
- (b) projections of diabetes complications and deaths by the UKPDS model for the Umbrella model's base population.

For (a), the model-system's baseline characteristics, Table 1 shows a remarkably close match with aggregate benchmark data published by the Australian Bureau of Statistics (ABS) and the Australian Institute of Health and Welfare (AIHW). For diabetes and CVD, baseline statistics were obtained from the NHS05 CURF. Treatment cost estimates for diabetes were produced by the UKPDS model (with unit costs in Australian dollars), which was at that stage linked to the Umbrella model.

Table 1: Preliminary validation of prototype, Australians aged 15 years or more

	Prototype	Benchmark	Source of benchmark
Baseline characteristics, 2005 (15+ year olds)			
15+ population	15,761,000	16,287,000	ABS 2005
Diagnosed type 2 diabetes, with or without CVD (No)	579,249	581,000#	AIHW 2008a
- treatment costs (million, A\$ in 2000)	1,595	1,664#	AIHW 2005
CVD, without diabetes (No)	627,000	-	
- treatment costs (million, A\$ in 2000)	4,514	4,547#	AIHW 2005

total population

The A\$1,664 million AIHW benchmark in Table 1 for diabetes costs is close to the model-system's estimate of A\$1595 million (both in 2000 dollars). Such a close match is remarkable, given that the model-system's population is survey based; that several variables needed to undergo transformations or imputations to line up the Umbrella model with the UKPDS model; and that complex changes to the UKPDS input cost data were needed to obtain estimates in Australian dollars. However, the *model-system result of A\$1595 million is likely to be an underestimate*, partly because it also includes the cost of the non-CVD complications of diabetes accounted for in the UKPDS model, and partly because NHS05 is a household survey and thus excludes very sick persons in hospitals and in nursing homes.

For the 627,000 Australians without diabetes who had CVD (83% of all people with CVD), we did not have cost data by CVD components. However, if we used \$7,200 per person per annum as the average cost (which falls between published estimates ranging from \$4000 to around \$10,000), then our model-system cost estimate of \$4514 million came close to the AIHW (2005) estimate of $0.83 * 5,479 = A\$4547$ million.

¹ Having up-dated in 2006 the Umbrella model's data from the 2001 NHS CURF to the 2004-05 CURF.

Re (b), while the baseline results were very promising, the opposite proved to be true for the projections of diabetes complications and deaths by the UKPDS model for the Umbrella model's base population. Indeed, the UKPDS model predicted deaths, over 5 years, for 47% of the model-system's base-year population with type 2 diabetes. This implied a very much higher death rate than the ABS-published rate with diabetes as main cause of death. Clearly, if we continued to use the UKPDS model, then we would have very quickly lost most of the records in the model-system's base population. Subsequent application of the Anderson (1991) equations to the model-system's baseline data to predict the risk of various CVD events also produced predictions well above the, in that case scarce, Australian benchmarks.

So an approach other than use of the UKPDS Outcomes model and the Anderson CVD equations needed to be developed.

A few months after the discovery of the inadequacy of the UK and UK data sources for our purposes, wave two data from the AusDiab study became available (2004-05). A little later we were granted use, within our ARC project, of unit record data on CVD events among AusDiab study participants.

As detailed in section 2.3 below, our tests indicated much lower diabetes and CVD incidences in Australian benchmarks (including the AusDiab dataset) than in the UK and US model/equations (based on those countries' longitudinal datasets).

Discussions with colleagues regarding possible reasons for this suggest that the much earlier time period in which the overseas data had been collected, and the considerable treatment improvements that occurred since then, may be the main reasons for these differences.

Overall, use of the AusDiab data for further development of *HealthAgeingMod* seemed an attractive alternative. This was in part because AusDiab survey participants were Australian - and thus better matched the model-system's NHS05-based population characteristics - and also because the AusDiab data are considerably more recent - and thus they better accounts for current health behaviours and medical treatment practices.

2.3 The current Prototype

This section presents a brief overview of the current Prototype, which is documented in Walker et al (2009b).

Use of AusDiab data instead of UK and US data

To correct the difficulties encountered with the UK and US data for modelling diabetes and CVD incidence, we chose the unit record AusDiab longitudinal data (International Diabetes Institute 2006) as an alternative data source. The 1999-00 wave of AusDiab comprised a nationally representative sample of 11,247 Australians aged 25 years more. 6,500 of these also attended the 2004-05 follow-up. Data on these participants were obtained by a self-reported interviewer-administered questionnaire, as well as - among other things - through height-weight measurements and a blood test. Another 2000 of the original group who could not attend in 2004-05 completed the self reported questionnaire. The first wave provided nationally representative data on the number of people with diabetes, pre-diabetes and the complications of diabetes (incl. CVD), as well as on measured values for risk factors (such as Body mass Index (BMI), blood pressure, cholesterol). Wave 2 provided data on how many new cases of diabetes and CVD occurred, and how risk factors changed over the 5-year period. Due to the relatively low Wave 2 response rate, the AusDiab incidence data could no longer be considered nationally representative. For that reason, use of all AusDiab incidence data in *HealthAgeingMod* is unweighted.

AusDiab variable definitions and incidence data

For model building purposes it was important to:

- (a) find AusDiab variables with definitions that matched as closely as possible the definitions of similar variables in *HealthAgeingMod*'s NHS05- based population, and of the definitions of the most accurate treatment cost data available; and
- (b) identify the elements of the recently released AusDiab incidence data - which has a much broader range of variables than the available external benchmarks - that best match the benchmarks.

Possible new incidence information from AusDiab included: new diabetes and CVD cases, and CVD deaths, over the 2000 to 2005 period. Re CVD deaths, the very small number of survey participants who died under a new CVD event meant that we could not use AusDiab data when building the CVD deaths module. So AusDiab was only considered further for estimating new diabetes and new CVD.

Re diabetes, we found one self-reported survey question common to both NHS05 and AusDiab. It asked: "Have you ever been told by a doctor or nurse that you have diabetes?" In AusDiab, 567 answered YES in 2000 (5.04% of the unweighted 25+ year old survey population) and 741 (8.41% of the unweighted 25+ year old survey population) in 2005. Using the last three National Health Survey CURFs, we found that the ABS's estimates of the prevalence of type 2 diabetes among 25+ year olds were 2.70% in 1995, 3.47% in 2001 and 4.41% in 2005. Thus the AusDiab estimates are much higher than the ABS estimates. AIHW (2008a) provides likely reasons for the high AusDiab estimates.

The above findings meant that we could not use responses to this common question in our model-system. So we needed to investigate the other AusDiab diabetes related variable, which was not only defined as self reported in the above survey question, but for which glucose levels were also required to fall in the diabetic range through the AusDiab blood test. Using this empirically checked variable of the AusDiab sample with diabetes, the unweighted prevalence estimates were reduced to 4.2% in 2000 (475 records) and 5.8% in 2005 (385 records). While still considerably higher than the corresponding ABS prevalence estimates, we chose the AusDiab diabetes variable defined in this tighter way for further development of our model-system and eventually rely on alignment processes for reducing the incidence estimates to meet benchmark totals.

Estimating incidence with diabetes status defined in this tighter way we found - among the 6519 participants with blood tests in *both* waves - 158 Ausdiab records of persons *without* type 2 diabetes in 2000, but *with it* in 2005. Under that definition, the incidence estimate is 2.4% over 5 years – or 0.48% per year. By comparison, using the non-constrained definition of diabetes status in AusDiab, Magliano et al (2008) estimated per year incidence of 0.8% for men and 0.7% for women for the population aged 25 years or over.

Overall, for our purposes AusDiab's tighter definition of diabetes status was preferable to the self-reported one. We chose this option to develop equations to estimate the probability of new diabetes, also taking into account of pre-diabetes. Choice of the tighter definition resulted in somewhat higher diabetes prevalence projections than what continuation of the ABS-published trends would suggest. To correct for this we plan to adjust the model-system outcomes later through alignment-to benchmarks processes, once the NHS08 (and other new data) become publicly available in the 2nd part of 2009.

Re CVD, the issues surrounding definition were more complex. The NHS-s have self-reported data on whether participants had been told by a doctor or a nurse that they have a range of cardiovascular conditions (including 'vascular conditions', such as high blood pressure). AusDiab also has similar questions, but only for heart attack (including 'coronary', 'coronary occlusion', 'coronary thrombosis' or 'myocardial infarction'); stroke; heart bypass operation (including 'coronary bypass'); or an angioplasty or stent for your heart (including 'coronary angioplasty', 'coronary stent' or 'balloon'. Our analyses showed similarities between the proportions with self-

reported angina, heart attack or stroke between the NHS05 and AusDiab estimates (around 5.8% for 25+year olds).

As for diabetes, AusDiab also carried out a medically verified check on CVD questionnaire information, in terms of hospital events of heart attack (angina, MI), stroke, Coronary artery bypass graft surgery (CABG) and Percutaneous transluminal coronary artery angioplasty (PTCA), with or without stent.

Those AusDiab participants who self-reported 'yes' to any of the above CVD events were asked to provide the date and hospital admission details of their event, and were asked if they consented to have their medical records reviewed. For those who consented, medical information on their reported hospital CVD events was sought by the AusDiab group. Next, based on such medical information, two independent physicians ascertained whether the self-reported events could be 'adjudicated', that is whether they complied with the modified World Health Organization/MONICA criteria for myocardial infarction (MI) or with the World Health Organization criteria for stroke, CABG and PTCA operation records.

For our model-system we chose the 'adjudicated' definition of CVD for non-fatal hospitalised heart attack (angina, MI), stroke, Coronary artery bypass graft surgery (CABG) and Percutaneous transluminal coronary artery angioplasty (PTCA). Part of the reason for this was consistency with our choices regarding modeling diabetes incidence. Another reason was that the hospital-based structure of AusDiab's 'adjudicated' CVD events was best matched by the Clarke et al (2008) CVD cost data (in Australian dollars). These cost data had been successfully matched to external aggregate cost benchmarks during our earlier experiments with the UKPDS Outcomes model (section 2.2).

Of the 8,802 AusDiab persons who completed the CVD questionnaire, 653 reported either MI, stroke, CABG or PTCA, with 323 of these having occurred prior to 2000. 330 records remained with information on non-fatal CVD events between 2000 and 2005. Among these only 191 could be 'adjudicated', indicating a non-fatal CVD hospital CVD event rate of $191/8,802=2.17\%$ over five years, or 0.43% per annum.

Among the scant external benchmark data for CVD incidence, AIHW (2004f) reported that in 2001-02 there were 48,700 coronary heart disease events in Australia among 40-90-year olds, with 26,300 of these having been non-fatal. AIHW (2004f) also noted that, based on local registers in Melbourne and Perth, incident stroke events nationally ranged between 40,000-48,000 each year. Thus, assuming a similar fatal/non-fatal split as for heart disease, 26,300 can also be seen as a rough estimate for incident non-fatal stroke per year.

With 40-90 year olds numbering 8.9 million in 2001-02, we estimate the published CVD (CHD+stroke) incidence to be $26,300*100/8,900,000=0.59\%$. ABS (2006e) reported that the number of Australians with heart, stroke and vascular conditions decreased from 4.5% of the total population in 2001 to 3.8% in 2004-05 (age adjusted). So the lower non-fatal CVD incidence estimate for 2004-05 from AusDiab (0.43% pa for heart and stroke events only) than from the 2001-02 benchmarks (0.59% pa) seems plausible.

Overall, for our purposes AusDiab's 'adjudicated' – ie medically verified – CVD hospital event (heart and stroke) definition was preferable to the self-reported one. We chose this variable for our equations estimating the probability of at least one CVD event over a 5-year period. This choice is expected to lead to somewhat lower CVD event estimates than what the external benchmarks implied. We plan to adjust the model-system outcomes later through alignment-to-benchmarks processes, once the NHS08 (and other new data) become publicly available in the 2nd part of 2009.

Building the CVD death module

The fact that CVD is a major cause of death presented difficulties for implementing *HealthAgeingMod*. This is mainly because the ABS population projections (ABS 2005), used as

targets when re-weighting the Umbrella model’s base in the projection years (Walker et al 2008b), have already accounted for deaths. In other words, the ABS population targets for future years (by age and sex) are for the alive persons only.

AIHW (2004f) reported around 500,000 CVD-related deaths in 2001-02 and in our model-system these deaths had to occur among Australians without a CVD event in the 5-year period under consideration. This is because predictions of at least one CD event - using equations based on AusDiab data - were for non-fatal events only. Also as seen above, we could not use AusDiab data to predict deaths due to very few people in that sample having died during a CVD event.

This left us with the Anderson (1991) equation as a suitable basis for predicting CVD deaths in *HealthAgeingMod* (Walker et al (2008b)). In the model-system we implemented the Anderson (1991) CHD death and stroke death equations, and aligned the mortality outcomes to future expectations based on mortality trends published by the ABS.

Then, we adjusted the weights of the remaining population so that the Umbrella model’s weighted population once again matched the ABS’s projected population within each 5-year age and sex group.

Diabetes and CVD unit costs

Table 2 summarises the per person, per annum costs (1999-2000 Australian dollars) used in the Prototype as ‘default’.

Based on data in Department of Health and Ageing (2000), the prototype also accounts for a 20% increase in treatment costs for persons with *both* CVD and diabetes, compared with the sum of the treatment cost for a person with diabetes alone and another with CVD alone (Walker et al (2008b)).

Table 2: **Diabetes and CVD unit costs in model-system**

	Cost per person A\$	per annum (1999-2000 dollars)
	<i>Non-fatal</i>	<i>Fatal</i>
Diabetes (no complications, cost per year)	1,289	
Coronary Vascular Disease_CVD (cost per hospital event)		
CHD (incl angina)	13,000	10,000
Stroke	13,000	10,000
Coronary Vascular Disease (per year, subsequent to hospital event)		
CHD (incl angina)	3,500	10,000
Stroke	3,500	10,000

Source: authors’ estimate based on Department of Health and Ageing (2000) for the average annual cost of treating people with diabetes without complications, and Clarke et al (2008) for other costs.

4 Illustrative Scenario: 10% weight reduction among obese Australians

Lowering the prevalence and severity of major chronic diseases would have considerable benefits in terms of improvements in Australians’ health, productivity and well-being. In addition, public and private health expenditures would be lower, the pool of skilled people entering or remaining in the workforce would be bigger, and living independently would be a possibility for a greater number of Australians.

As noted in Section 1, many chronic diseases share common lifestyle risk factors and common underlying health conditions. For example Barr *et al* (2007) found that abnormal glucose metabolism was not only a major risk factor for diabetes, but also a major contributor to CVD and CVD deaths in Australia's general population. These authors concluded *that interventions aiming to prevent cardiovascular disease could be warranted in people with diabetes and pre-diabetes*. Also, Australia's current government has initiated a review of public health services and has shown particular interest in prevention-type interventions.

Hence our choice of an illustrative Scenario targeting obesity, one of the major common risk factors to both diabetes and CVD. The Scenario estimates the impact of a 10% weight reduction among Australia's obese population. The aim of presenting this illustrative Scenario at this stage is to highlight the novel features of *HealthAgeingMod*. The Scenario projects to 2010, and makes the simplifying assumption that Australia's obese people were able to have their weights reduced in 2005 by 10%. As the aligning processes to external benchmarks are not at this stage complete, the results reported – while realistic – should not be seen as final. Also, once *HealthAgeingMod* is completed and fully tested, it will be able to simulate much more complex and realistic scenarios.

4.1 Description of Scenario

The Scenario assumes that all obese baseline persons in *HealthAgeingMod* (BMI ≥ 30) had a weight reduction of 10% in 2005. That year Australia's obese population was around 2.5 million (13% of total population and 17% of 25+ year olds).

Starting with these 10% lower body weights – and BMI values - in 2005, the model-system was used to estimate diabetes and CVD disease patterns in 2010.

Next, the Scenario results for 2010 were compared with the 2010 'No Intervention' option results. Under the latter option, the model-system estimated diabetes and CVD disease patterns in 2010 without changes in the original BMI values.

4.2 Results

Table 3 presents the preliminary Scenario results. It illustrates the advantages of the person-level Prototype compared with traditional models. With our model we were able to separately identify persons:

- with *diabetes only* (pre-existing as well as new diabetes), estimating 57,226 less persons with type 2 diabetes under the Scenario than under the 'No Intervention' option over the five year period (a saving of A\$187 million in treatment costs);
- with *diabetes as well as a CVD hospital event* over the five years, estimating 7,362 less persons with both these conditions ((a saving of A\$147 million in treatment costs);
- with *a CVD hospital event only*, over the five years, estimating 8,206 less persons with CVD only (a saving of A\$173 million in treatment costs); and
- who die in hospital as a result of their CVD event. With this Scenario no reduction in the numbers dying occurred, as BMI proved not to be significant in the Anderson (1991) equation we used to predict deaths.

The Table shows that, overall, we estimate the Scenario treatment costs to be A\$507 million lower over the five years than under the 'No intervention' option.

What our complex unit record based model-system also allowed us to estimate were the parts of that A\$507 million that arose from 'diabetes only' patients, 'diabetes with CVD as complication' patients and 'CVD only' patients.

Using a much simpler diabetes only model, Colagiuri and Walker (2008) estimated the benefits and costs of a realistic diabetes screening intervention, with 55-75 year old Australians found with undiagnosed diabetes and pre diabetes having been offered life-style changing programs. The

intervention cost for the screening of the 2.1 million Australians in that age group amounted to around A\$500 million over 5 years. This suggests that the A\$507 million treatment cost savings over 5 years from the 10% lower weight Scenario could be sufficient to finance a similar program for the close to 2.5 million Australians who were obese in 2005. Thus, using *HealthAgeingMod*, a similar level of intervention expenditure would lower the prevalence of not only diabetes – as in Colagiuri and Walker (2008) – but also the prevalence of hospitalised CVD events.

Table 3: 10% lower Body Mass Index in Australia’s obese population*, 2005 to 2010

	Baseline:	Scenario:
	No Intervention	10% Lower BMI
Persons** (Number)		
Australians with diabetes only	951,706	894,480
difference Scenario -to- Baseline		- 57,226
Australians with diabetes+CVD event	50,749	43,387
difference Scenario -to- Baseline		- 7,362
Australians with non-fatal CVD event only	285,222	277,016
difference Scenario -to- Baseline		- 8,206
ALL PERSONS WITH DIABETES AND CVD	1,287,677	1,214,883
difference Scenario -to- Baseline		- 72,794
Expenditures (AU\$ million)		
Total expenditure_ <i>diabetes only</i>	4,816	4,629
difference Scenario -to- Baseline		- 187
Total expenditure_ <i>diabetes_non-fatal CVD event</i>	1,128	981
difference Scenario -to- Baseline		- 147
Total expenditure_ <i>non-fatal CVD event only</i>	5,767	5,594
difference Scenario -to- Baseline		- 173
Expenditure_ <i>fatal CVD events</i>	1,317	1,317
difference Scenario -to- Baseline		0
TOTAL CVD plus DIABETES COSTS	13,028	12,521
difference Scenario -to- Baseline		- 507

* People with Body Mass Index (BMI) of 30 or more were defined as ‘obese’ in NHS05 – and in this study. Since BMI is the ratio of weight to height², for the same model-system person a 10% reduction in weight is equivalent to a 10% reduction in his/her BMI. ** weighted estimates

Source: Model-system Prototype simulations

5 Conclusions

The paper demonstrates the usefulness of studying chronic diseases a group, rather than by a single disease at a time. It also demonstrates the technical feasibility of accounting in model-systems such as *HealthAgeingMod* for the complex processes through which individuals acquire several of such diseases as they age.

Future development and applications of the model system could simultaneously consider additional chronic diseases (eg arthritis, cancer), and assess the work and financial implications of prevention efforts (Walker 2007b), as well as their implication for people with several chronic diseases to continue to live independently.

References

- ABS (Australian Bureau of Statistics), 2006a, *National Health Survey 2004-05, Summary of Results*, Cat No 4364.0, Canberra.
- 2006b, *National Health Survey 2004-05*, Confidentialised Unit Record Files.
- 2006c, *National Health Survey 2004-05: CURF Information Paper*, Cat No 4324.0 and *National Health Survey 2004-05 Questionnaire*, Cat No 4363.0.55.002.
- 2006d, *National Health Survey 2004-05, User Guide*, Cat No 4363.0.55.001.
- 2006e *Cardiovascular Disease in Australia: A Snapshot, 2004-05*. Cat No 4821.0.55.001.
- 2005, *Projections of the Populations of Australia: 2004-2101*, Cat no 3222.0
- AIHW (Australian Institute of Health and Welfare), 2008a, *Diabetes: Australian Facts 2008*, Diabetes Series No. 8 AIHW Cat. No. CVD 40, Canberra.
- 2008b, *Indicators for chronic diseases and their determinants 2008*, Cat. no. PHE 75. Canberra: AIHW.
- 2006a, *Australia's Health 2006*, AIHW cat No. AUS 73, Canberra.
- 2006b, *Socioeconomic inequalities in cardiovascular disease in Australia: Current picture and trends since 1992*, AIHW Bulletin 3, Canberra.
- 2006c, *Chronic diseases and associated risk factors in Australia 2006*. AIHW Cat No PHE 81, Canberra.
- 2006d, *Health expenditure Australia 2004-05*, Canberra.
- 2005, *Health system expenditure on disease and injury in Australia 2000-01*, Canberra.
- 2004a, *Australia's Health 2004*, AIHW Cat. No. AUS 44, Canberra.
- 2004b, *Disability and its relationship to health conditions and other factors*, Canberra.
- 2004c, *The impact of dementia on the health and aged care systems*. Canberra.
- 2004d, *Cancer Australia 2001*, Canberra.
- 2004e, *The relationship between overweight, obesity and cardiovascular disease*, Cat. No. CVD 29, Canberra.
- 2004f, *Heart, Stroke and Vascular Disease - Australian facts 2004*, AIHW Cat. No. CVD 27, Canberra.
- Anderson K, Odell P, Wilson P, Kannel W. Cardiovascular disease risk profiles, *Am Heart J*, 1991; 121 (1, part 2): 293-98.
- Barr E, Zimmet P, Welborn T, Jolley D, Magliano D, Dunstan D, Cameron A, Dwyer T, Taylor H, Tonkin A, Wong T, McNeil J, Shaw J. Risk of Cardiovascular and All-Cause Mortality in Individuals With Diabetes Mellitus, Impaired Fasting Glucose, and Impaired Glucose Tolerance: The Australian Diabetes, Obesity, and Lifestyle Study (AusDiab). *Circulation* 2007; (116):151-157.
- Begg S, Vos T, Barker B, Stevenson C, Stanley L, Lopez A. *The burden of disease and injury in Australia 2003*, Australian Institute of Health and Welfare, 2007; AIHW cat. no. PHE 82.
- Clarke P, Leal J, Kelman C, Smith M, Colagiuri S, FRACP (Department of Endocrinology, Prince of Wales Hospital, NSW, Australia). Estimating the cost of complications of diabetes in Australia using administrative health-care-data, *Value in Health* 2008; 11(2):199-206.
- Clarke P, Gray A, Briggs A, Farmer A, Fenn P, Stevens R, Matthews D, Stratton M, Holman R (2004). A model to estimate the lifetime health outcomes of patients with Type 2 diabetes: the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes Model (UKPDS no. 68), *Diabetologia*, 47:1747-59.
- Colagiuri S, Walker A, Using an Economic Model of Diabetes to Evaluate Prevention and Care Strategies in Australia, *Health Affairs*, 2008; 27(1):256-268.
- Department of Health and Aged Care, 2000, *Insights into the utilisation of health services in Australia based on linked administrative data*, Occasional Papers, New series No 9, Canberra.
- Eckersley R. Being better off but feeling worse: what's happening to people in Australia? *New Community Quarterly*, 2004; 2 (3): 3-7.
- Griffiths C, Foster G, Ramsay J, Eldridge S, Taylor S. How effective are expert patient (lay led) education programmes for chronic disease?. *BMJ* 2007;334:1254-1256.

- Hubert H, Feinleib M, McNamara P, Castelli W. Obesity as an independent risk factor for cardiovascular disease: a 26- year follow-up of participants in the Framingham Heart Study, *Circulation* 1983;67:968-77.
- International Diabetes Institute (2006). *AusDiab 2005: Tracking the Accelerating Epidemic: Its Causes and Outcomes*. The Australian Diabetes, Obesity and Lifestyle Study, Melbourne.
- Lopez A, Mathers C, Ezzati M, Jamison D, Murray C (Eds), *Global Burden of Disease and Risk Factors*, 2006, World Bank, Washington.
- Magliano D, Barr E, Zimmet P, Cameron A, Dunstan D, Colagiuri S et al, Glucose Indices, Health Behaviors and Incidence of Diabetes in Australia. *Diabetes Care*, 2008; 31(2): 267-272.
- Mui S-L. Projecting coronary heart disease incidence and cost in Australia: Results from the Incidence module of the Cardiovascular Disease Policy Model, *Australian and New Zealand Journal of Public Health*, 1999; 23 (1): 11-19.
- Seymour L. Health, wealth and the pursuit of happiness, *Journal of the Royal Society for the Promotion of Health*; 2007; 127: 2.
- Shwartz M, Iezzoni L, Moskowitz M, Ash A, Sawitz E, The importance of comorbidities in explaining differences in patient costs, *Medical Care*, 1996; 34(8):767-82.
- Treasury (2007). *Intergenerational Report*, Commonwealth of Australia, Canberra
- Walker A, Multiple chronic diseases and quality of life: patterns emerging from a large national sample, Australia, *Chronic Illness*, 2007a; 3(3): 202-218.
- (2007b). Health Status, Health Inequalities and the Ability of Older Australians to Stay in the Labour Force in Gupta A and Harding A (eds), *Modelling Our Future: Population Ageing, Health and Aged Care*, International Symposia in Economic Theory and Econometrics, North Holland, Amsterdam.
- Walker A, Colagiuri, S. 2009, Cost-Benefit Model System of Chronic Diseases in Australia: to Assess and Rank Prevention and Treatment Options, *International Journal of Microsimulation* (submitted 13 May 2009).
- Walker A, Butler J, Colagiuri S. 2009a, Cost-Benefit Model System to Assess and Rank Prevention and Treatment Options of Chronic Diseases in Australia: A novel approach, *Journal of Population Ageing* (resubmitted 14 April 2009).
- 2009b, *Cost-Benefit Model System of Chronic Diseases in Australia: to Assess and Rank Prevention and Treatment Options – Description of Prototype*, Australian Centre for Economic Research on Health Research Report No 4, Australian National University (forthcoming)
- 2008a, *Cost-Benefit Model System of Chronic Diseases in Australia: to Assess and Rank Prevention and Treatment Options - Proposed Approach*, Australian Centre for Economic Research on Health Research Report No 3, Australian National University - www.acerh.edu.au/publications/ACERH_RR3.pdf
- 2008b, *Cost-Benefit Model System of Chronic Diseases in Australia: to Assess and Rank Prevention and Treatment Options – the prototype*, paper presented at the *Australian Conference of Health Economists*, Adelaide, 23 September.
- WHO (World Health Organisation) 2005a, *Preventing chronic diseases: a vital investment*, Geneva.
- Yach D, Hawkes C, Gould CL, et al. The Global Burden of Chronic Diseases: Overcoming Impediments to Prevention and Control, *JAMA* 2004; 291 (21):2616-262.