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An analysis of health risk and health care usage
The UK experience

Professor Les Mayhew Hon FFPH, Hon FIA
Faculty of Actuarial Science and Insurance
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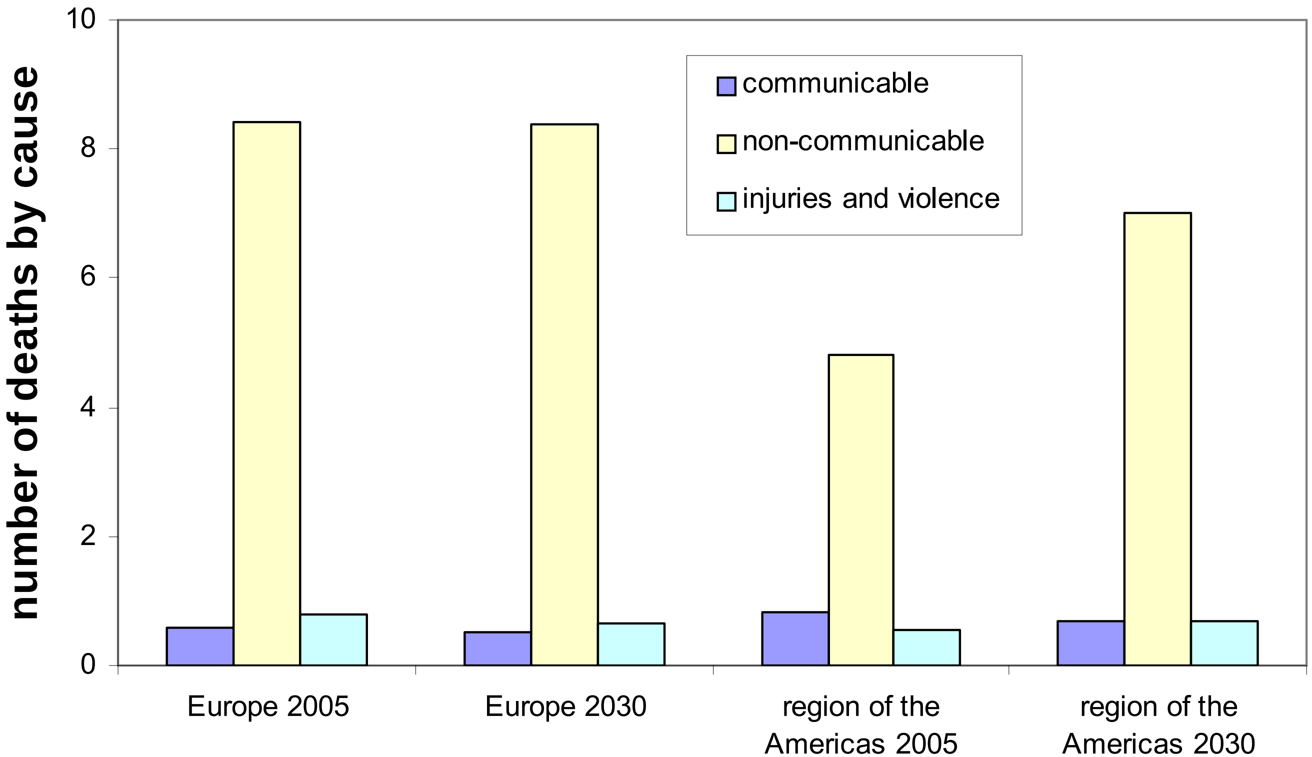
Global Burden of Disease



Source: WHO

C. Mathers and D. Loncar ‘Projection of global mortality and burden of disease from 2002 to 2030 PloS medicine (update on original GBD study by Murray and Lopez, 1990)

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Leading causes of death in 2030

Cause of death	World rank	rank in high income countries
Ischaemic heart disease	1	1
Cerebrovascular disease	2	2
Lung cancer	6	3
Diabetes	7	4
COPD	4	5
Lower respiratory infections	5	6
Alzheimers	-	7
HIV/AIDS	3	-
Colon/ rectal cancer	-	8
Stomach cancer	10	9
Prostate	-	10

C. Mathers and D. Loncar 'Projection of global mortality and burden of disease from 2002 to 2030 PloS medicine (update on original GBD study by Murray and Lopez 1990)

Diseases investigated

‘A long term condition that can be treated and managed but not cured’

- Coronary heart disease
- Hypertension
- Diabetes
- Chronic obstructive pulmonary diagnosis (COPD)
- Stroke

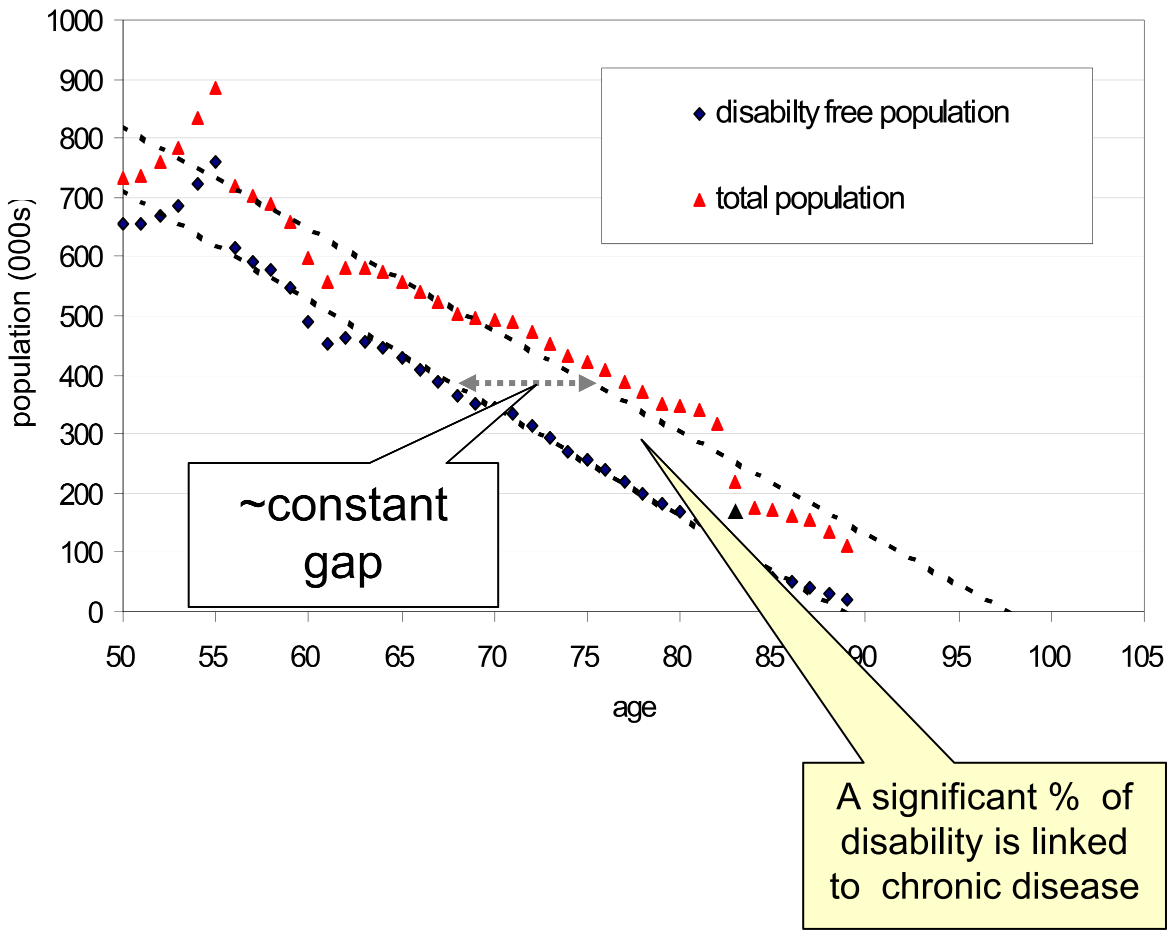
Scope

- A simplified UK demography of disability and chronic disease
- Research publication: ‘Chronic disease burden – and analysis of health care risk and health care usage’
  - Scope
  - Data sources used
  - Techniques
  - Results
  - Further applications
- Conclusions

UK health care system

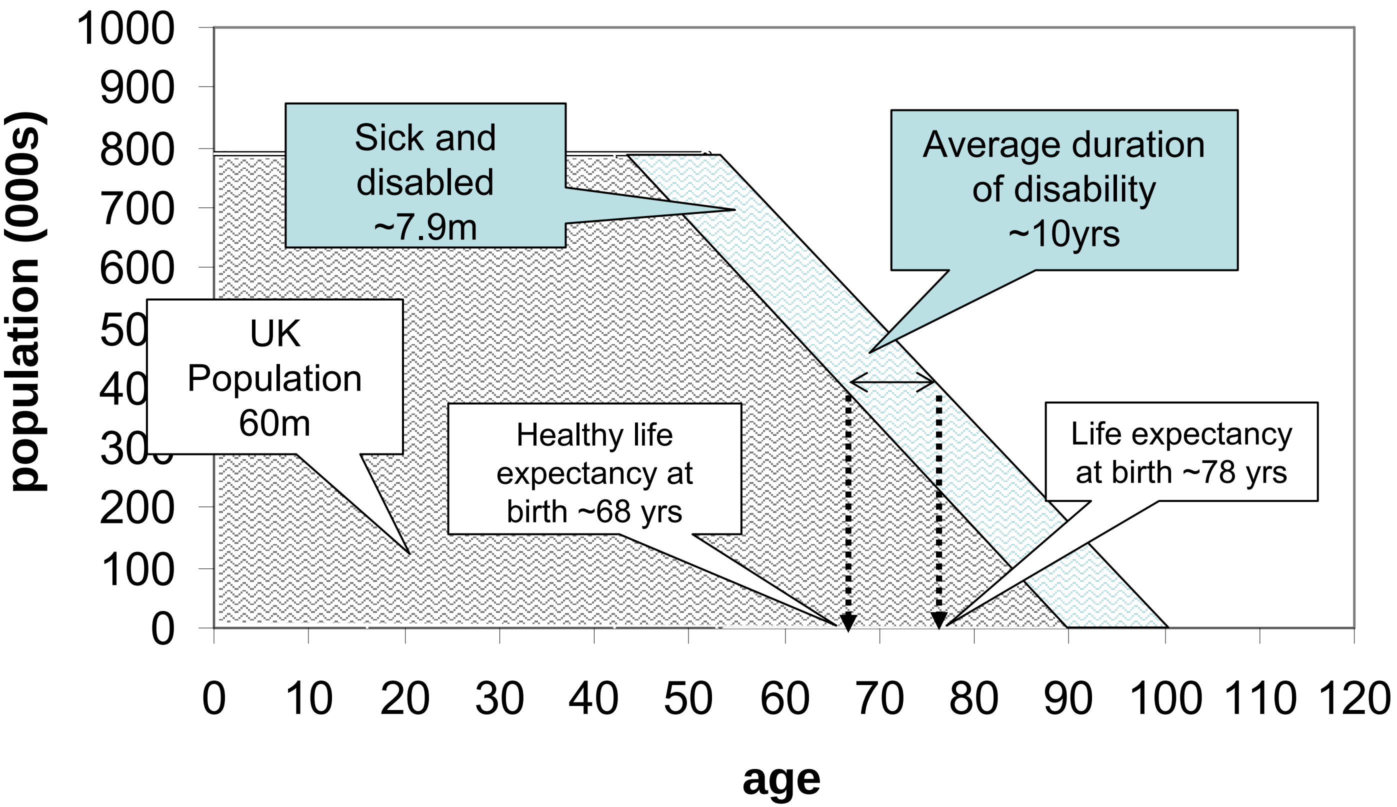
- UK spends about 9% of GDP on health care
- Publicly funded free at point of use but may be required to pay for long term care and dentistry
- NHS is the main provider of health care with small but stable private medical care sector
- GPs (general practitioner family doctors) are gateways to treatment and specialists
- Unified system of life time medical records held by GPs of all registered patients (about 97% of population)
- GPs are commissioners of services and are separate from providers
- Increasingly providers will include private sector to ramp price up competition and quality
- Such changes are expected to lead to continuous improvements in data quality

Disability prevalence in the UK among population aged 50+

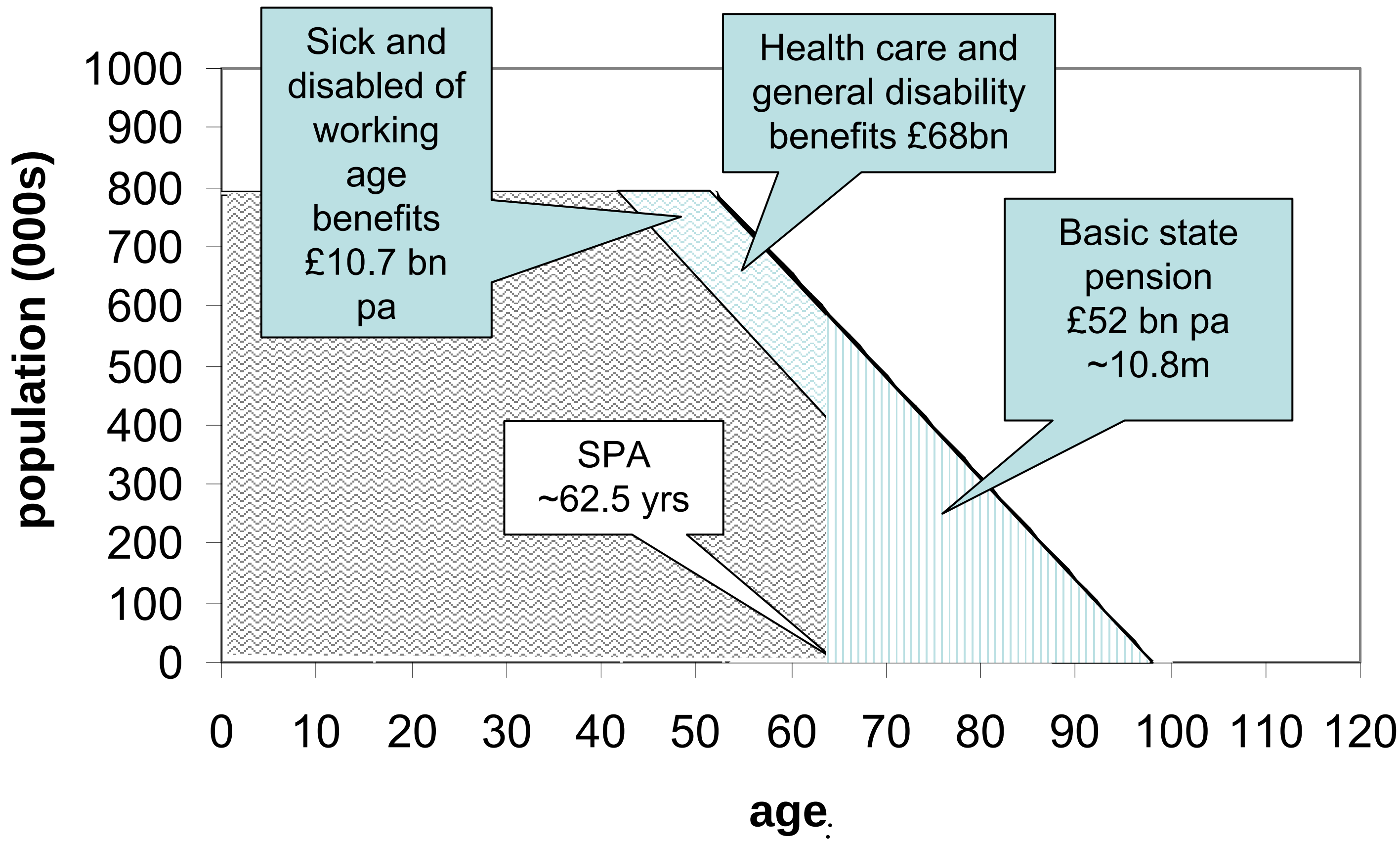


- *The number of disabled is broadly constant at any age*
- *Prevalence of disability increases with age.*
- *Constant gap indicated suggests that the period spent in disability, prior to death may not be strongly dependent on age*

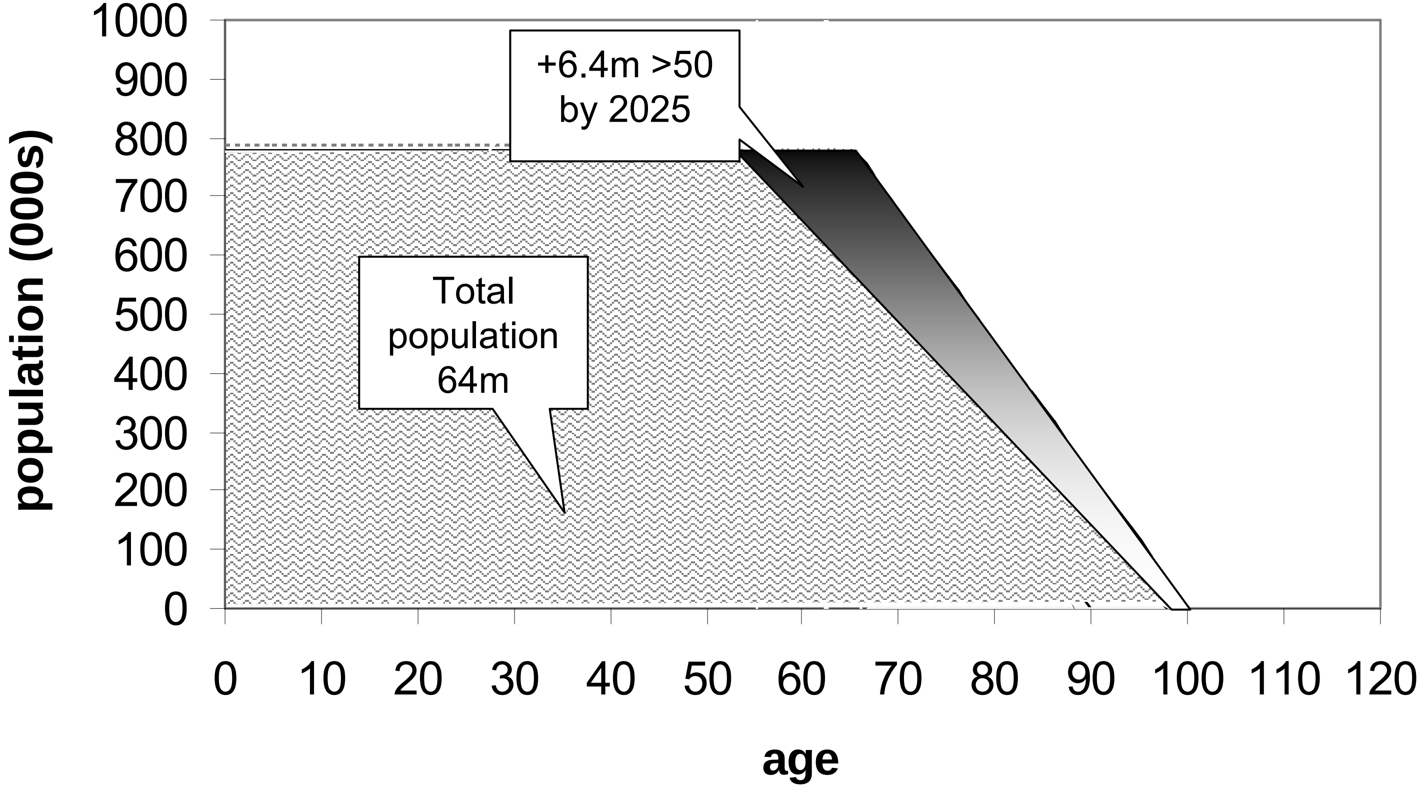
Demography and the strategic significance of disability



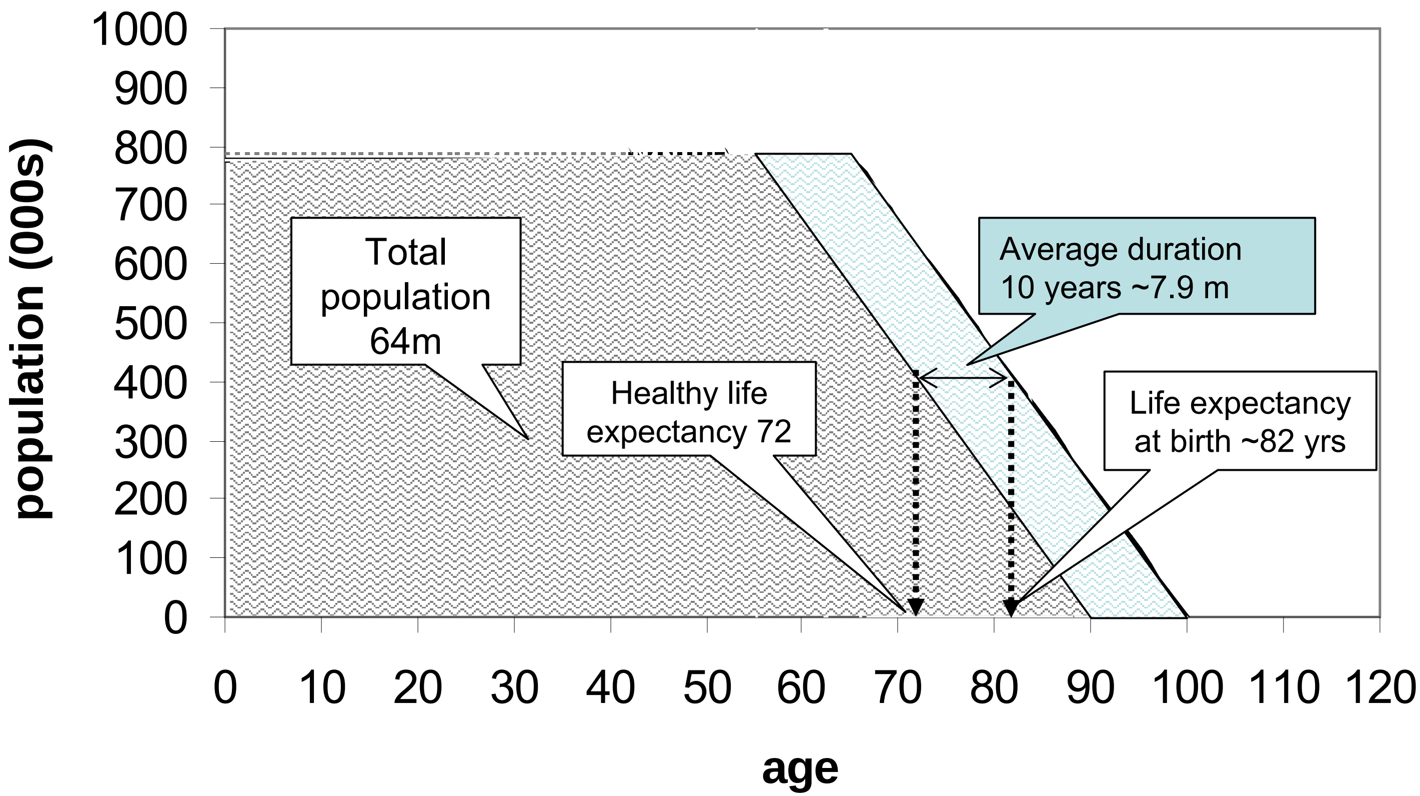
Public expenditure consequences of old age, disability and ill health



Changes to the UK population in 2025

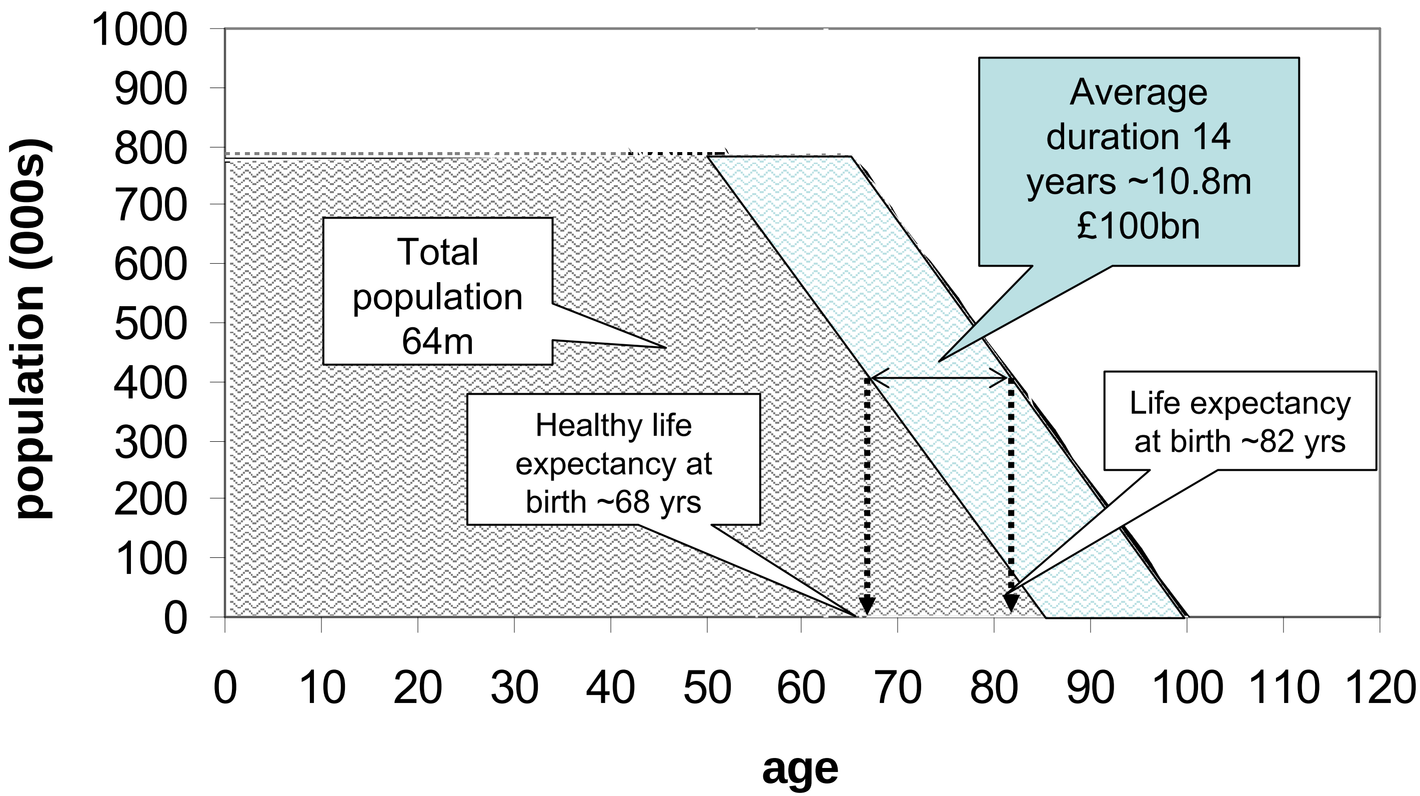


Scenario 1 -Healthy life expectancy moves in step with life expectancy



Note: LTC – long term care

Scenario 2: Healthy life expectancy unchanged



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Key issues for public policy

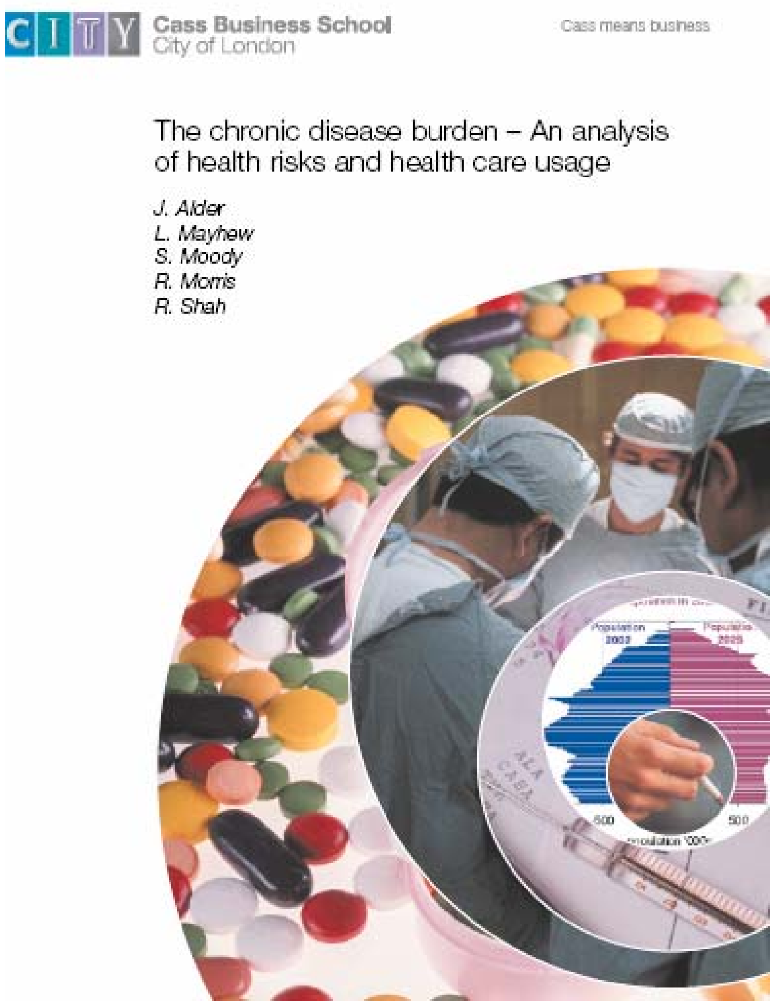
- Chronic disease account for significant percentage of disability
- Disability is an important constraint on economic activity
- Life style factors can accelerate the onset of chronic disease, especially smoking, exercise and diet
- Little known about co-morbidity and disease progression that could lead to early identification of risk and possible intervention
- Need to know cost effectiveness of public health campaigns and policy - prevention versus cure
- One element of this is better targeting, another is behaviour modification

Aims of the chronic disease project

- To learn about chronic diseases: their prevalence, cost and progression

- Bring data together from different sources

- To further actuarial knowledge in this area using non-standard techniques



Background to the data used

- Medical records:
  - Records have been largely computerised
  - Medical records are included in the basis for remunerating general practitioners

- Local administrative data:
  - Local areas keep registers of all properties
  - Data on housing, related social security benefits and other public sector services

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Particular data sources used

- 'THIN' data – GP encounter data over a number of years covering approx 5m patients covering the whole UK

- Islington data (a socially mixed inner city district in central London) – snapshot data covering 25,000 linkable to other administrative data such as property taxes

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Areas of focus

- Measurement of morbidity co-prevalence
- Risk analysis
- Pathways to chronic disease
- Identifying impact of social factors using ‘neighbourhood analysis
- Survival analysis
- Health care utilisation

Methodology

Methodology

• Use ‘Risk Ladders’ to investigate co-morbidity and chronic disease risk factors such as smoker, BMI and housing status

• Use larger data set to quantify effect of different disease combinations on doctor visits, hospital outpatient attendance and admission

•Include risk modifiers such as age, gender, smoker and BMI status

•Benchmark results where possible by literature.

The use of ‘risk ladders’ in risk analysis - some terminology

- A summary table
- An ordered table (i.e. in event order)
- A risk ladder
- A risk tree
- A risk map

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Structure of a summary table

Patients are bar coded by diagnosis

Case	*ABC*	*Observed n*	*A*	*B*	*C*
1	000	n_1			
2	100	n_2	n_2		
3	010	n_3		n_3	
4	001	n_4			n_4
5	110	n_5	n_5	n_5	
6	101	n_6	n_6		n_6
7	011	n_7		n_7	n_7
8	111	n_8	n_8	n_8	n_8
	Total	$\sum_i n_i$	$\sum_{i \in A} n_i$	$\sum_{i \in B} n_i$	$\sum_{i \in C} n_i$
	Prevalence (p)	$\bar{p}$	p_A	p_B	p_C

A summary table has 2^n rows where n is the number of factors

A summary table is an exhaustive representation of all subjects according to diagnosis

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Example of a summary table

Case	*ABC*	*Observed n*	*A*	*B*	*C*
1	000	22546			
2	100	176	176		
3	010	202		202	
4	001	1088			1088
5	110	19	19	19	
6	101	121	121		121
7	011	186		186	186
8	111	63	63	63	63
	Total	24401	379	470	1458
	prevalence (p)	*0.03155*	*0.0155*	*0.0193*	*0.0598*

A -Coronary heart disease
B -Diabetes
C -Hypertension

Structure of an ordered table

case	*ABC*	*Observed n*	*A*	*B*	*C*
1	000	n_1			
2	100	n_2	n_2		
3	010	n_3		n_3	
4	001	n_4			n_4
5	120	n_5	n_5	n_5	
6	210	n_6	n_6	n_6	
7	102	n_7	n_7		n_7
8	201	n_8	n_8		n_8
9	012	n_9		n_9	n_9
10	021	n_{10}		n_{10}	n_{10}
11	123	n_{11}	n_{11}	n_{11}	n_{11}
12	132	n_{12}	n_{12}	n_{12}	n_{12}
13	213	n_{13}	n_{13}	n_{13}	n_{13}
14	312	n_{14}	n_{14}	n_{14}	n_{14}
15	231	n_{15}	n_{15}	n_{15}	n_{15}
16	321	n_{16}	n_{16}	n_{16}	n_{16}
	Total	$\sum_i n_i$	$\sum_{i \in A} n_i$	$\sum_{i \in B} n_i$	$\sum_{i \in C} n_i$
	Prevalence (p)	$\bar{p}$	p_A	p_B	p_C

	Number of factors m					
	1	2	3	4	5	6
sequences	2	5	16	65	326	1957
m!e	2.718	5.4	16.3	65.3	326.2	1957.2

A bar code sequence is defined as an ordering of diagnoses:

0 = no diagnosis

1 = first diagnosis

2 = second diagnosis

3= third diagnoses

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Example of an ordered table

Case	*ABC*	*Observed n*	*A*	*B*	*C*
1	000	22546			
2	100	176	176		
3	010	202		202	
4	001	1088			1088
5	120	13	13	13	
6	210	6	6	6	
7	102	58	58		58
8	201	63	63		63
9	012	83		83	83
10	021	103		103	103
11	123	8	8	8	8
12	132	10	10	10	10
13	213	7	7	7	7
14	231	13	13	13	13
15	312	11	11	11	11
16	321	14	14	14	14
	Total	24401	379	470	1458
	Prevalence (p)	*0.03155*	*0.0155*	*0.0193*	*0.0598*

A -Coronary heart disease
B -Diabetes
C -Hypertension

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A risk ladder

Case	*ABC*	*Observed n*	*A*	*B*	*C*	*Number of times D observed*	*Risk*
1	000	n_1				m_1	$r_i = \frac{m_i}{n_i}$
2	100	n_2	n_2			m_1	$r_i = \frac{m_i}{n_i}$
3	010	n_3		n_3		m_1	$r_i = \frac{m_i}{n_i}$
4	001	n_4			n_4	m_1	$r_i = \frac{m_i}{n_i}$
5	110	n_5	n_5	n_5		m_1	$r_i = \frac{m_i}{n_i}$
6	101	n_6	n_6		n_6	m_1	$r_i = \frac{m_i}{n_i}$
7	011	n_7		n_7	n_7	m_1	$r_i = \frac{m_i}{n_i}$
8	111	n_8	n_8	n_8	n_8	m_1	$r_i = \frac{m_i}{n_i}$
	Total	$\sum_i n_i$	$\sum_{i \in A} n_i$	$\sum_{i \in B} n_i$	$\sum_{i \in C} n_i$	$\sum_i m_i$	$\bar{r} = \frac{\sum_i m_i}{\sum_i n_i}$
	prevalence (p)	$\bar{p}$	p_A	p_B	p_C	p_C	

A - Coronary heart disease
B - Diabetes
C – Hypertension
D- Stroke

Example of risk ladder – outcome stroke

case	ABC	frequency	A	B	C	stroke	%stroke
1	111	63	Y	Y	Y	11	17.5
2	101	121	Y		Y	14	11.6
3	100	176	Y			17	9.7
4	011	186		Y	Y	14	7.5
5	001	1088			Y	63	5.8
6	110	19	Y	Y		1	5.3
7	010	202		Y		7	3.5
8	000	22546				84	0.4
	total	24401	379	470	1458	211	0.9
		prevalence	0.0155	0.0193	0.0598	0.0086	

A - Coronary heart disease
B - Diabetes
C – Hypertension
D- Stroke

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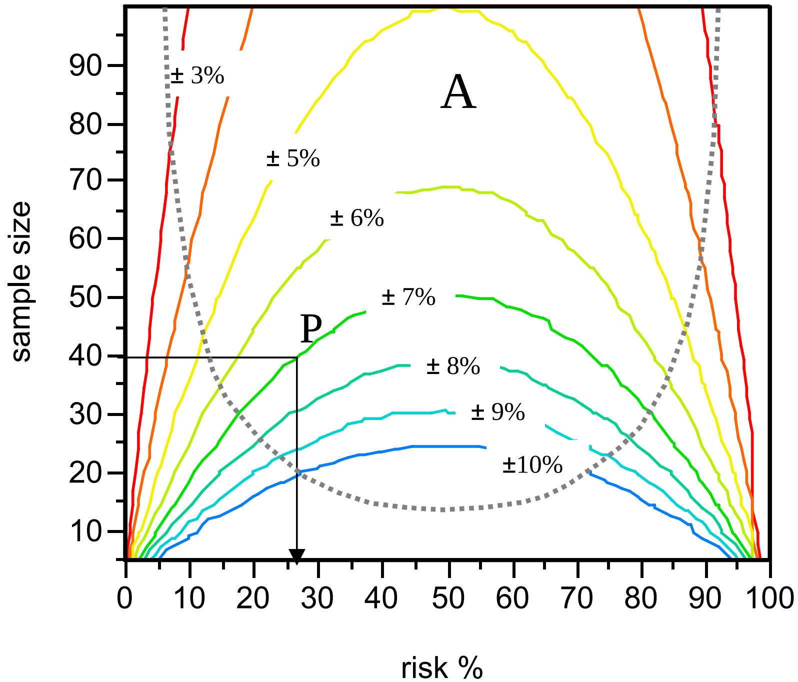
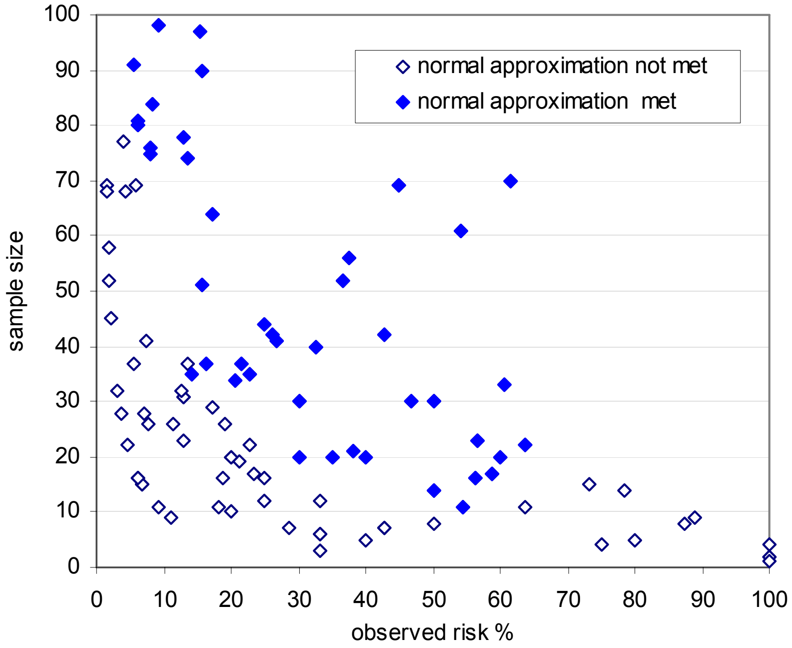
Adding confidence limits to risk ladders





Use the normal approximation to the binomial distribution only when *nr>5* and *n(1-r)>5*

Adding life style and other risk factors

- Gender
- Housing
- Smoking status
- BMI status
- Co-morbidity

This risk ladder, with 64 rows, would show that:
.

❑ Female risk of having CHD with no factors present is 0.3% whereas male risk is 0.4%

❑ Male risk for smoker with a high BMI increases to 3.6% and female risk to 1.5%

❑ Living low value housing increases male CHD risk with no other factors to 0.7%

Risk increases if hypertension or diabetes is present. Thus:

❑ a male smoker with diabetes has a 7.3% risk which increases to 12.5 % if he has a BMI of over 30.

❑ this increases to 15.5% if diabetes is replaced by hypertension.

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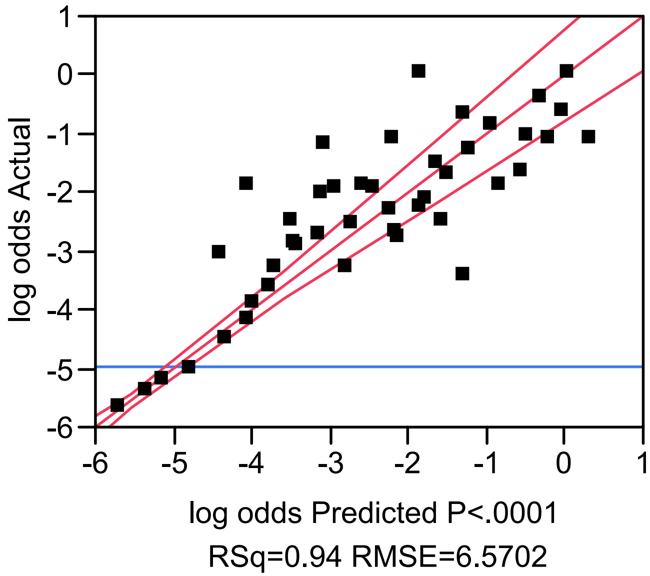
Fitting logistic models to risk ladders



Predicted odds of having CHD increase:

- 1.4 times if person is a male
- 1.3 times if person has BMI>30
- 1.7 times if person lives in low value housing
- 3.9 times if person is smoker
- 3.6 times if person has diabetes
- 9.2 times if person has hypertension

- To check on robustness of factors
- Derive other useful statistical diagnostics
- Extend model in other ways

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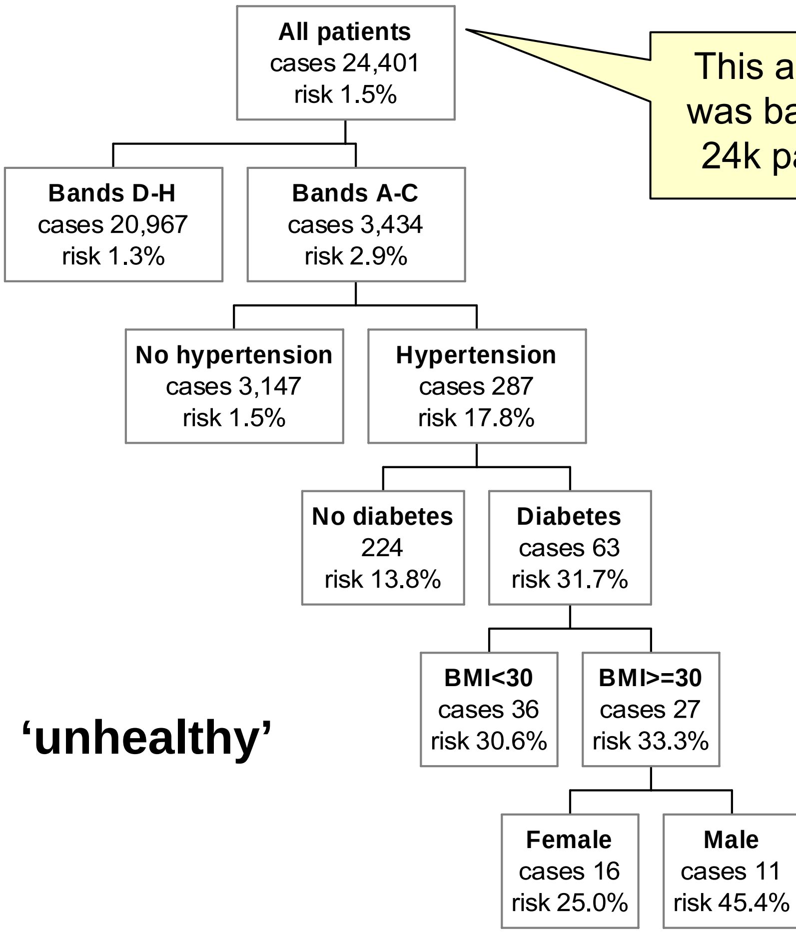
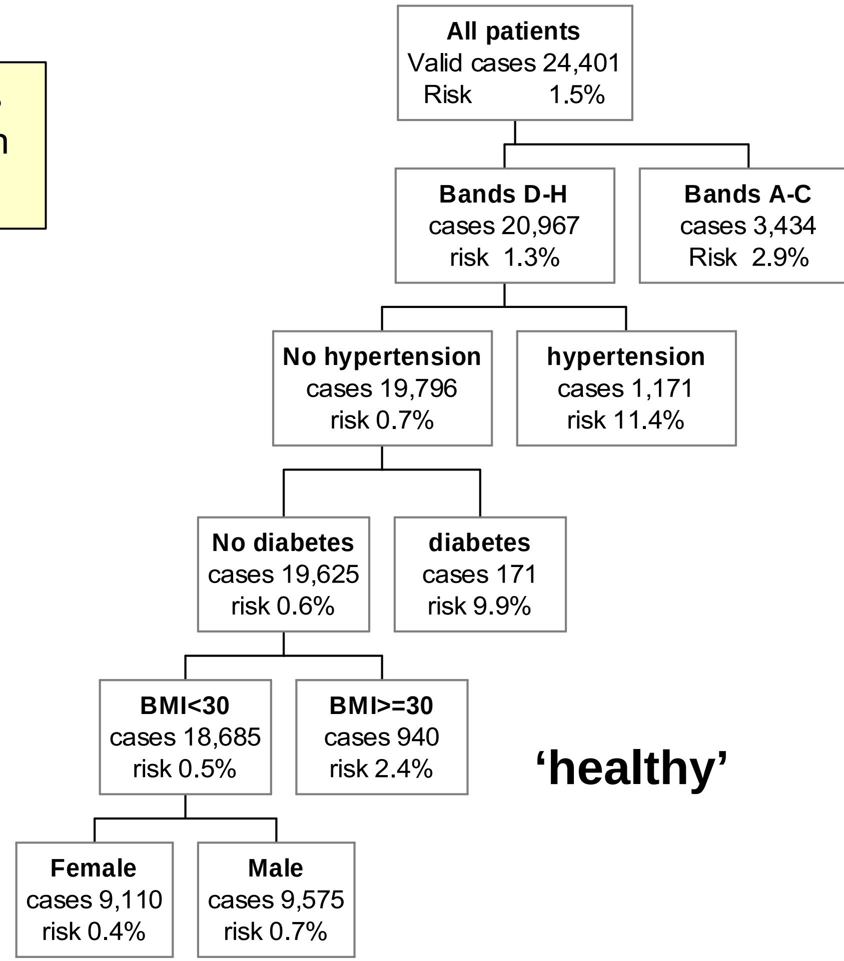
Drilling down using ‘risk trees’



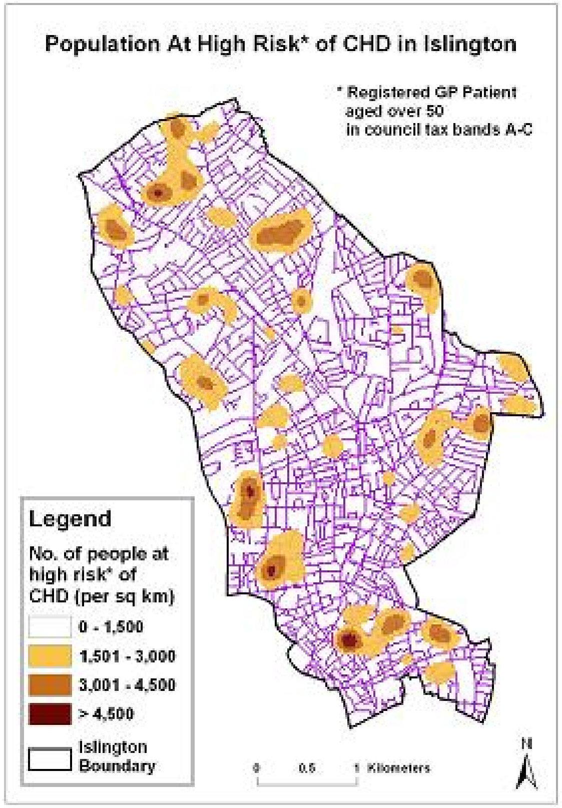
This analysis was based on 24k patients

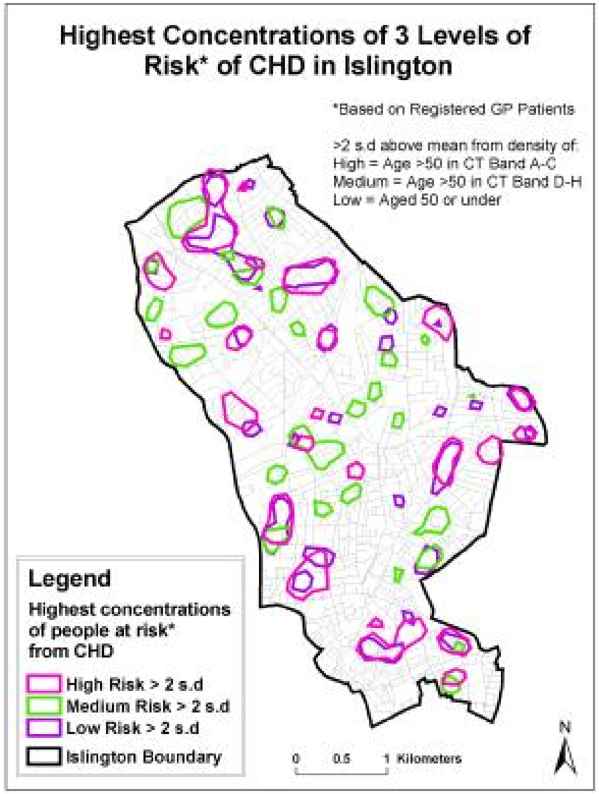
‘unhealthy’



‘healthy’

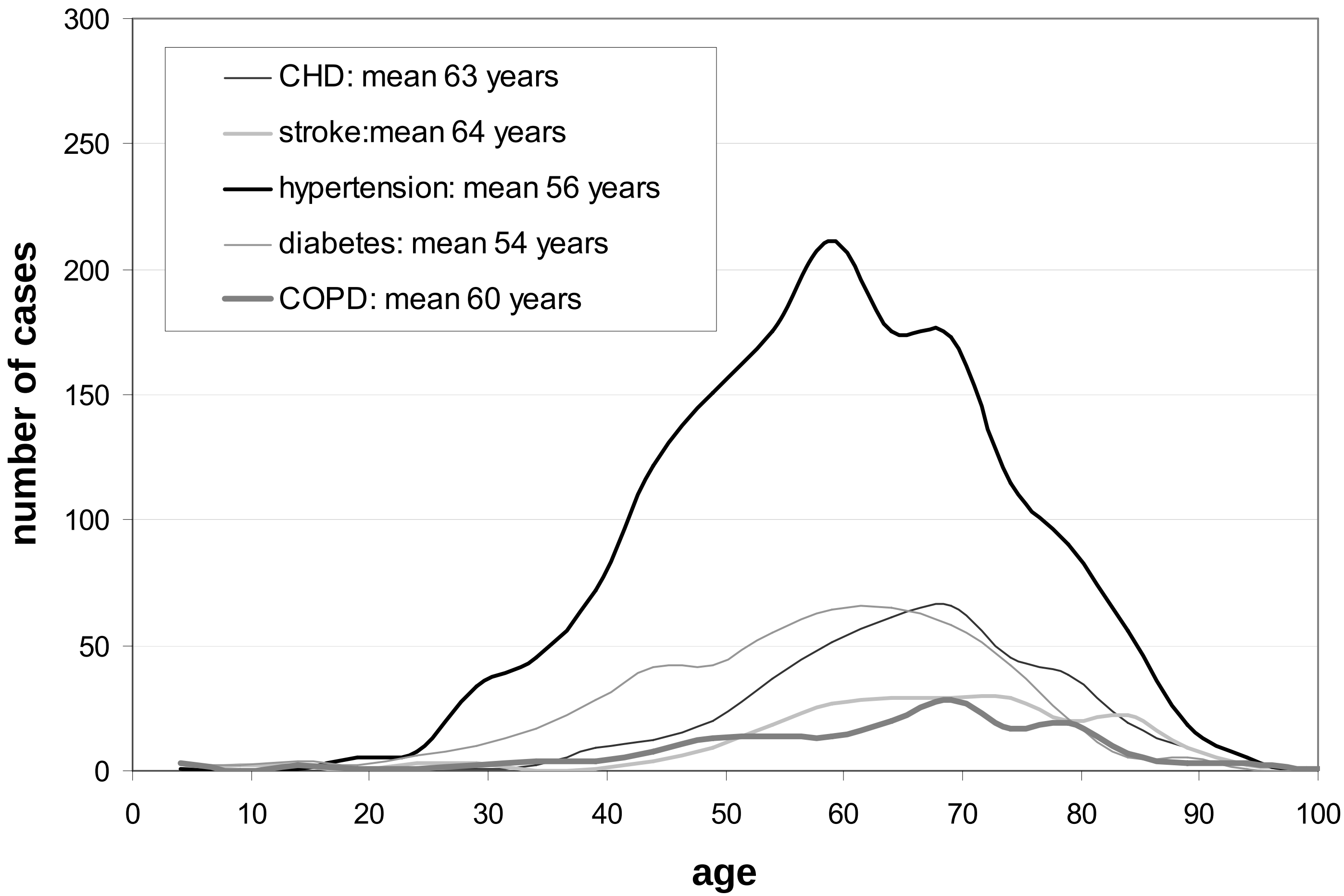
Adding the geographical dimension



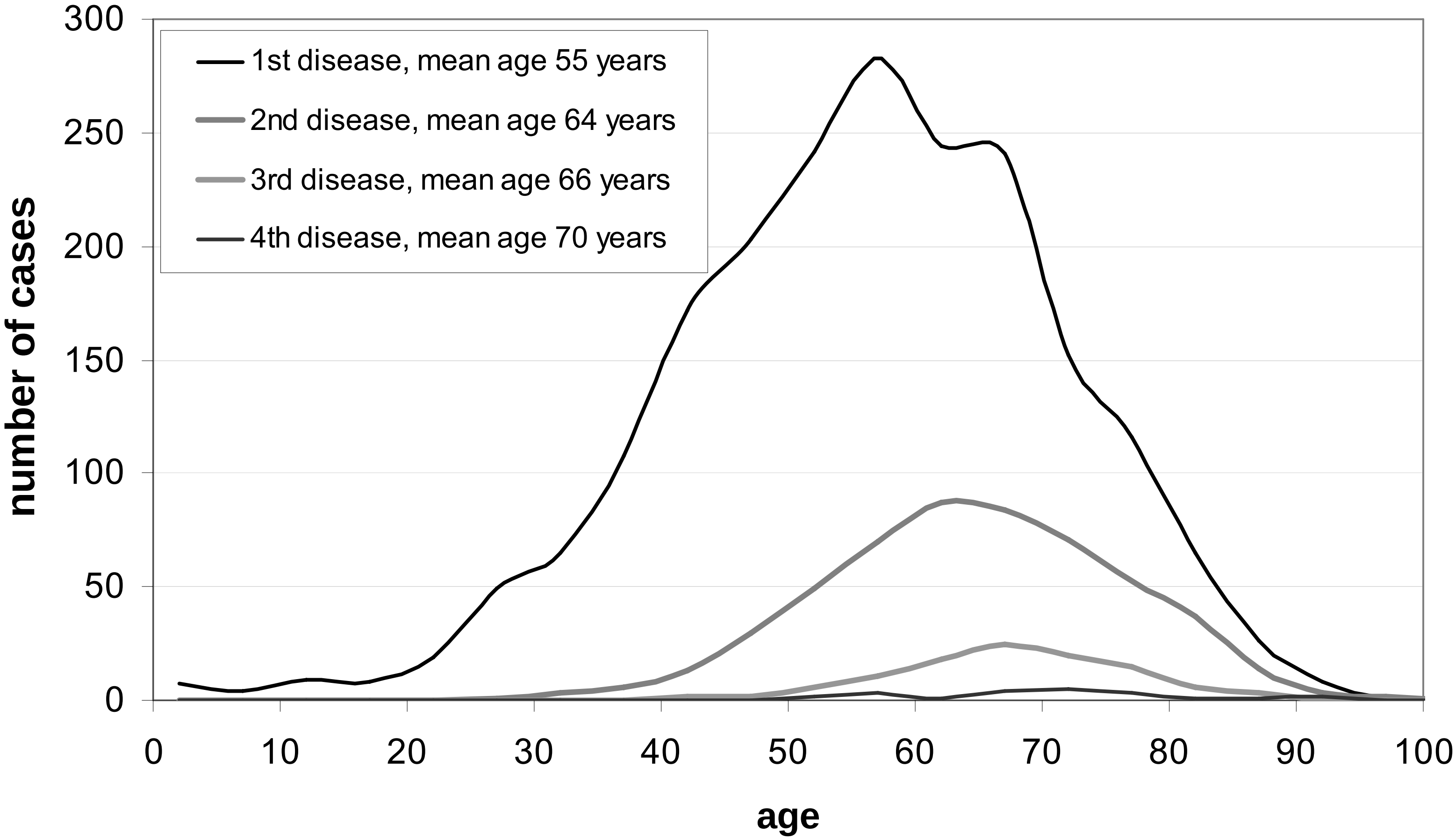


Risk was individually assessed and patients geo-referenced according to where they lived and then risk mapped

Adding the age dimension

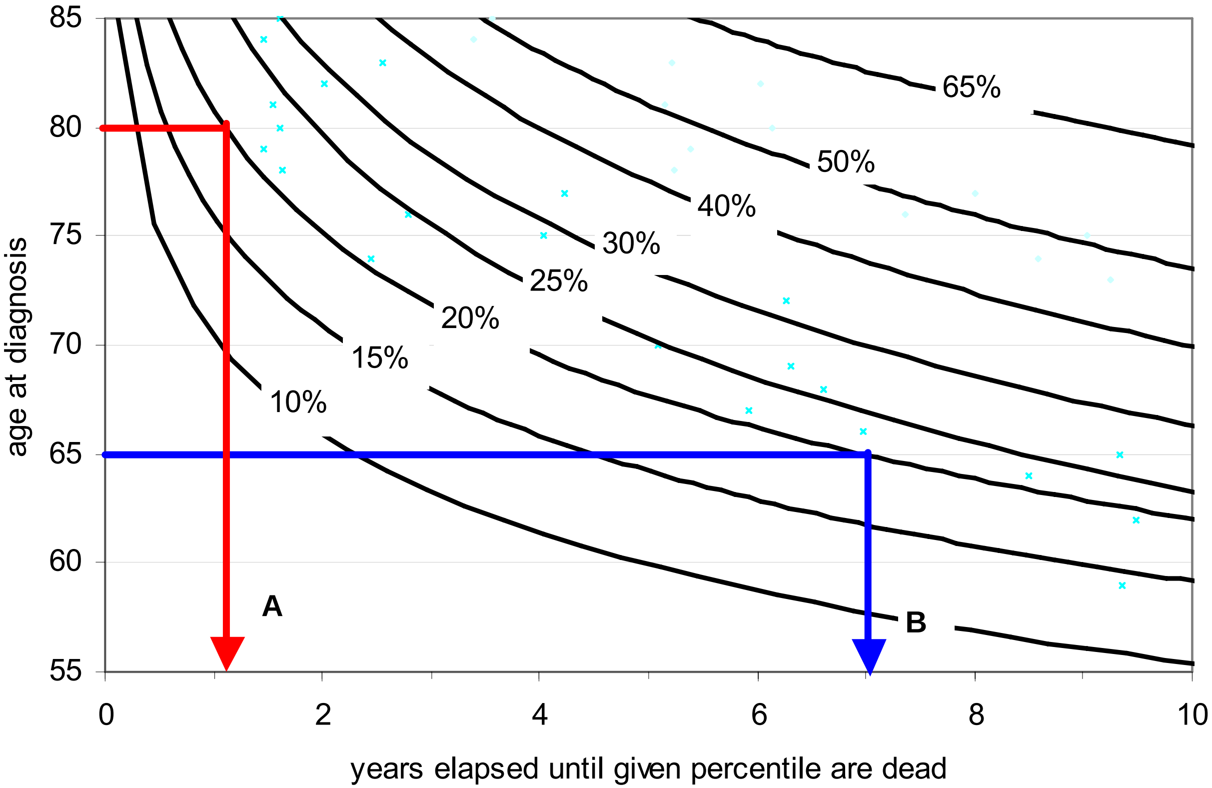


Adding the age-co-morbidity dimension



Survival analysis

Given you are diagnosed with 'x' at age 'y' how long do you have to live?



Example:

20% of males diagnosed with CHD at age 80 can expect to die within about a year (point A); if aged 65 20% can expect to die within 7 years (point B).

Research questions with actuarial applications

- Probability that an individual, diagnosed at age x (1) with chronic disease i dies before age x(2)
- Probability that individual diagnosed with disease 1 at age x(1) , with disease 2 at age x(2), …., etc. dies between ages y(1) and y(2)
- Probability that an individual will survive and be healthy up to age x to calculate the expected healthy life span
- Calculate the expected time to death, given that the individual has suffered chronic diseases, with indexes 1, 2 ,3 etc before dying.
- Calculate the expected time spent in disability as the difference between expected healthy life span and expected time to death.
- Calculate the effect of eliminating one, two or any number of chronic diseases on expected life spans

Analysing health care

- About the ‘THIN’ data set
- Illustrative application:
  - use of health services based on age, gender, lifestyles and diagnosis
- Concluding remarks and extended applications

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About the 'THIN' data set

- Automatic monthly collection of data from 250+ GP practices around country
- Includes current and deceased patients from people alive in 1989 onwards
- Provides a longitudinal records of patients registered with GPs in the sample
- Data consists of demographic, consultation, prescription information
- Information included on referrals to specialists and hospitals
- Contains some life style characteristics such as BMI, smoker status, blood pressure
- Covers the histories of around 4m patients
- Data are anonymised

'THIN' is a collaboration between EPIC, provider of patient level data for medical research, and In Practice Systems (InPS), developer of 'Vision' computer system.

Modelling health care utilisation

Hypothesis

- The annual number of visits to a doctor is a function of personal characteristics such as demographic factors, life style, and current morbidity
- These can be represented by variables such as age, sex, body-mass index (BMI), smoking status, disease diagnosis, etc.
- The relationship can be estimated by a regression model of the form

$$\log(\mu_i) = \beta_0 X_{i,0} + \beta_1 X_{i,1} + \beta_2 X_{i,2} + \ldots + \beta_{30} X_{i,30} = X_i^T \beta$$

- The response variable, the annual number of GP visits, is assumed to follow Poisson distribution with mean; X's are the known elements of vector for observation i, and β's are unknown parameters of coefficient vector to be estimated. Around 30 variables are used.

Frequency of GP visits by age and gender

Age	*Males*	*Females*
0-49	2.6	4.1
50-54	2.9	4.1
55-59	3.1	4.0
60-64	3.3	3.9
65-69	3.4	3.9
70-74	3.6	4.0
75-79	3.9	4.3
80+	4.1	4.3

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Sequence	COPD	Stroke	Hypertension	CHD	Diabetes	Relativity
1	Y	Y	Y	Y	Y	3.34
2	Y	Y	Y	Y	N	2.74
3	Y	Y	Y	N	Y	2.94
4	Y	Y	Y	N	N	2.24
5	Y	Y	N	Y	Y	3.46
6	Y	Y	N	Y	N	2.88
7	Y	Y	N	N	Y	2.54
8	Y	Y	N	N	N	2.25
9	Y	N	Y	Y	Y	3.00
10	Y	N	Y	Y	N	2.39
11	Y	N	Y	N	Y	2.63
12	Y	N	Y	N	N	2.03
13	Y	N	N	Y	Y	2.95
14	Y	N	N	Y	N	2.37
15	Y	N	N	N	Y	2.55
16	Y	N	N	N	N	1.91
17	N	Y	Y	Y	Y	2.32
18	N	Y	Y	Y	N	1.83
19	N	Y	Y	N	Y	2.11
20	N	Y	Y	N	N	1.61
21	N	Y	N	Y	Y	2.35
22	N	Y	N	Y	N	1.78
23	N	Y	N	N	Y	1.97
24	N	Y	N	N	N	1.49
25	N	N	Y	Y	Y	2.21
26	N	N	Y	Y	N	1.66
27	N	N	Y	N	Y	1.88
28	N	N	Y	N	N	1.31
29	N	N	N	Y	Y	2.05
30	N	N	N	Y	N	1.51
31	N	N	N	N	Y	1.66
32	N	N	N	N	N	1.00

Multiplicative effects of different chronic disease diagnoses:

For example a male aged 70-74 diagnosed with CHD and diabetes

Visits his GP on average

3.6 x 2.05 = 6.27 times a year

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Examples of findings based on analysis

The results show for example that:

- **A male non-smoker with a normal BMI visits his GP three times a year and is prescribed 18 sets of prescription drugs**

- **A male with a BMI>30 who has CHD and diabetes visits his GP 14 times a year and is prescribed 28 prescription drugs**

- **An underweight male (BMI<20) visits the GP as often as an obese male and is just as likely to be admitted to hospital**

- **A male non-smoker aged 75-79 has a 14% chance of being admitted to hospital compared with a 6% chance for a 50-year old male non-smoker**

In general:

- **Females visit the GP more often at every age but are less likely than males to be admitted to hospital at older ages**

- **Current and ex-smokers visit the GP more often, and are more likely to be referred to a consultant or be admitted to hospital**

Other work

- The CDB report also covers hospital admissions, specialist referrals, risk ladders for each disease etc.
- Updating our analysis to take advantage on data improvements since the introduction of new GP contracts
- Noticeable that BMI status and smoker status are acting as greater effect modifiers than in our previous analysis and that gradient between disease combinations has moderated

Modified relativities based on more recent data

BMI status	Relativity
Underweight(<20)	1.34
Normal(20-25)	1.00
Overweight(25-30)	1.36
Obese(30-35)	1.52
Morbidy Obese(35-40)	1.67
40+	1.74

Smoking status	Relativity
non smoker	1.00
current smoker	1.41
ex smoker	1.32

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Research agenda

- Quantifying impact of ageing population on health care utilisation and long term care
- Through inclusion of socio-economic risk factors, target health promotion and prevention initiatives
- Through the inclusion of ‘geography’ to target sub groups and areas
- Refinement of health insurance premiums e.g. rewarding people with healthy life styles
- Resource allocation in public medical systems (national and local health administrations)
- Assessing life time risk and typical chronic diseases pathways to identify and evaluate different types of intervention
- Combine with mortality analyses to investigate issues including co-morbidity and competing causes of death

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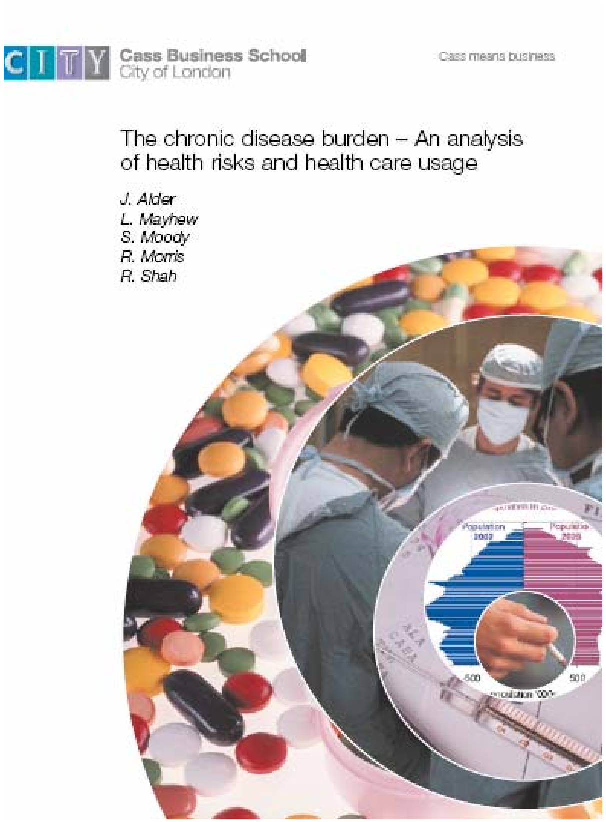
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Cass means business

The chronic disease burden – An analysis of health risks and health care usage

J. Alder
L. Mayhew
S. Moody
R. Morris
R. Shah

END

lesmayhew@blueyonder.co.uk