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Microsimulation models of disease incidence and development, and of associated mortality

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Topics

- Microsimulation
- Past trends in major causes of death
- Risk factors, and reasonable guesses about future cause of death trends
- Mortality risk relativities
- Disease risk relativities
- Relativity compression above age 80
- Life expectancy calculators
- Implementing relativities in microsimulation

A definition of microsimulation

"…a modelling technique that operates at the level of individual units such as persons, households, vehicles or firms. Within the model each unit is represented by a record containing a set of attributes … A set of rules are then applied to these units leading to simulated changes in behaviour"

International Microsimulation Association (2009)

High costs of microsimulation models

"…the developers of the MINT, CBOLT and POLISIM models of the US have estimated that the total development costs of each model have exceeded US$6m… budgets of this magnitude have also been involved for the Canadian DYNACAN model, the Norwegian MOSART model and the Swedish SESIM model."

Harding 2007

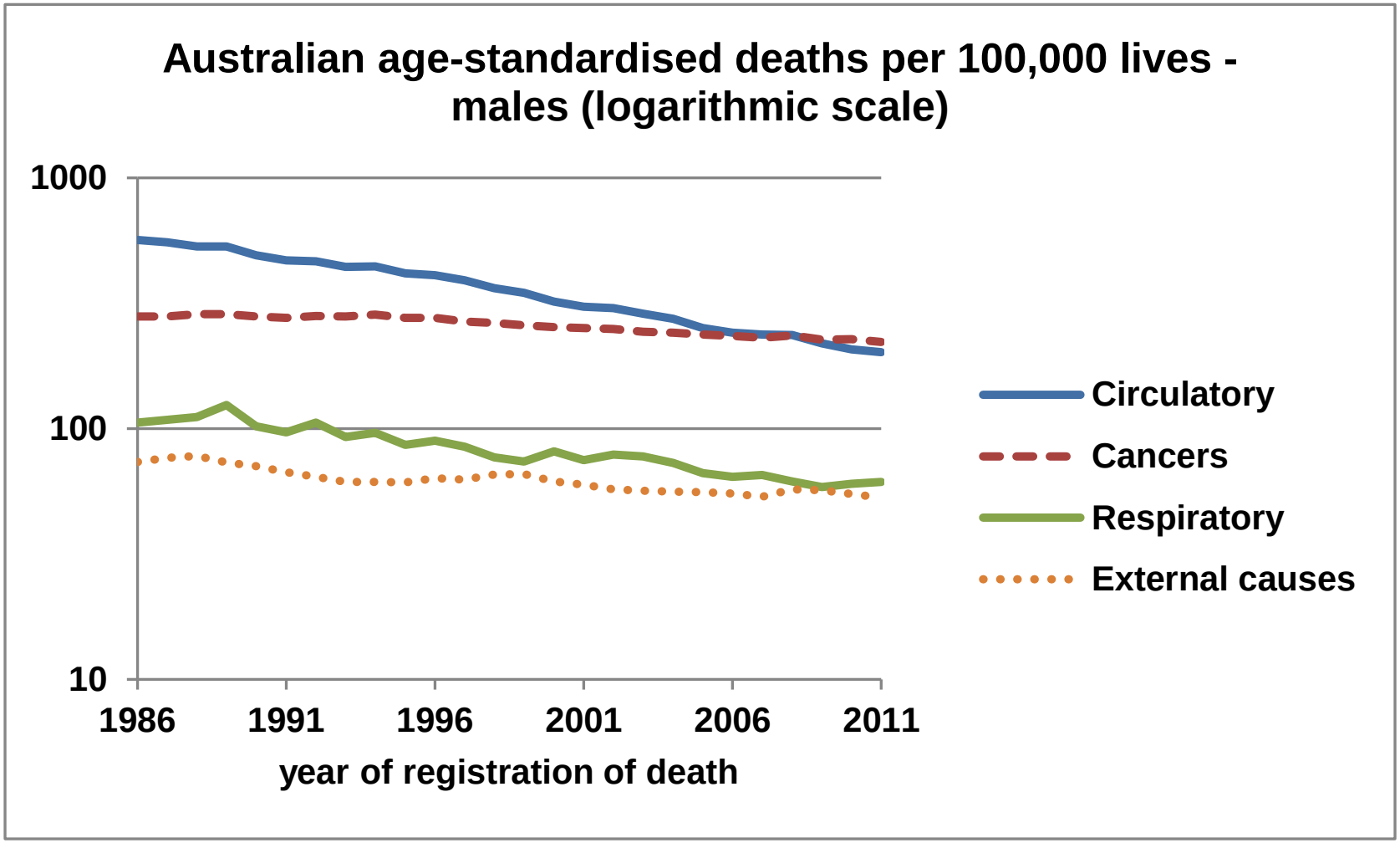
Possible uses for microsimulation models

- Government policy decisions
- Commercial decisions on optimal locations
- Advice to individuals about their life expectancies???
- Underwriting???

We want to spread the high development costs across many users. But it is not yet clear whether advising individuals or underwriters is worth the extra model complexity.

Diseases in our microsimulation model

- We are using 124 disease models developed by the Australian Institute of Health and Welfare (Mathers 1999)
- In all, 584 disease stages are modelled
- Each disease has incidence, development and mortality assumptions based on age & sex
- Persons die from diseases, rather than age
- We are thus very interested in disease trends and disease risk relativities



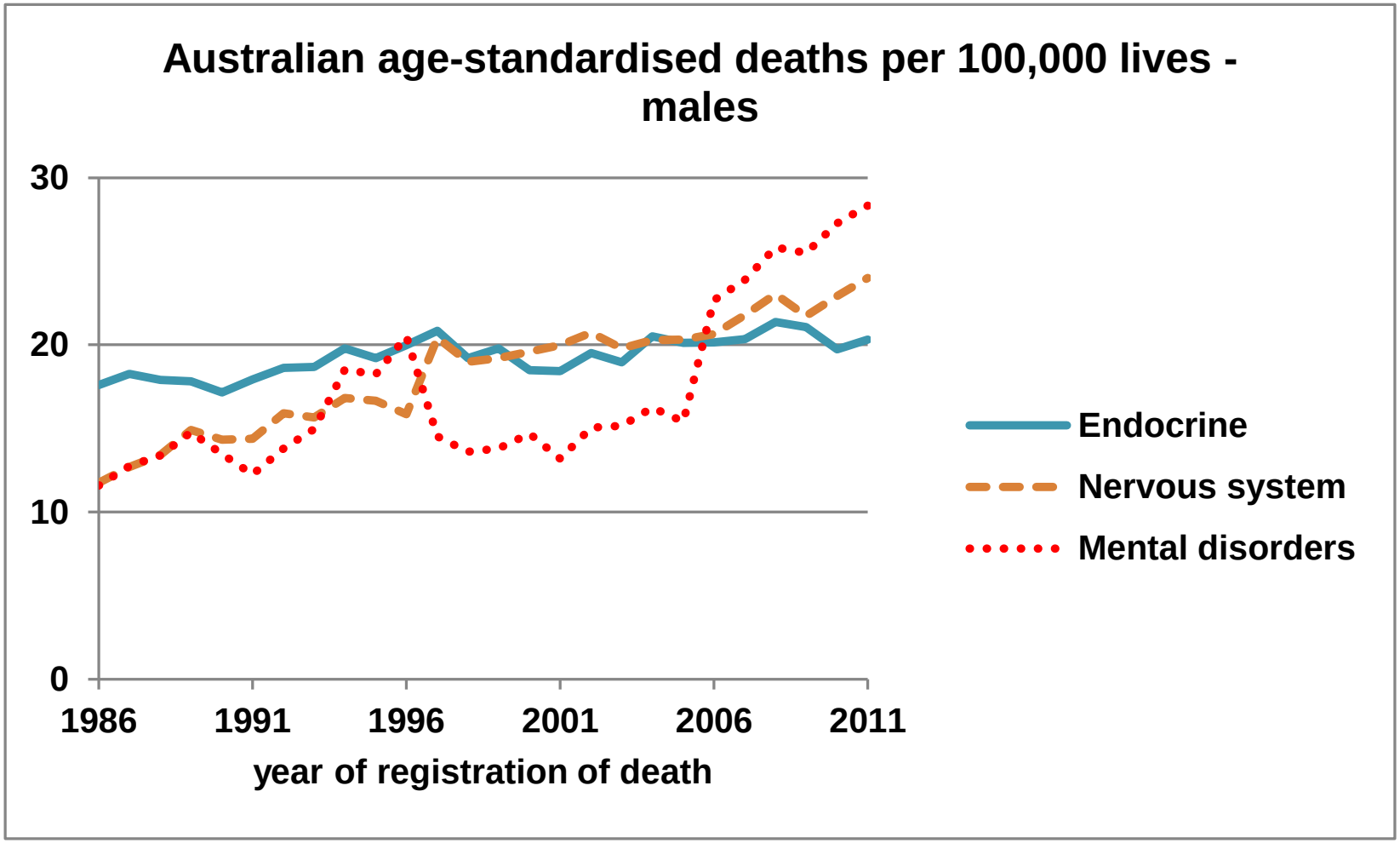
- The 4 largest causes accounted for 75% of deaths in 2012
- Age-standardised deaths calculated using 2001 estimated resident population (AIHW 2013)
- All are dropping, with circulatory dropping fastest

The four major causes of death

- Many developed countries have had similar falls (Ridsdale & Gallop 2010)
- The rapid drops in circulatory disease deaths reflect much greater use of medications to lower blood pressure, cholesterol and triglycerides, and improved surgical procedures
- Smoking rates have fallen, but obesity has risen
- There is a 30-year population latency period between cigarette smoking prevalence and lung cancer mortality (Weiss 1997). One study of mesothelioma found a median latency period of 51 years(Bianchi et al 1997)

The four major causes of death (ctd)

- Health measures such as asbestos legislation and smoking deterrents can take many decades to show gains, but are still affecting circulatory, cancer and respiratory deaths
- Diseases such as cancer have many types, with continuing research making gradual improvements, and with genetic therapies likely to slowly become effective
- Road safety research and legislation has gradually created a capital stock of safer vehicles and safer drivers



- The next 3 causes accounted for 14% of deaths in 2012
- Alzheimer's and other dementias make up a substantial part of both "mental & behavioural disorders" and "nervous system disorders".

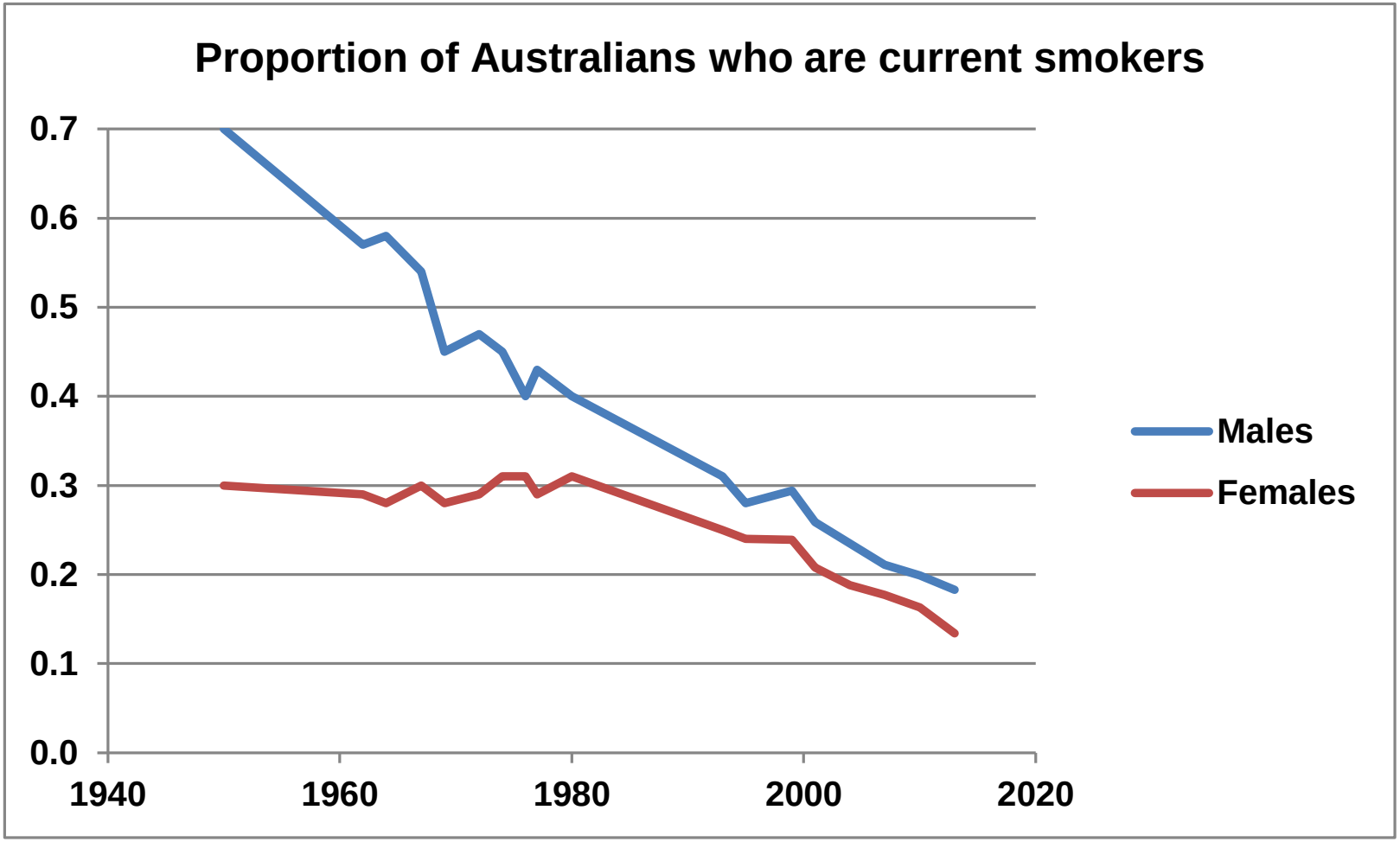
Declining dementia incidence?

Study	Start	Years	Change	Rate pa
Sweden Lundby	1947	10	Stable	0.000
US Rochester	1976	24	Stable	0.000
US National Long Term Care	1982	17	0.51	-0.039
UK MRCCF CFAS	1989	19	0.76	-0.014
Netherlands Rotterdam	1990	10	0.75	-0.028
US African Americans	1992	9	1.10	0.011
US Health and Retirement Study	1993	10	0.71	-0.033
US Chicago	1997	11	0.97	-0.003

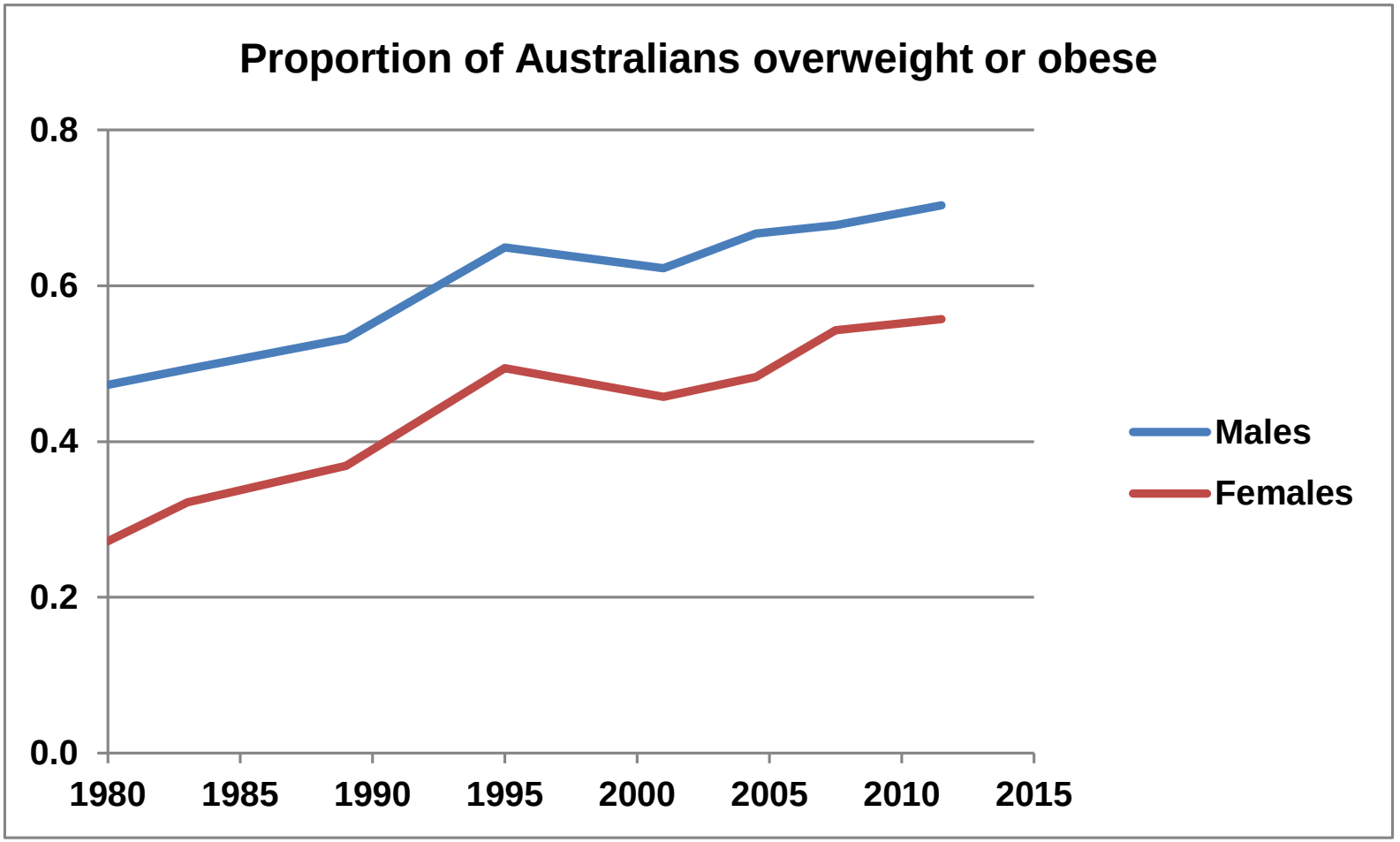
References to these studies are in Sachdev (2014). Although the two oldest studies showed no change, the 6 most recent show rates of change from -3.3% pa to +1.1%. Some improvement is expected, because dementia risk factors include smoking, low education and midlife hypertension (Norton et al 2014).

Future deaths from mental disorders, nervous system and endocrine are unclear

- All three have had positive growth rates over last 25 years
- Deaths are often recorded under other causes. Diabetes was the underlying cause for 4,209 deaths in 2011, but an associated cause in another 10,684 deaths (ABS 2013b)
- Erratic rising numbers for nervous system and mental disorder deaths may reflect reporting changes
- The incidence of dementia in older individuals may be declining (Sachdev 2014)
- Safety and effectiveness trials can take many years
- High initial prices may slow adoption of new treatments



Proportions up to 1980 are from Walker (1984 p93), and are for various minimum ages. Proportions from 1993 on are from AIHW (2014) and similar earlier reports, and are for persons aged 14+.



Proportions up to 1989 are from Risk Factor Prevalence Surveys, and are for persons aged 25-64. Subsequent values are from National Health Surveys, and are for persons 18+. Values for 2001 and 2004-05, were increased by 8.3% or men, and 14.1% for females, to allow for underestimation caused by self-reporting of height and weight.

Trends for major causes of death

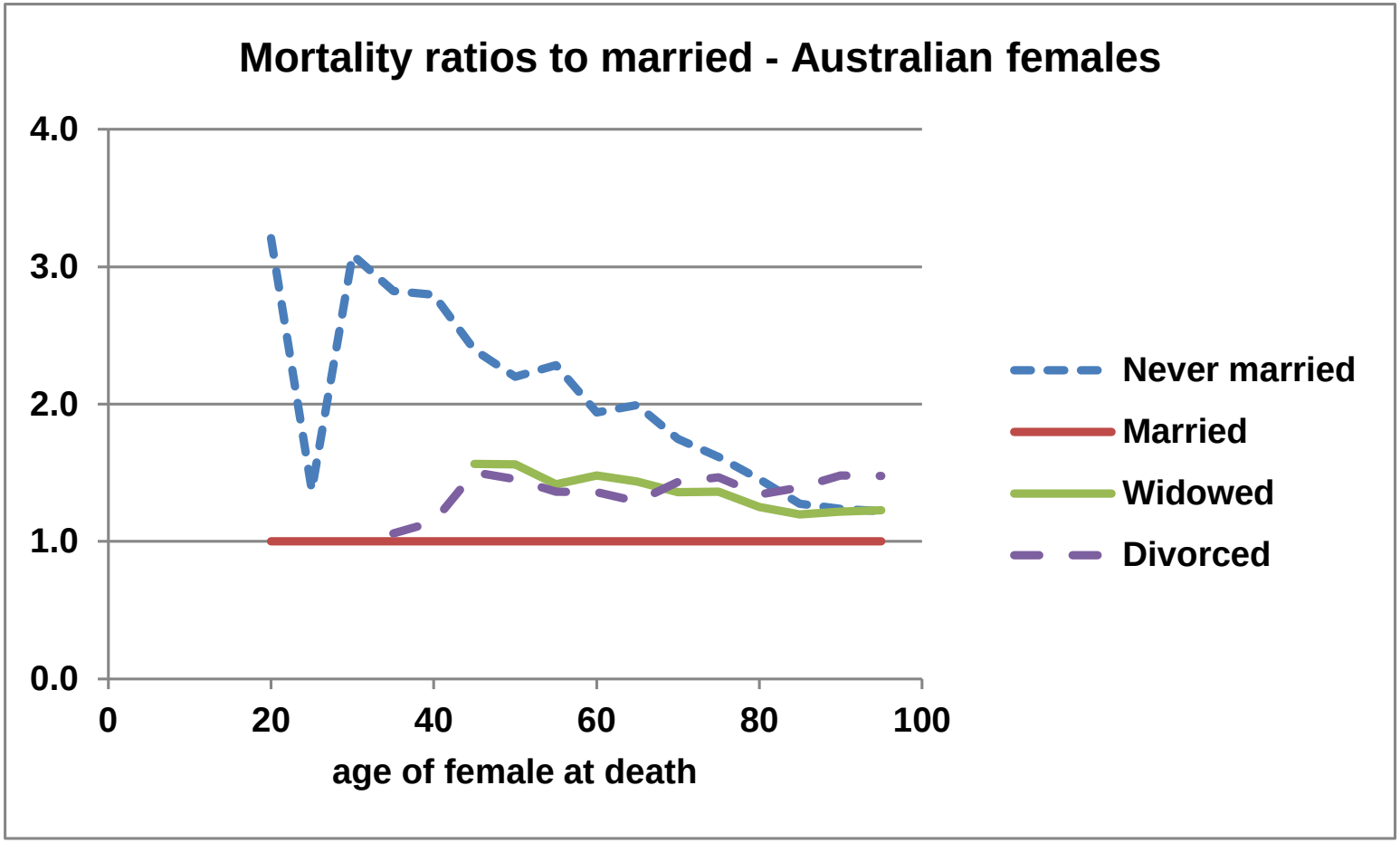
Underlying cause of death	Deaths 2012 Percent	Trend %pa 1986-2011 Males	Trend %pa 1986-2011 Females	Guessed future trend %pa
Circulatory system	29.9	-4.0	-3.8	-2.0
Cancer	29.6	-0.9	-0.7	-1.0
Respiratory system	9.0	-2.2	0.0	-1.0
External causes	6.3	-1.3	-1.0	-1.0
Mental & behavioural disorders	5.5	2.0	3.6	-2.0
Nervous system	4.7	2.1	2.9	-2.0
Endocrine, nutritional & metabolic	4.1	0.8	0.6	0.0
All other	10.9	-0.7	-0.4	0.0

Guessed trends are broadly based on the last 25 years, except that

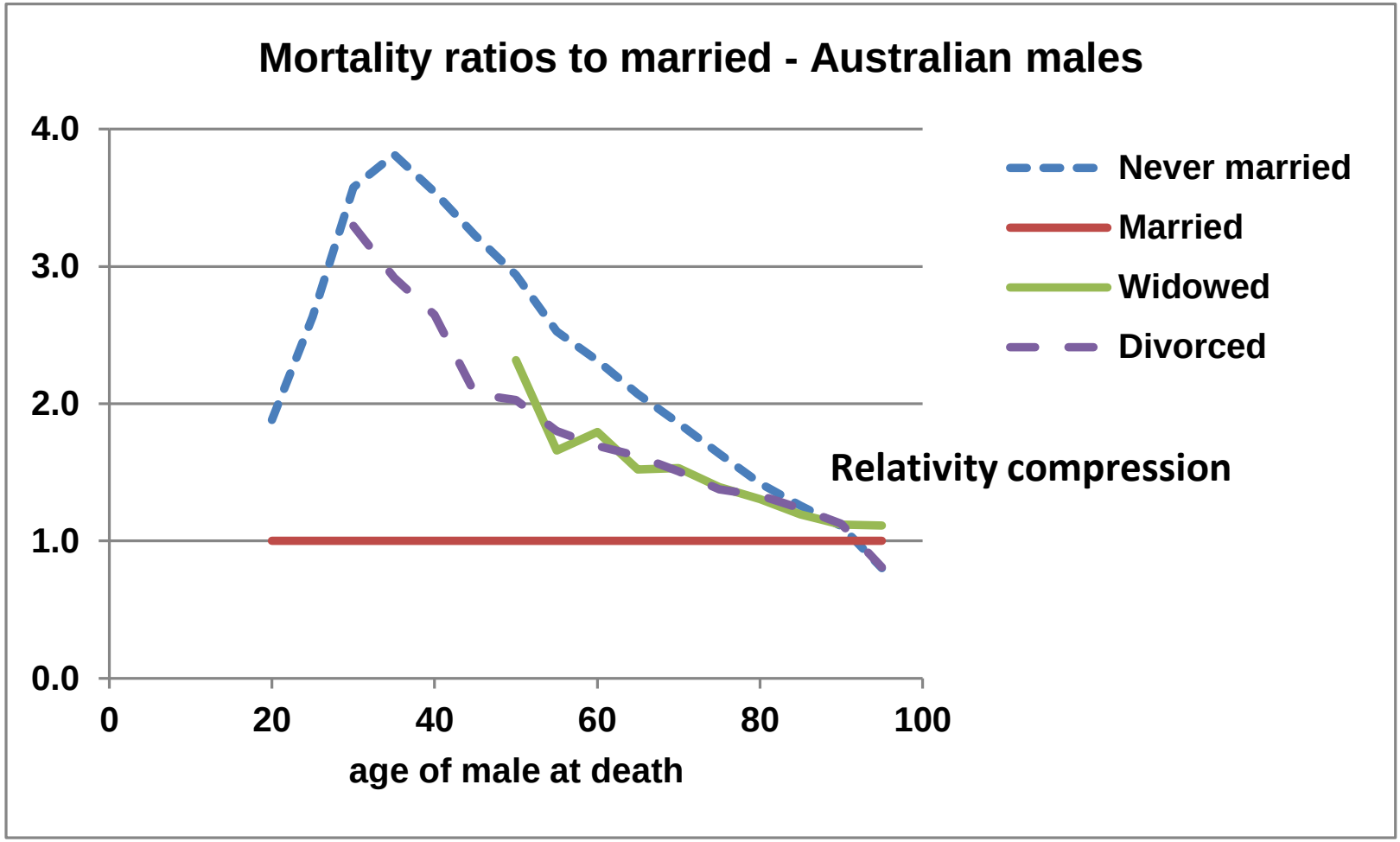
- Drops in circulatory disease deaths are guessed at 2% pa
- Mental disorder and nervous system deaths are guessed to fall in line with circulatory diseases, being subject to similar risk factors

Need for expert advice

- Ongoing changes to legislation, behaviour and treatment have reduced mortality rates.
- Long latency periods and capital investment have helped spread changes.
- Not clear whether obesity increases will reverse some of the trends down.
- Expert advice is needed on the reasons for past changes, and likely future trends (as suggested by Pinnington 2008)
- Experts could be asked to provide scenarios or uncertainty funnels around their trend estimates



Ratios are numbers of deaths of females in 2010 to 2012 (ABS 2013c), divided by numbers of females in each marital status reported by 2011 Australian census. There were 213,895 female deaths from 2010 to 2012.



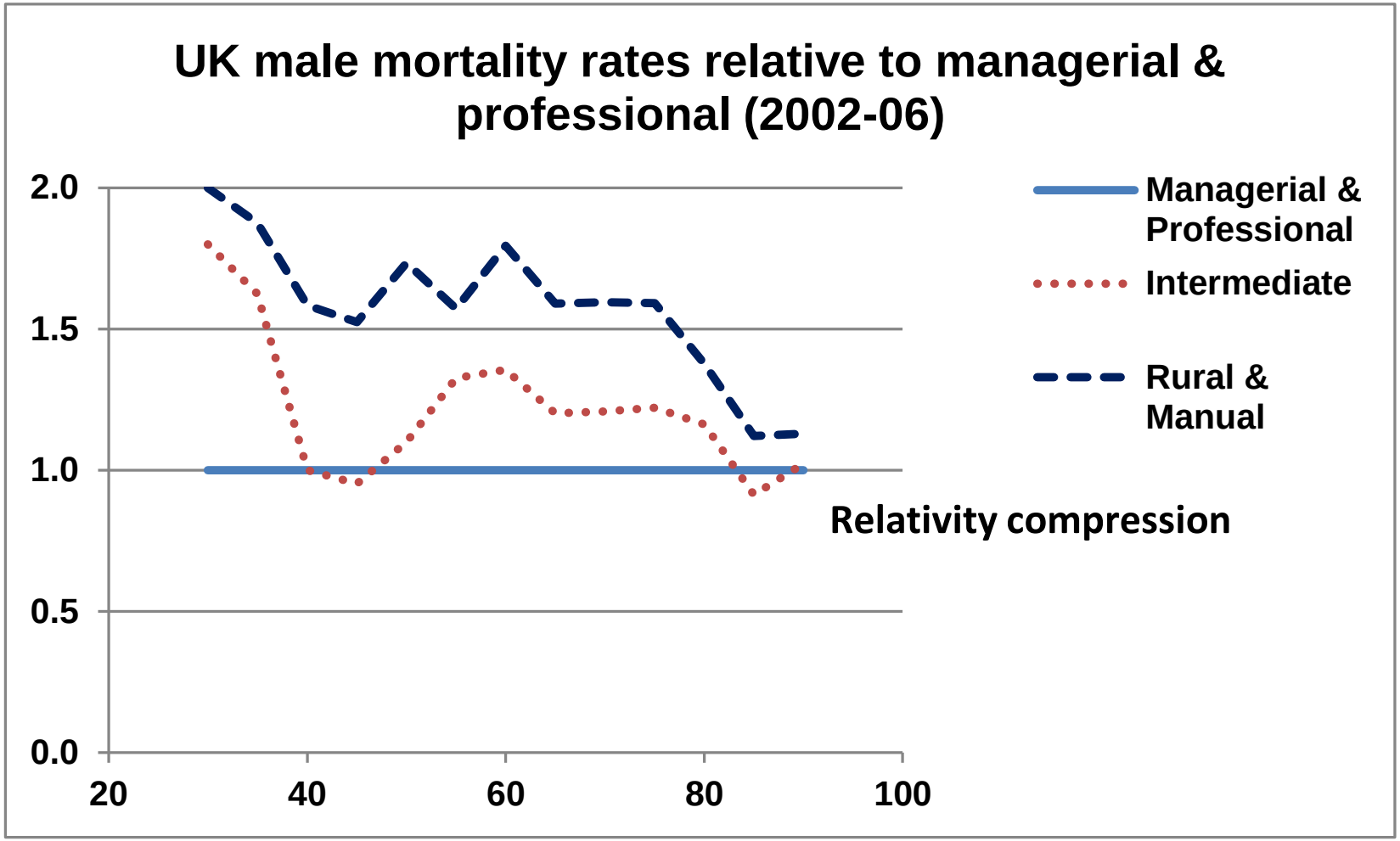
Males cope worse with widowhood or divorce, with mortality ratios not much lower than for the never married. Note the compression of relativities above age 80.

Suggested reasons for lower mortality of married

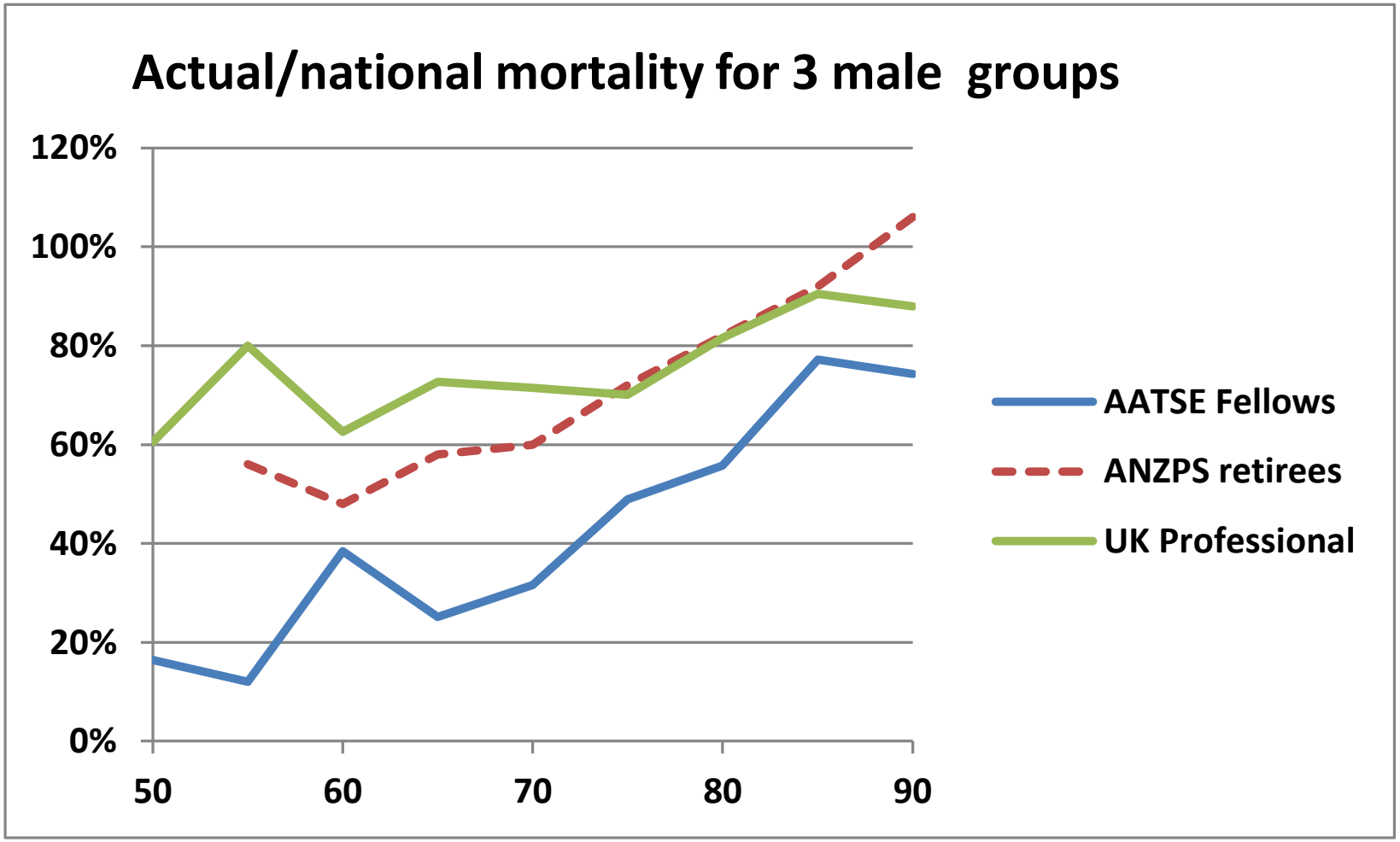
"…access to financial resources is a key pathway through which marriage improves well-being and life chances … men benefit immediately from reduced mortality risk at marriage … the advantages for women accumulate with the length of the marriage" (Lillard & Waite 1995)

"Marriage may reduce stress and stress-related illness … may encourage healthy types of behaviour, and discourage unhealthy ones (drinking, substance abuse, etc). A spouse makes it more likely that an individual receives adequate care if ill…marriage may increase material well-being, by resource pooling and task specialization. Alternatively, there may be no beneficial effects of marriage upon health, but it may simply be that more healthy individuals are selected into marriage

(Gardner & Oswald 2004)

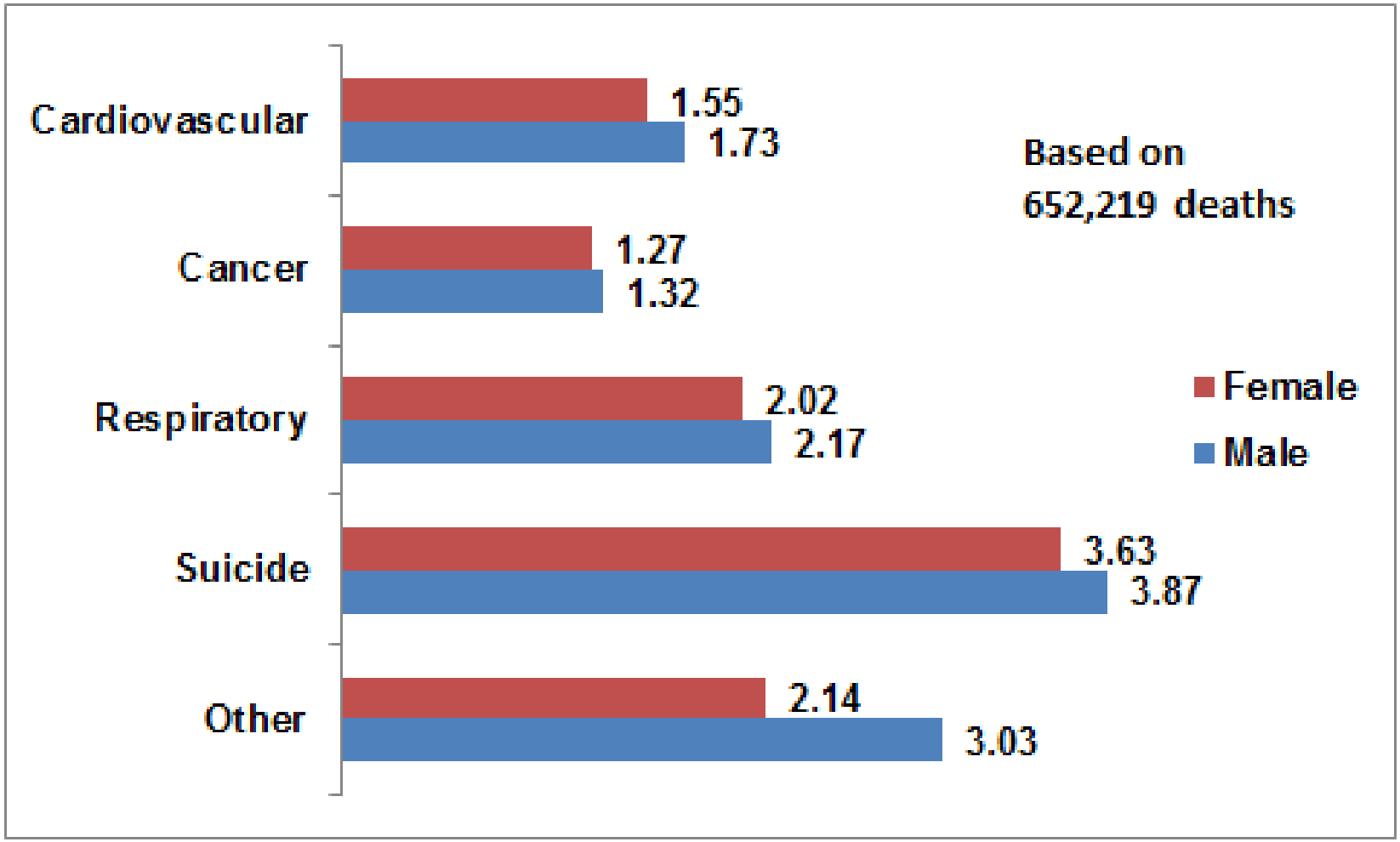


Above mortality relativities are from Office for National Statistics (2013). There are 12,245 deaths in the data. Note compression of mortality relativities above age 80.



"AATSE" is the mortality experience of Fellows of the Australian Academy of Science, Technology and Engineering from 1977 to 2008. "ANZPS" is the mortality of public service pensioners in Australia and NZ for 2009-12 (Wilson & Boyfield 2014). UK professional experience is for 2002-06.

Mortality odds ratios for lone persons



Derived from Danish Civil Registration System data 2000-2010 (Frisch & Simonsen 2013). Odds ratios are to partnered persons.

Survey of Disability Ageing & Carers 2012

This survey (Australian Bureau of Statistics 2014) reported personal and disability details for 77,570 persons. After omitting 10,362 persons in non-private dwellings, 12,878 under 15 and 681 with missing values, there were 25,987 males and 27,661 females for analysis.

Lone parents and lone persons were grouped as “lone adults”. Children, related persons, unrelated persons in families and group members were grouped as “other”. Diplomas and certificates were grouped as “technical ”, and year12, bachelor, graduate diploma and postgraduate degrees as “year 12 plus”.

Exploratory logistic regressions were done, keeping coefficients with about 20% probability or less. Age and age square variables were included in each regression. Odds ratios for household status are relative to partnered persons, and those for education are relative to persons with less than year 12 education.

Disability odds ratios – Australian females

Variable	Circu-latory	Cancer	Respi-ratory	External causes	Mental disorder	Nervous system	Endo-crine
lone	1.17	1.35	1.48	2.18	2.52	1.51	
other	1.12			1.22	2.02		1.24
technical			0.93		0.82		0.89
year 12+	0.73	0.77	0.74	0.73	0.52	0.81	0.71

Odds ratios greater than one are shown in red. For example, lone and "other" females have double the risks of having mental disorders than partnered females. Females with year 12 or university qualifications are less likely to have each disability type than those with year 11 or less.

Disability odds ratios – Australian males

Variable	Circu-latory	Cancer	Respi-ratory	External causes	Mental disorder	Nervous system	Endo-crine
lone	1.19		1.37	2.65	3.04	1.48	
other	0.88			1.16	3.19	1.36	1.25
technical		1.22	0.84			0.89	0.91
year 12+	0.71	0.76	0.69	0.59	0.55	0.71	0.81

Lone and "other" males have triple the risks of having mental disorders than partnered males. Males with year 12 or university qualifications are less likely to have each disability type than those with year 11 or less.

Disability odds ratios for lone persons compared with partnered persons

Sex/age	Circu-latory	Cancer	Respi-ratory	External causes	Mental disorder	Nervous system	Endo-crine
M15-39			1.43	3.22	3.58	1.60	1.65
M40-59	1.21		1.62	3.41	4.10	1.77	
M60-79	1.17		1.20	2.03	2.18	1.29	
M80+	1.36						
F15-39	1.79		1.48	3.27	2.69	1.89	1.72
F40-59	1.28	1.73	1.70	2.42	2.91	1.49	1.45
F60-79	1.13	1.39	1.43	1.77	2.17	1.26	1.16
F80+			1.38	1.42			

For example, lone males aged 40-59 are 4 times more likely to have a mental disorder than a partnered male. Most differentials between lone and partnered persons seem to disappear by age 80+.

Disability odds ratios for persons with year 12+ education, compared with those with year 11 or less

Sex/age	Circu-latory	Cancer	Respi-ratory	External causes	Mental disorder	Nervous system	Endo-crine
M15-39	0.55		0.71	0.72	0.34	0.46	
M40-59	0.65	0.47	0.68	0.44	0.49	0.73	
M60-79	0.75	0.67	0.64	0.60	0.59		0.73
M80+	0.71		0.52			2.44	
F15-39	0.45		0.76		0.45	0.72	0.56
F40-59	1.38		0.76	0.65	0.48	0.72	0.75
F60-79	0.76	0.69	0.72	0.83	0.63		0.76
F80+				1.62		1.57	

For example, males aged 40-59 with year 12+ education are half as likely to have a mental disorder than those with year 11 or less. Most education differentials seem to disappear or reverse by age 80+.

Examples of life expectancy calculators

- www.livingto100.com/calculator (47 questions)
- www.mylongevity.com.au (51)
- http://gossett.wharton.upenn.edu/mortality/perl/CalcForm (45)
- www.zurich.com.au/zurich_au/individuals/life_insurance/calculator (6)
- www.uwic.ac.uk/shss/dom/newweb/lifestyle/age_expectancy2 (12)

These calculators are all available on the web for personal use. The underlying assumptions are largely undocumented, and there is no evidence of any validation process. Filling out all 5 for one person gave a range of more than 2:1 in life expectancies. Relativity compression may make these calculators less reliable at older ages.

Schonberg index to predict 9-year mortality

Variable	Points	Variable	Points
Age 70-74	1	Diabetes	2
Age 75-79	3	Cancer	2
Age 80-84	5	One overnight hospital stay	1
Age 85+	7	Two or more stays	3
Male	3	Perceived health good	1
Former smoker	1	Perceived health fair/poor	2
Current smoker	3	Dependent on at least 1 IADL	2
BMI<25 kg/m2	2	Difficulty walking several blocks	3
COPD	2		

From Schonberg et al (2011). Adding the points gives a validated index that predicts mortality within 9 years. The index is intended for community-dwelling adults aged 65+. Note that 2 points are added for BMI<25. A 10-year Lee index has been validated by Cruz et al (2013). Neither index allows for income, education or cohabitation status.

Microsimulation functions needed for individual life expectancies

Needed	Not needed
Relationships	Births
Education	Immigration
Employment	Emigration
Occupation	Internal migration
Earnings	Housing
Diseases	Superannuation
Deaths	Non-private dwellings

Mechanics of microsimulation

- Search processes are used to find partners
- Logistic models are used for birth, employment, occupation, earnings, migration, retirement savings and entry to aged care
- Assumptions are made about disease incidence, development and associated mortality

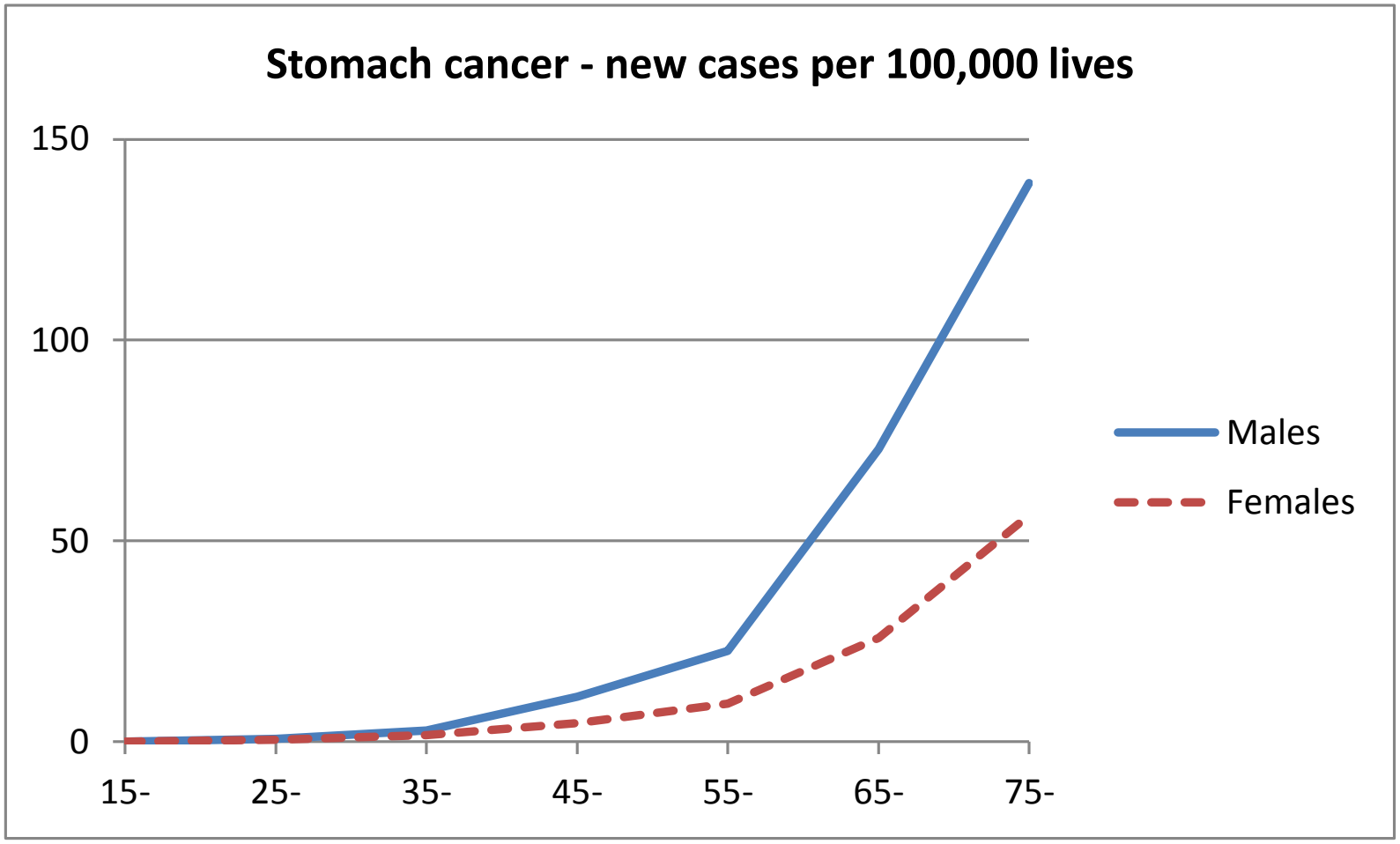
Partner search processes

- We use a “best of n” process, where n potential partners are randomly selected, and a compatibility index used to select the best
- n is chosen by age to approximately replicate the observed differences between partners
- Allowance could be made for the health of each potential partner

Logistic models of entry into employment

Variable	Employee	Business
lone parent	0.75	
partner		2.48
postgraduate	2.97	2.67
technical	1.57	
undergraduate	1.94	2.00
children age 0-4	0.48	
children age 5-14	0.85	1.22

Models of females entering employment and self-employment were fitted to data from waves 1-6 of the HILDA longitudinal study (Watson 2008), omitting variables not significant at the 5% level. Odds ratios are shown, with values below 1 in red.



Above incidence assumptions are from Mathers (1999). Incidence and development assumptions are modified to give reasonable balances with recent death numbers by cause.

Stomach cancer development (males)

Stage	Transition rate	Remission rate	Mortality rate
Diagnosis & treatment	2		
Remission	0.444	0.148	
Disseminated	1.761		
Pre-terminal & terminal			4

This is one of 175 disease models released by Mathers et al 1999. Average duration in a stage = 1/rate. For stomach cancer, the last stage averages 3 months.

Event occurrence is proportional to rate, eg stomach cancer remission probability from stage 2 = .148 / (.444 + .148)

Allowing for relativities in microsimulation

- The “protective” effect of partnership may largely reflect lower disease incidence rates
- Not clear why this stops over age 80
- Many of our logistic models may need to be modified to allow for diseases
- For example, persons with some diseases have much lower chances of being employed

Possible data sources

- Longitudinal surveys (often limited in size)
- Censuses and surveys
- Administrative data (education, taxation, immigration…)
- Birth, marriage, divorce & death records
- Disease models

Data available are rarely enough, so assumptions have to be reverse-engineered to match data. Validation of simulation outputs against data is essential.

Conclusions

- Expert advice on the causes of past mortality changes, and on likely future trends, is needed
- Individual life expectancies depend strongly on cohabitation status, education and income, and on existing diseases
- Microsimulation may be the only feasible method of estimating individual life expectancies, taking into account personal situation and health.

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