Health-Adjusted Life Expectancy (HALE) training workshop

Muscat – Nov 20 to 23 2023

Day 1 (Monday Nov 20th 2023)

Subject
GCC- Stat Welcome Remarks
GCDC Welcome Remarks
GCC – STAT experience in the exchange of statistical data and unifying concepts
Training objectives
Group Photo
Introduction of Participants and Facilitators
Monitoring health of populations; position of DALYs and HALE
BREAK
Calculating DALY & HALE; macroprocesses
Data requirements: Availability and Usability of data components
Orientation on the required software tools
Basic demography and life tables
Lunch Break
Calculating life expectancy (LE) / Practical data analysis with sample data

GCDC

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Monitoring Health of Populations; the Position of DALY and HALE

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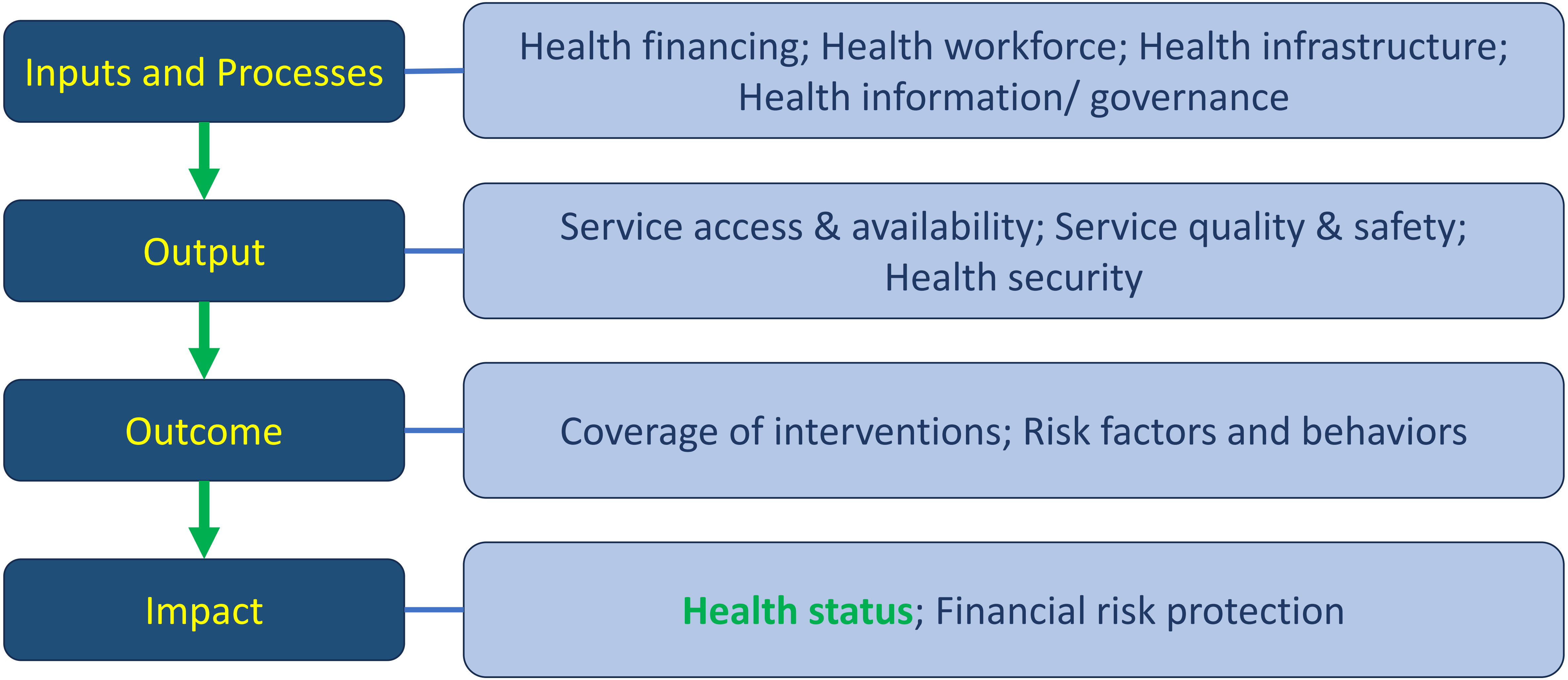
Core Health Indicators



WHO: Global reference list of 100 core health indicators

Health-Adjusted Life Expectancy (HALE)

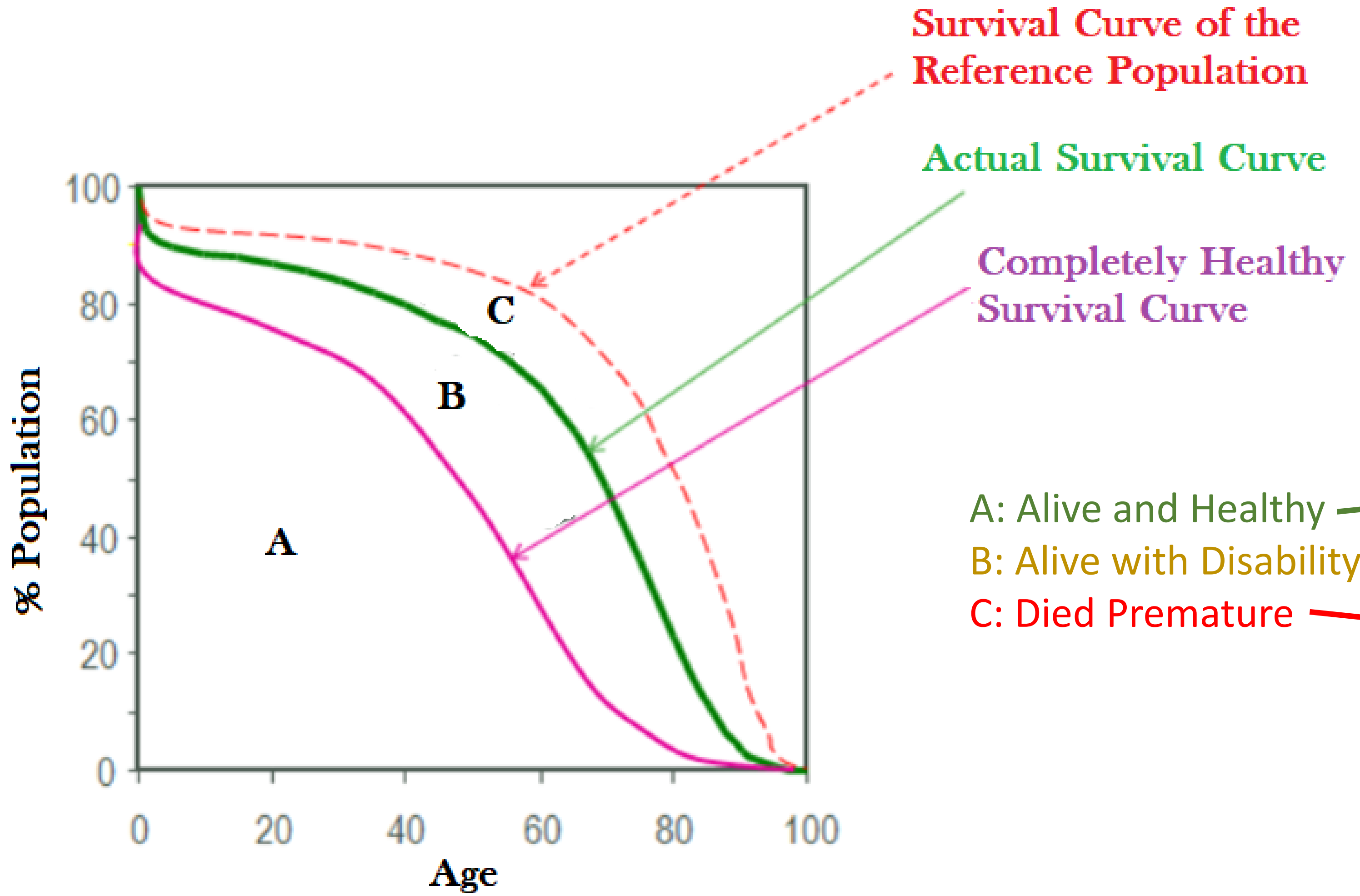
- An indicator of impact
- A summary measure of population health
- Comparable [Terms & Conditions apply!!]
- Quantification of fatal and non-fatal consequences of diseases in one number (at each age)
  - Mortality
  - Morbidity
  - Duration of disease
  - Severity of disease
  - Interventions

} **HALE**

Life Expectancy (LE) is the number of years that a person at a given age can expect to live.

Health-Adjusted Life Expectancy (HALE) is the number of years that a person at a given age can expect to live in good health, taking into account mortality and disability.

Population Health:
Health loss & Health expectancy

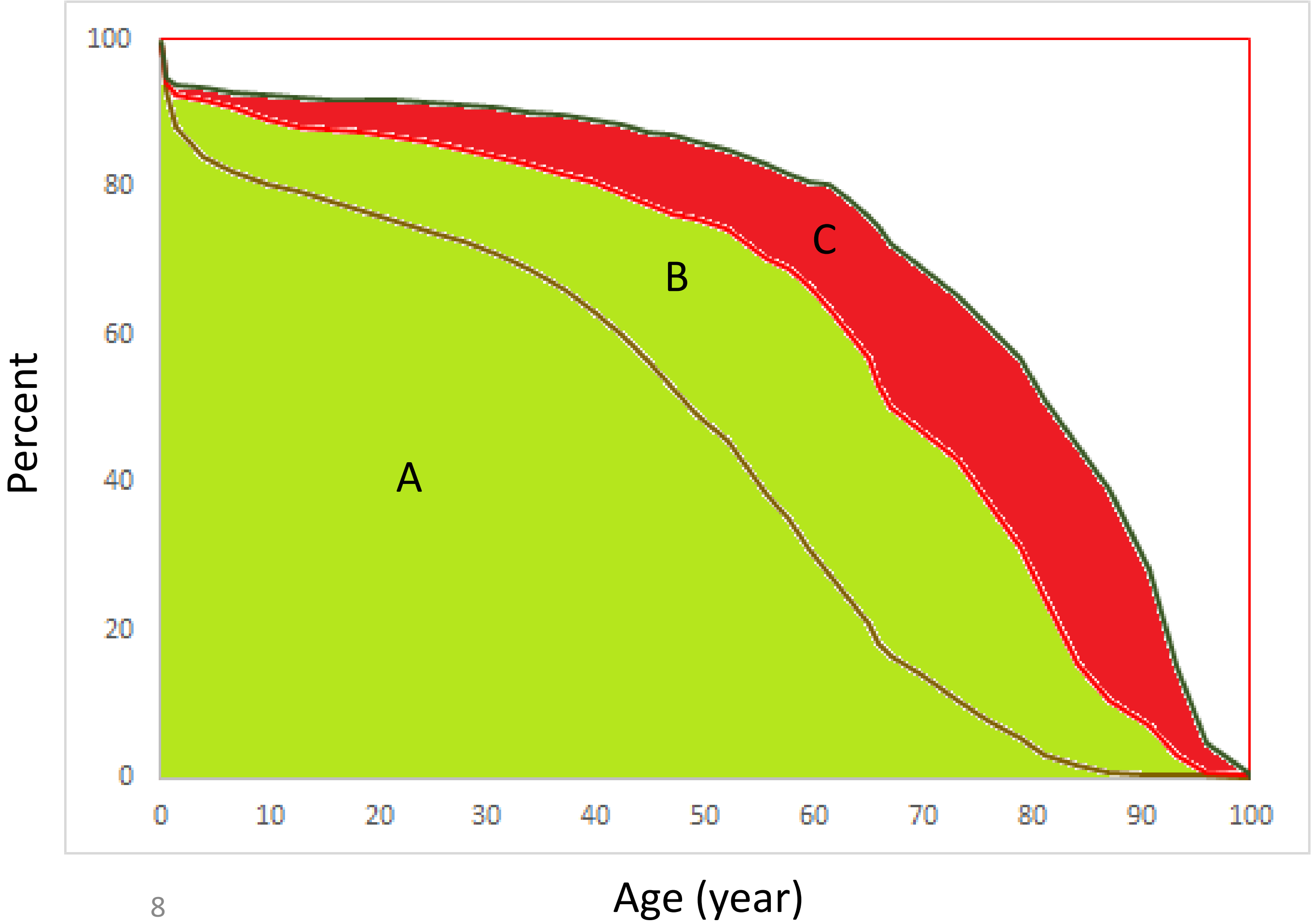


A: Alive and Healthy → Health expectancy = A + f(B)

B: Alive with Disability → Health expectancy; Health gap

C: Died Premature → Health gap = C + g(B)

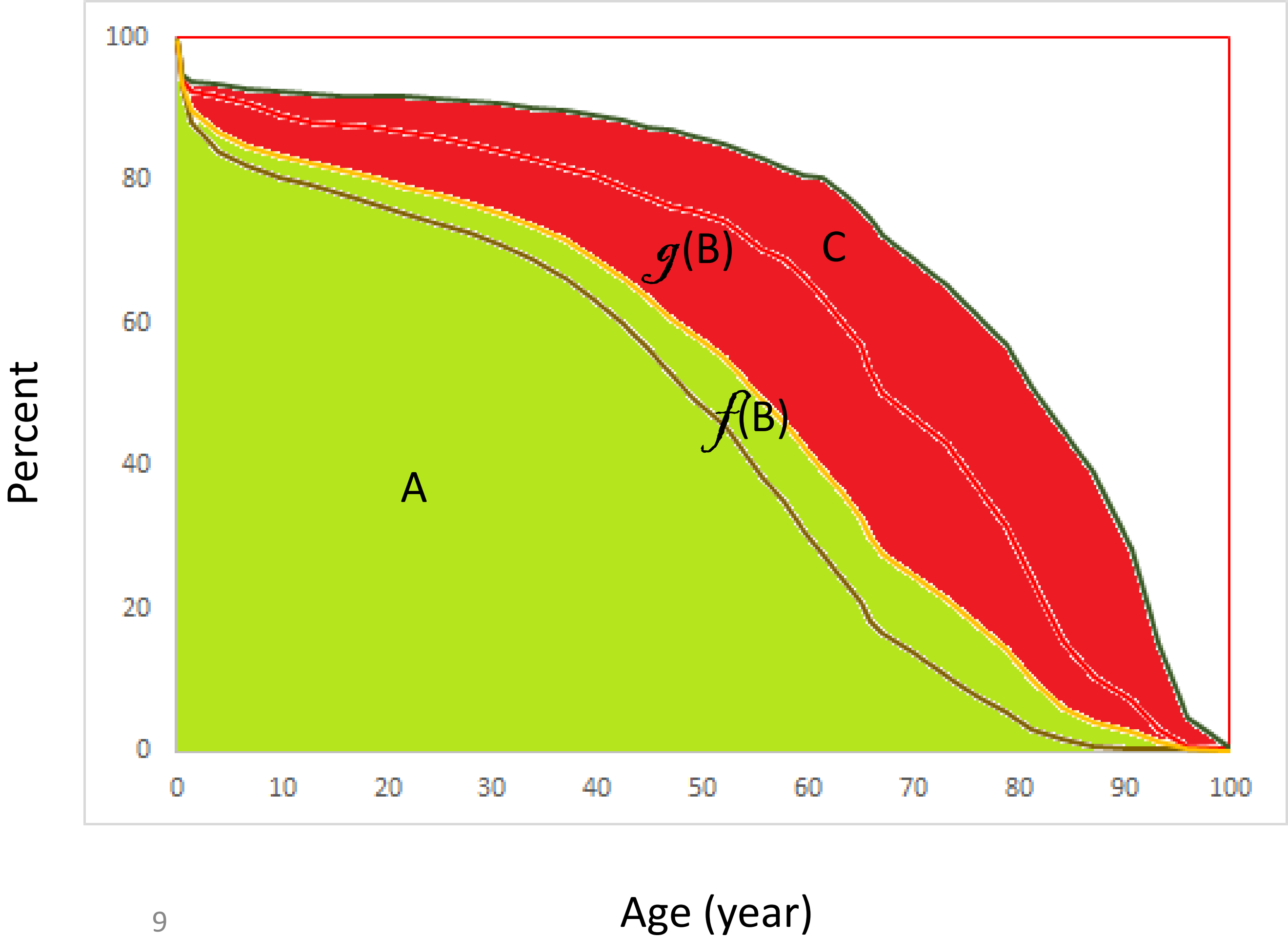
Years of Life Lost & Life expectancy



Life expectancy = A + B

Years of Life Lost (YLL)= C

Disability-adjusted Life Year (DALY) & Health-adjusted Life expectancy (HALE)



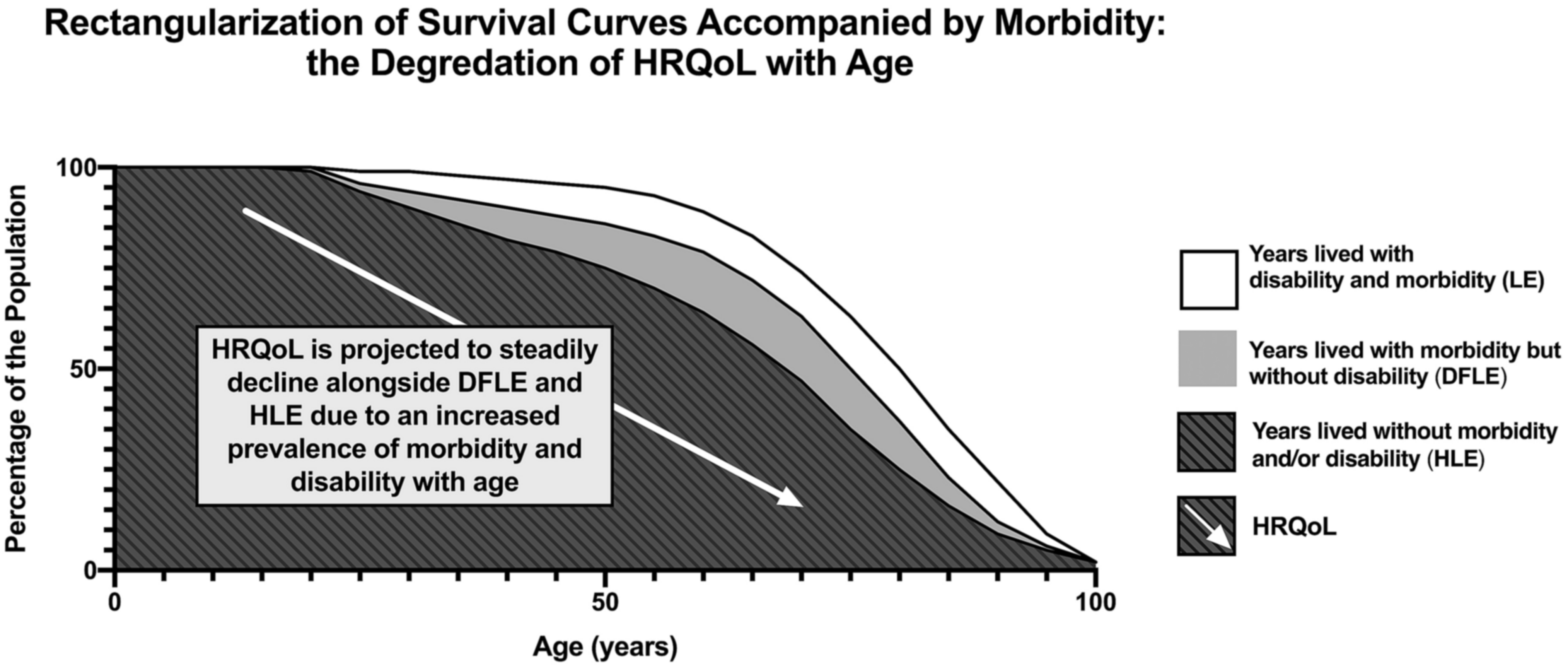
Health-adjusted Life expectancy = A + f(B)

Disability-adjusted Life Year= C + g(B)

g(B)= Years Lived with Disability (YLD)

Life expectancy - g(B) = HALE

Different terminologies



Calculating DALY & HALE: Macroprocesses

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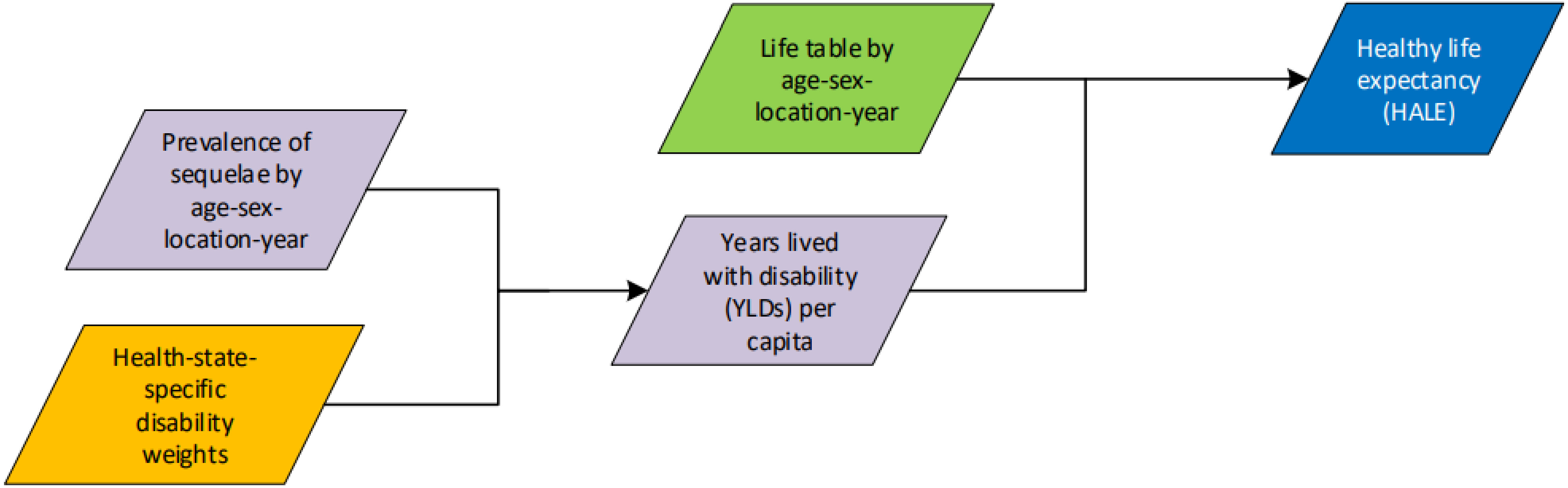
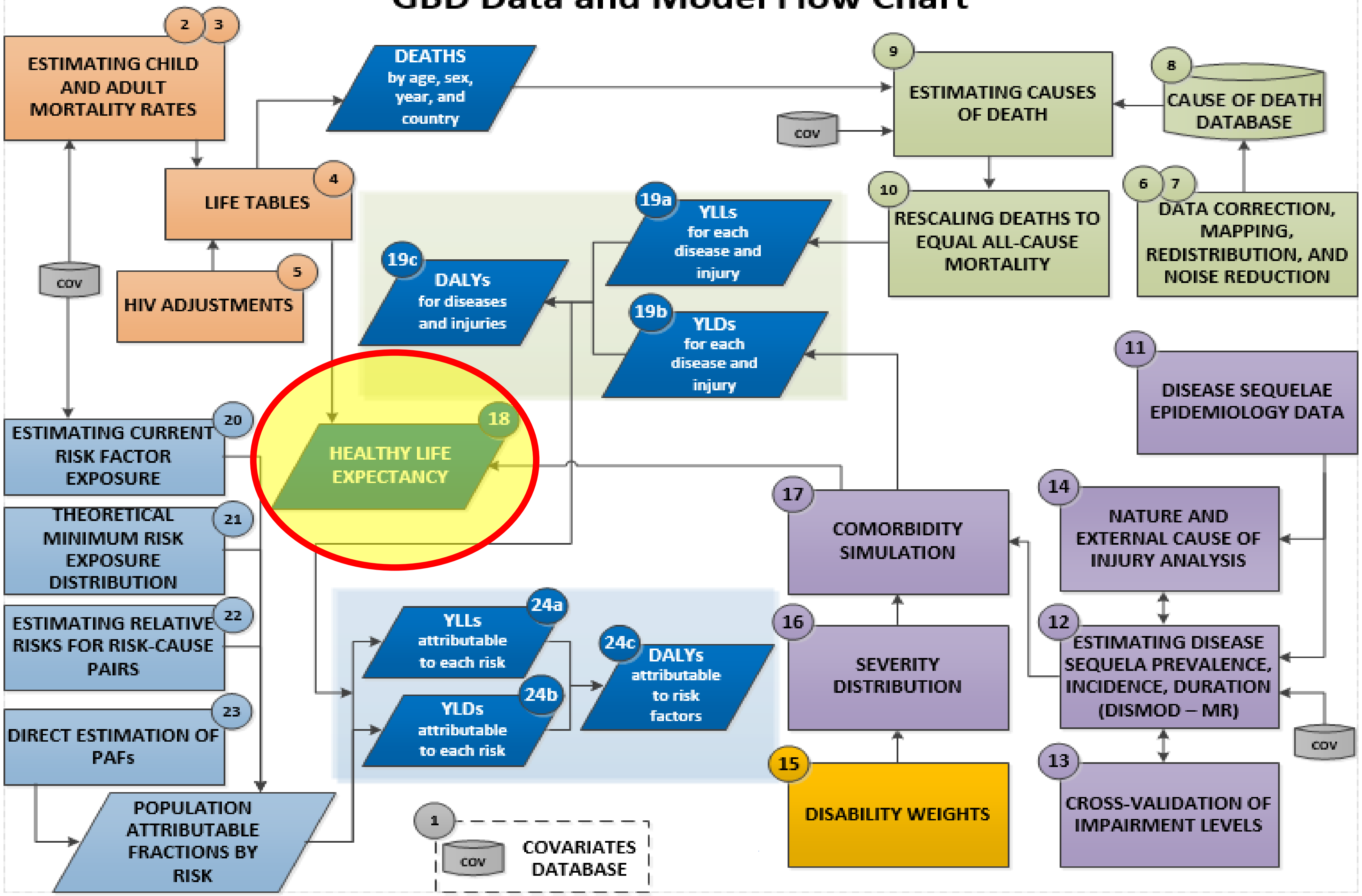
Simplified process for calculating HALE

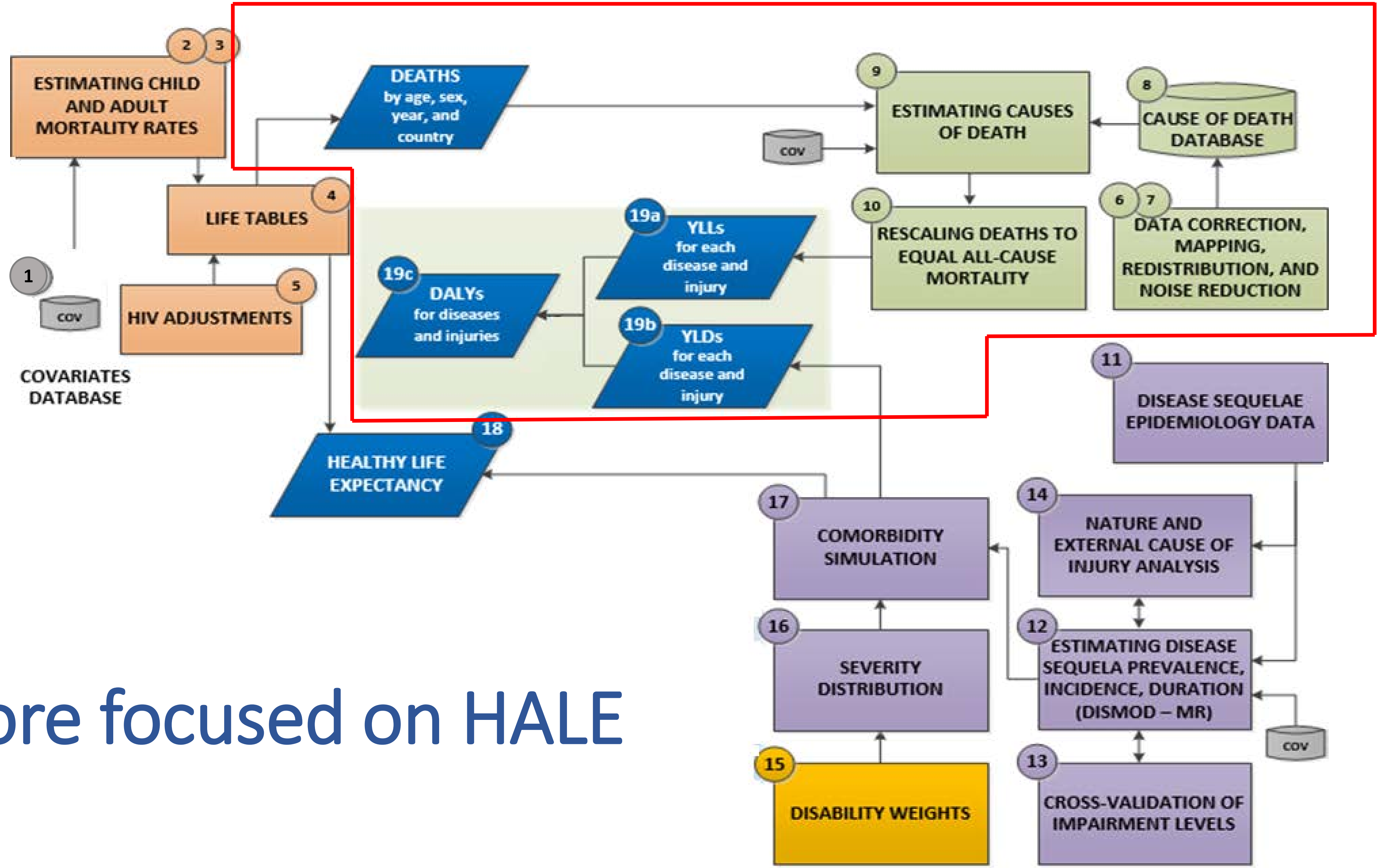


GBD 2017 (Appendix 1); GLOBAL HEALTH METRICS| 392(10159), P1859-1922, 2018

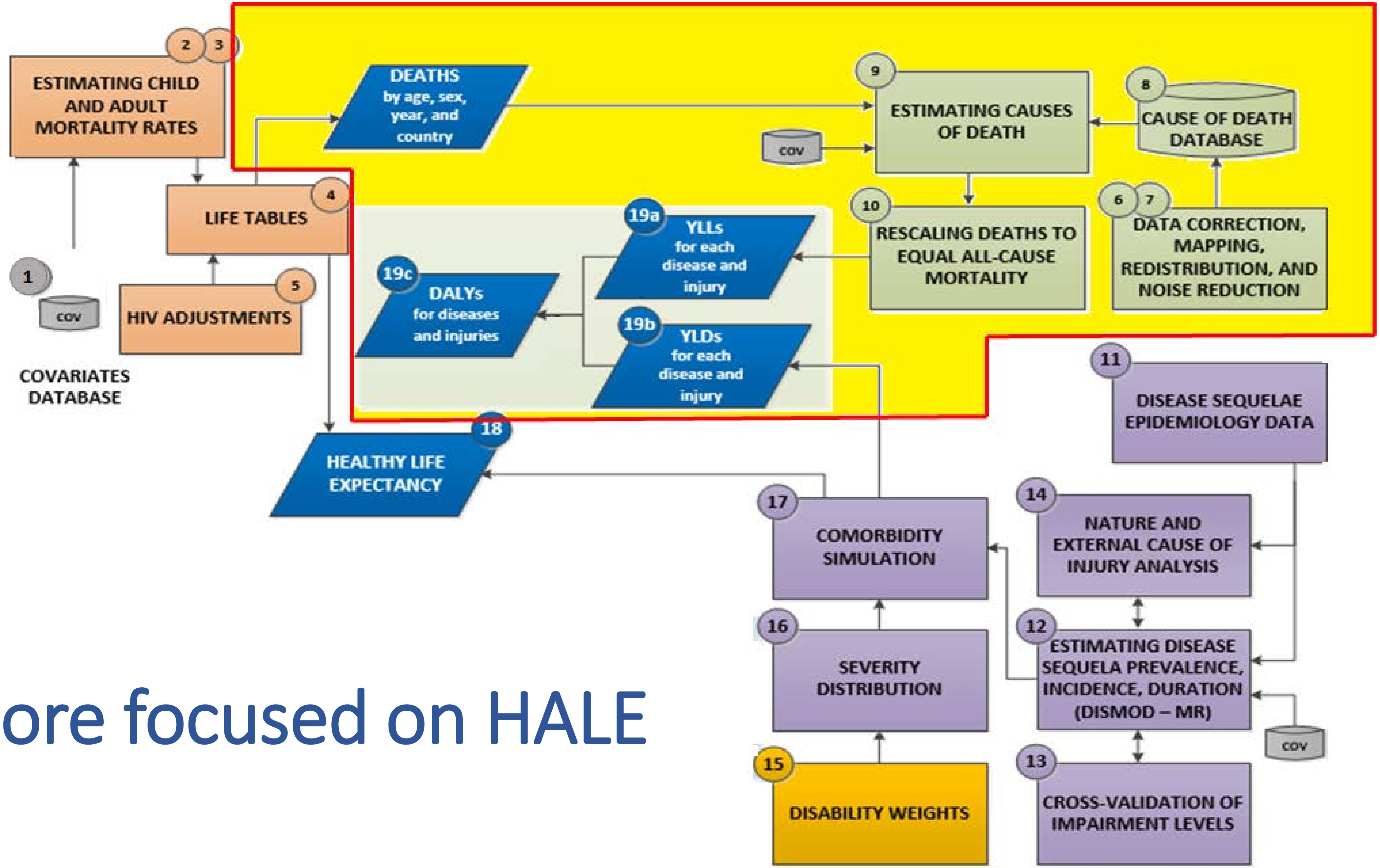
GBD Data and Model Flow Chart



IHME, GBD workshop



More focused on HALE



More focused on HALE

Data requirements: Availability of different components of data

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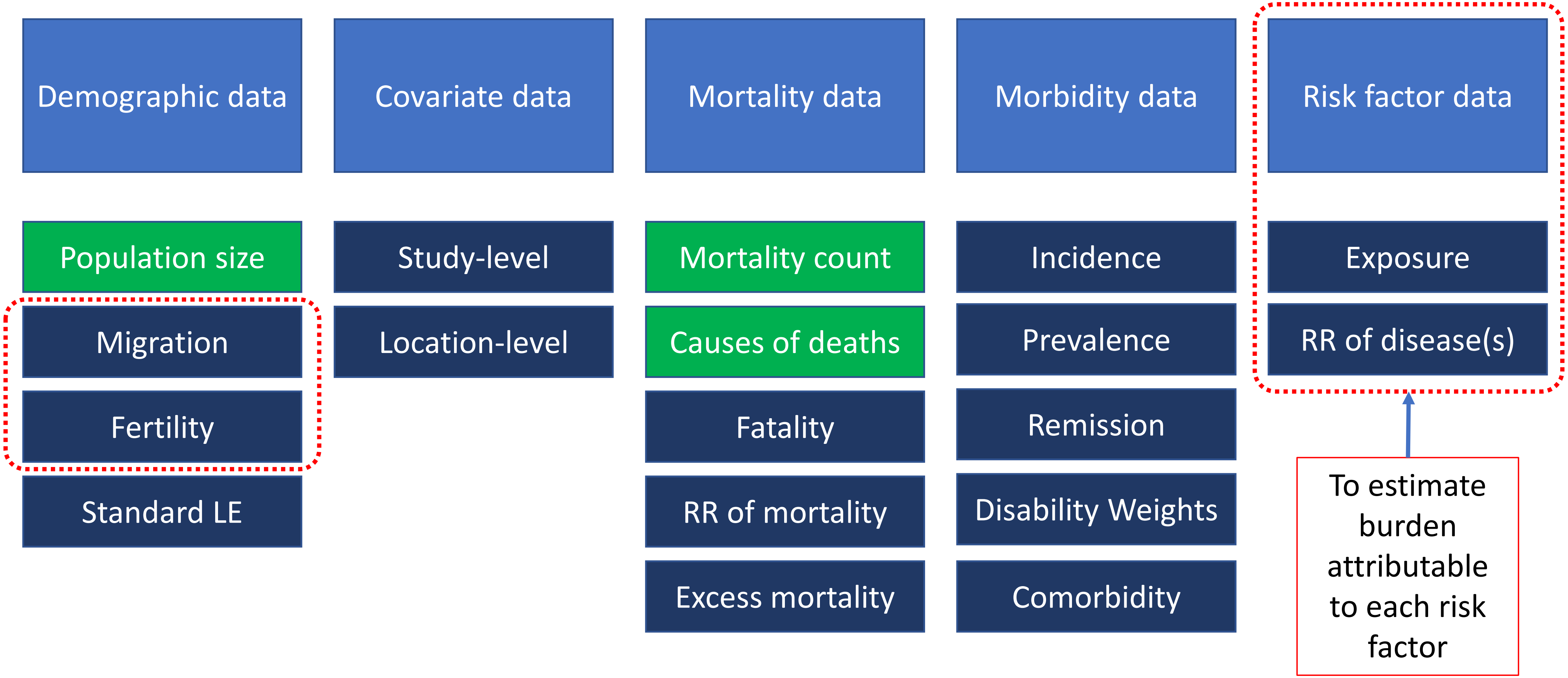
The required data burden of disease and HALE



Population and all-age mortality data

- Discussion points

  - Stratification?
    - Sex/ Age group/ Governorate
    - Nationality?

  - Quality indicators
    - Any adjustment for completeness?
    - Ill-defined and impossible causes of deaths?

  - Issue with uncommon causes of deaths
    - Need to aggregate annual data?

Sources of mortality data

Number and causes of deaths

- Registration
  - Vital registration, full coverage of the population
  - Sample registration, representative of the population
  - Sentinel registration, not-representative of the population
- Censuses
- Surveys
  - Complete or Summary birth history (CBH or SBH) from standard household surveys (such as WHS, DHS and MICS)
  - Household recall and Sibling survival history for number of deaths
  - Verbal autopsy surveys for causes of deaths
- Disease registries (sometimes for cause-specific mortality data)
- Surveillance systems (sometimes for cause-specific mortality data)

Mapping of causes with ICD codes

- Mapping of different version of ICD
- Mapping of ICD codes to causes
- List of ICD codes mapped to the GBD list
  - Road injuries: V30-V79.9, V87.2-V87.3

List of International Classification of Diseases (ICD) codes mapped to the Global Burden of Disease cause list

	Cause	ICD10	ICD10 Used in Hospital/Claims Analyses	ICD9
2	HIV/AIDS and sexually transmitted infections	A50-A60.9, A63-A64.0, B20-B23.8, B24-B24.0, B63, B97.81, C46-C46.52, C46.7-C46.9, F02.4, I98.0, K67.0-K67.2, M73.0-M73.8, N70-N71.9, N73-N74, N74.2-N74.8, O98.7-O98.73, Z11.3-Z11.4, Z20.2, Z20.6, Z21, Z22.4, Z83.0	A50-A60.9, I98.0, K67.0-K67.1, N74.3-N74.4	042-044.9, 054.1, 054.11-054.19, 090-099.9, 131-131.9, 176-176.9, 613-615.9, V01.6, V02.7-V02.9, V08, V73.8, V73.88, V73.9-V73.98, V74.5-V74.6
3	HIV/AIDS	B20-B23.8, B24-B24.0, B97.81, C46-C46.52, C46.7-C46.9, F02.4, O98.7-O98.73, Z11.4, Z20.6, Z21, Z83.0		042-044.9, 176-176.9, V08
4	HIV/AIDS - Drug-susceptible Tuberculosis	B20.0		
5	HIV/AIDS - Multidrug-resistant Tuberculosis without extensive drug resistance			
6	HIV/AIDS - Extensively drug-resistant Tuberculosis			
7	HIV/AIDS resulting in other diseases	B20.1-B23.8, B24-B24.0, B97.81, C46-C46.52, C46.7-C46.9, F02.4		176-176.9
8	Sexually transmitted infections excluding HIV	A50-A60.9, A63-A64.0, B63, I98.0, K67.0-K67.2, M73.0-M73.8, N70-N71.9, N73-N74, N74.2-N74.8, Z11.3, Z20.2, Z22.4	A50-A60.9, I98.0, K67.0-K67.1, N74.3-N74.4	054.1, 054.11-054.19, 090-099.9, 131-131.9, 613-615.9, V01.6, V02.7-V02.9, V73.8, V73.88, V73.9-V73.98, V74.5-V74.6
9	Syphilis	A50-A53.9, I98.0, K67.2, M73.1-M73.8	A50-A52.9, I98.0	090-097.9
10	Chlamydial infection	A55-A56.8, K67.0, N74.4	A55-A56.11, K67.0, N74.4	099.41, 099.5
11	Gonococcal infection	A54-A54.9, K67.1, M73.0, N74.3	A54-A54.29, K67.1, N74.3	098-098.9
12	Trichomoniasis	A59-A59.9	A59-A59.9	131-131.9

Cause-specific data

- Cause-specific deaths
  - Garbage codes?
  - Coverage
- Notifiable diseases
  - Incidence data
    - Stratification?
    - Completeness?
- Health Information Systems
  - Information of governmental, other public and private health institutions
  - Morbidity and Mortality data

Survey data

- Access to original data
  - Check for potential errors
  - Confidence intervals
  - Stratification

Governorate	High BP (SBP≥140 and/or DBP≥90 mmHg)		Diabetes (glucose ≥7.0 mmol/L)		Total cholesterol (≥5.0 mmol/L)		Obesity (BMI≥30 KG/m2)	
	Omani	Non-Omani	Omani	Non-Omani	Omani	Non-Omani	Omani	Non-Omani
Muscat	40.8%	38.9%	13.7%	18.2%	39.6%	32.7%	34.6%	16.5%
Dhofar	24.3%	29.3%	10.8%	22.0%	36.9%	31.3%	45.4%	25.8%
Al-Dakhiliyah	29.9%	30.6%	15.9%	15.9%	38.0%	38.5%	27.7%	23.0%
North Sharqiyah	36.3%	25.9%	13.9%	13.0%	39.1%	8.7%	3.3%	37.0%
South Sharqiyah	32.9%	34.9%	18.5%	15.7%	3.0%	14.0%	38.9%	12.8%

- Direct use as data for morbidity or risk factors

- Can be used to validate HIS data

Availability and accessibility of data

Type of data	General status
Population data	Usually accessible in most of the countries - National censuses - International estimates
Number and causes of deaths	Mortality envelope - Most of the high and middle income countries - Completeness and representativeness of data Causes of deaths - More issues in availability, accessibility and quality of data - Not usable in many cases without proper correction
Morbidity data	The most challenging section regarding availability of data - Disease registries and surveillance system - Hospital data and outpatient service records - Surveys

Orientation on the required software tools

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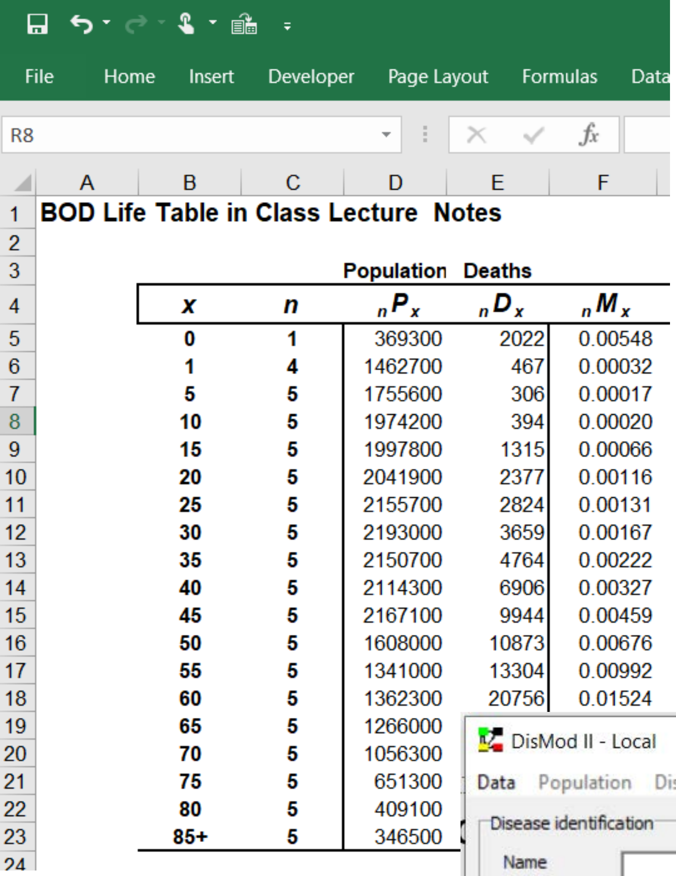
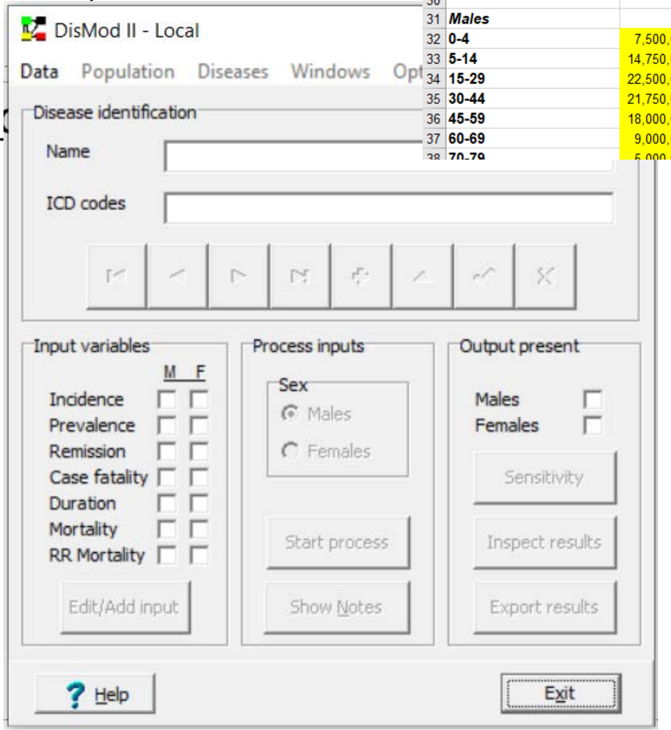
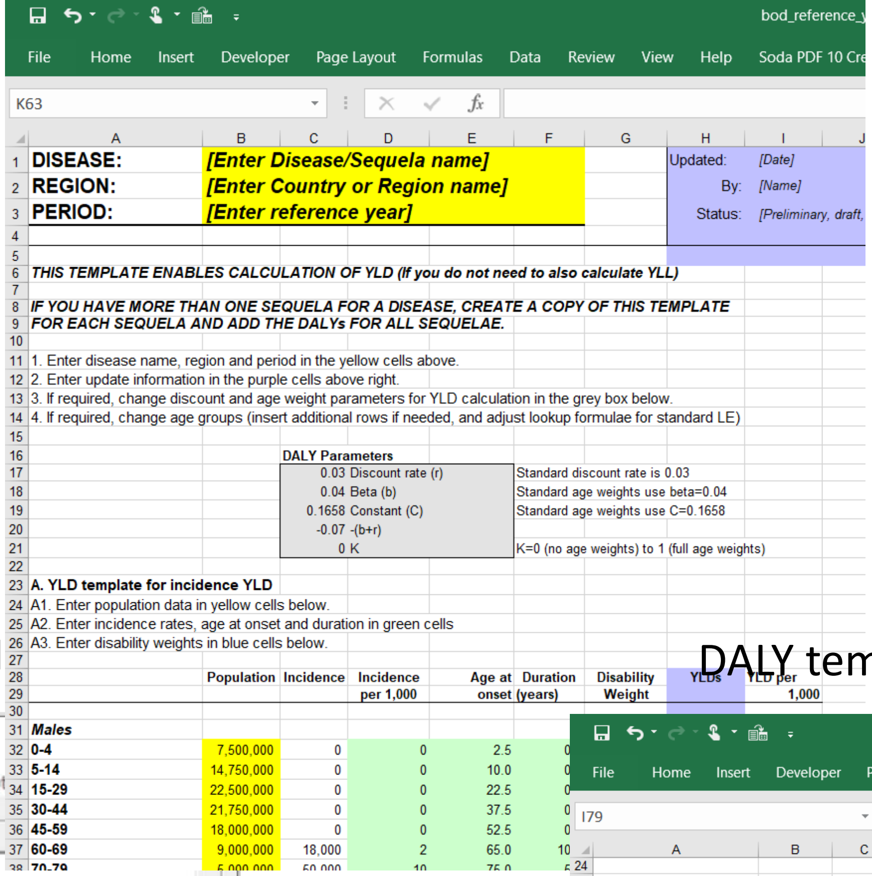


DisMod II

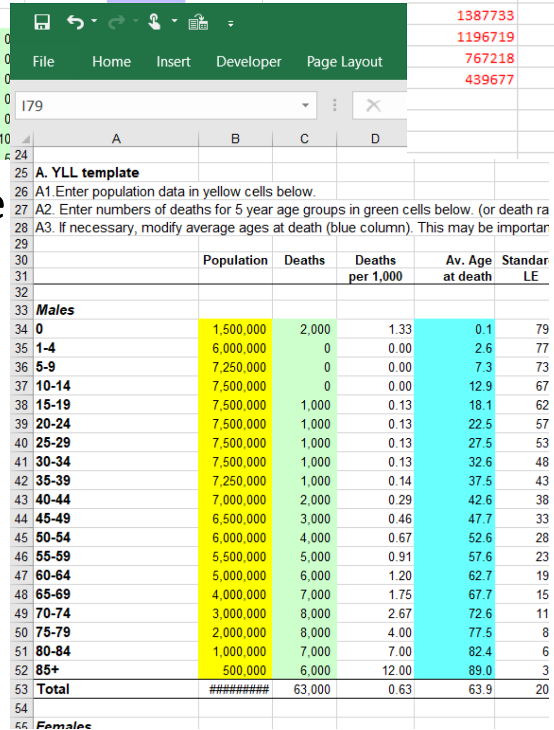


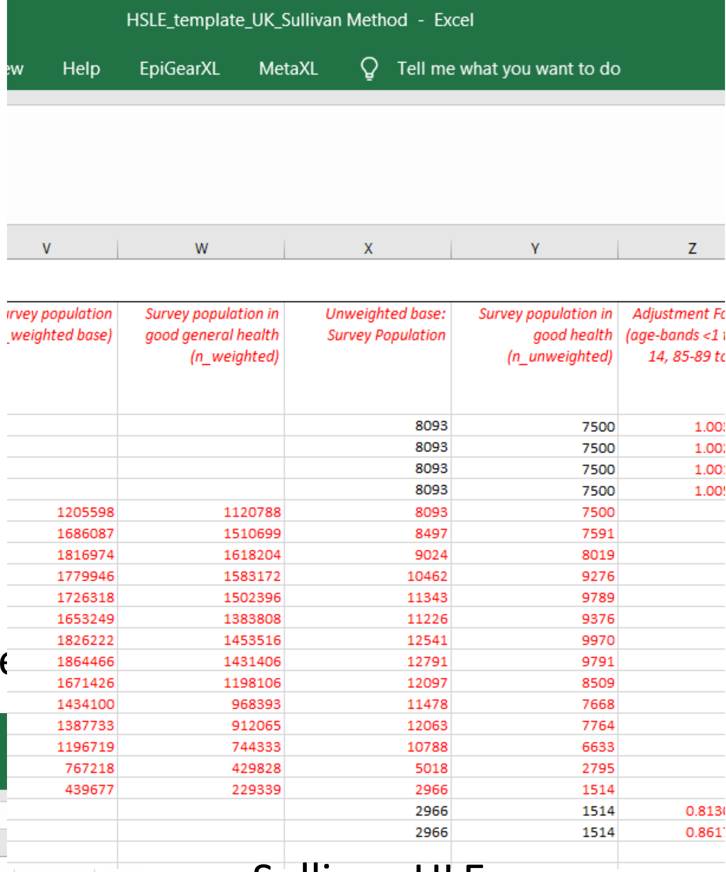


DALY template

LE template

YLD template





Sullivan HLE

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Basic Demography and Life Tables

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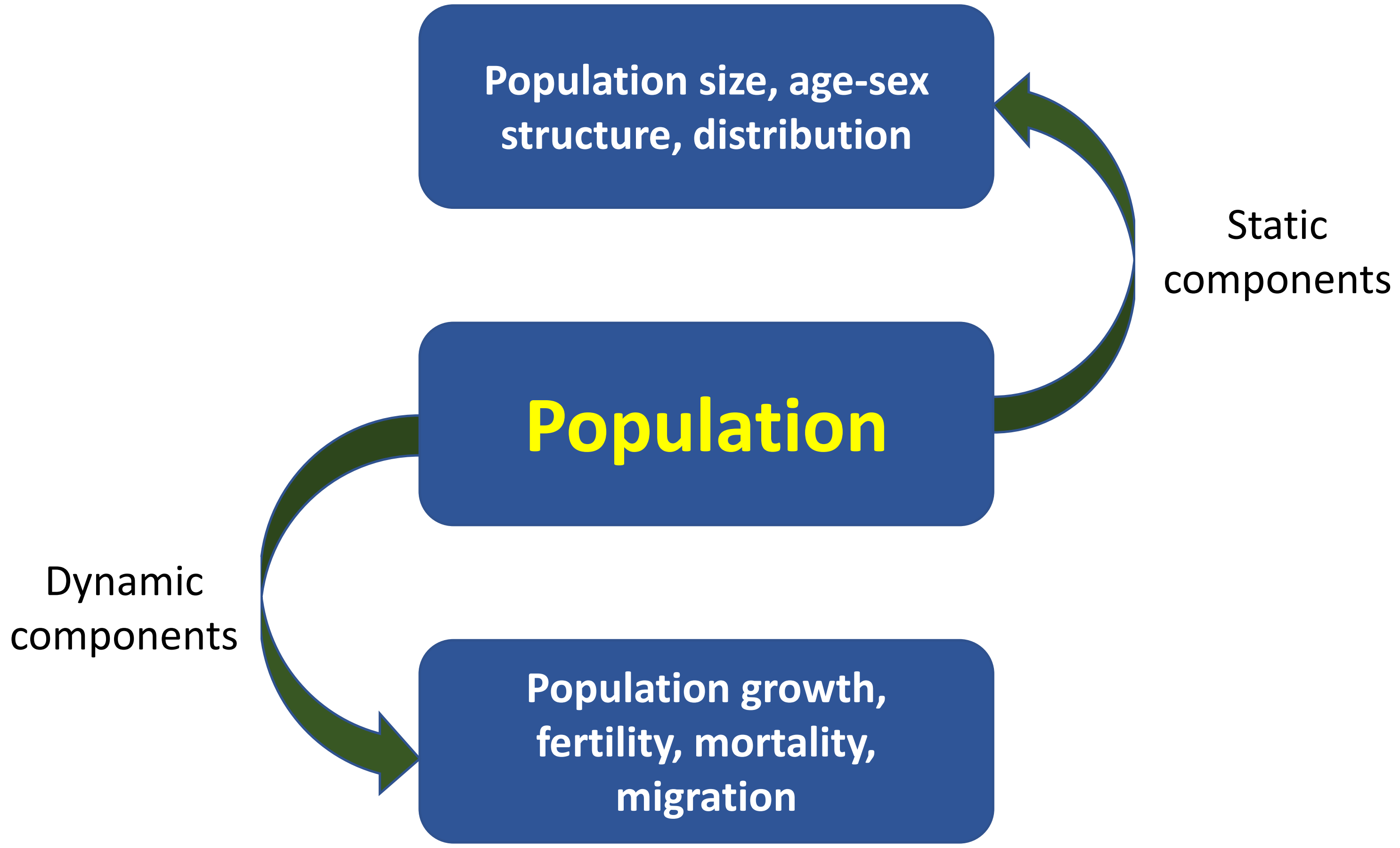
Why do we need demography for estimating burden of disease and HALE?

- Each event of disease or death happens in a population. Characteristics of the population are determinants of health and disease
- To calculate rates (such as incidence rate or mortality rate) and proportions (such as prevalence), we need population as a denominator
- We need demographic methods to calculate mortality rates, adjustment of completeness and calculating LE and HALE,

Core components of demography

- Fertility
- Mortality
- Migration
- Ageing



Population size at time *t*

$$P_t = P_0 + F - M + IM - OM$$

- P_0: Initial population
- Fertility (F) = births (new entrants to a population
- Mortality (M) = deaths ('exits' from a population)
- In-migration (IM): people moving in
- Out-migration (OM): people leaving a population

Annual arithmetic growth rate

$$R = \frac{P_t - P_0}{t}, \text{ t being number of years}$$

Population at risk

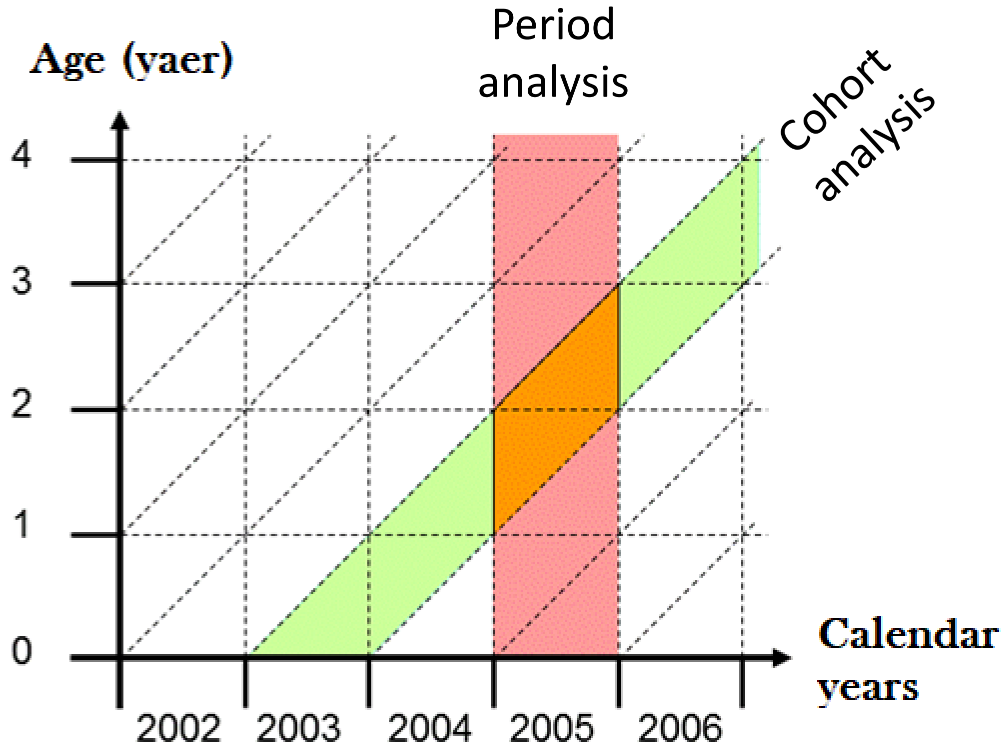
- Population-at-risk is used as a denominator in some of the epidemiological indicators, such as the age-specific death rates
- Usually mid year Population is used as a surrogate for population-at-risk

Sources of demographic data

- Vital registration
  - Coverage? Completeness?
- Population census
- Demographic surveys
  - Recall of birth/ death in households
  - Indirect estimate of age-specific mortality

Population analysis and life tables

- Period of time approach **(M type)**
  - Interval of time
  - Point in time
- Cohort of population **(q type)**
  - Birth cohort
  - Marriage cohort



Lexis diagram

Life tables

- Cohort vs. Period life tables
  - Synthetic or hypothetical cohort
- Complete vs. Abridge life tables
  - All age groups
  - Aggregated neighboring groups

Sample Abridged Life Table

x	N	${}_nP_x$	${}_nD_x$	${}_nM_x$	a	${}_nq_x$	${}_np_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x
0	1	369300	2022	0.005	0.1	0.005	0.995	100,000	545	99,510	7,471,253	74.71
1	4	1462700	467	0	0.4	0.001	0.999	99,455	127	397,516	7,371,743	74.12
5	5	1755600	306	0	0.5	0.001	0.999	99,328	87	496,425	6,974,227	70.21
10	5	1974200	394	0	0.5	0.001	0.999	99,242	99	495,961	6,477,802	65.27
15	5	1997800	1315	0.001	0.5	0.003	0.997	99,143	326	494,899	5,981,841	60.34
												55.53
												50.84
												46.15
												41.52
												36.95
												32.52
												28.22
												24.1
60	5	1362300	20756	0.015	0.5	0.073	0.927	84,671	6,214	407,823	1,710,456	20.2
65	5	1266000	28937	0.023	0.5	0.108	0.892	78,458	8,482	371,084	1,302,634	16.6
70	5	1056300	36075	0.034	0.5	0.157	0.843	69,976	11,009	322,356	931,549	13.31
75	5	651300	33265	0.051	0.5	0.226	0.774	58,967	13,353	261,450	609,193	10.33
80	5	409100	37544	0.092	0.5	0.373	0.627	45,613	17,024	185,505	347,743	7.62
85+	5	346500	61059	0.176		1	0	28,589	28,589	162,238	162,238	5.67

		Population	Number of Deaths during interval	Annual death rate in the interval	Fraction of life for deceased individuals	Probability of dying during the interval	Probability of surviving the interval	Number of alive at start of interval	Number dying during the interval	Number of years lived in interval	Total number of years lived beyond start of interval	Life expectancy at start of interval
x	**n**	${}_nP_x$	${}_nD_x$	${}_nM_x$	**a**	${}_nq_x$	${}_np_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x
0	**1**	317000	3914	0.01235	**0.1**	0.01221	0.9878	100,000	1,221	98901	7,125,688	71.26
1	**4**	1254300	652	0.00052	**0.4**	0.00208	0.9979	98,779	205	394623	7,026,787	71.14
5	**5**	1557600	391	0.00025	**0.5**	0.00125	0.9987	98,574	124	492560	6,632,164	67.28
10	**5**	1947500	546	0.00028	**0.5**	0.00140	0.9986	98,450	138	491906	6,139,604	62.36

Sample Abridged Life Table

x	N	${}_nP_x$	${}_nD_x$	${}_nM_x$	a	${}_nq_x$	${}_np_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x
0	1	369300	2022	0.005	0.1	0.005	0.995	100,000	545	99,510	7,471,253	74.71
1	4	1462700	467	0	0.4	0.001	0.999	99,455	127	397,516	7,371,743	74.12
5	5	1755600	306	0	0.5	0.001	0.999	99,328	87	496,425	6,974,227	70.21
10	5	1974200	394	0	0.5	0.001	0.999	99,242	99	495,961	6,477,802	65.27

$$ {}_nq_x = \frac{n.{}_nM_x}{1 + n.(1 - {}_na_x).{}_nM_x} $$

$$ {}_np_x = 1 - {}_nq_x $$
$$ \therefore {}_np_x + {}_nq_x = 1 $$

${}_na_x$: the proportion of the interval lived by those who died

l_x : the number of people alive at exact age x

$$ {}_np_x = \frac{l_{x+n}}{l_x} $$

$$ {}_nd_x = l_x - l_{x+n} $$
$$ = l_x . {}_nq_x $$

For the last age interval (open-end): $d_{x+} = l_x$

Sample Abridged Life Table

x	N	${}_nP_x$	${}_nD_x$	${}_nM_x$	a	${}_nq_x$	${}_np_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x
0	1	369300	2022	0.005	0.1	0.005	0.995	100,000	545	99,510	7,471,253	74.71
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${}_nL_x$: the total number of person-years lived (by those alive or died) between exact ages x and x+n

T_x : the total number of person-years lived after age x (i.e. cumulative ${}_nL_x$ function from the bottom)

e_x: the expected (average) number of years of life left for a person aged x

$$e_x = \frac{T_x}{l_x}$$

$$e_0 = \frac{T_0}{l_0}$$

Expectation of life (life expectancy) at birth

Calculating life expectancy (LE) / Practical data analysis with sample data

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Practical analysis of mortality envelope and LE

- Open 2019 data of your national mortality data
- Compare total mortality rates for Male/Female, national/non-national, with and without age-standardization
- Use the LE template to calculate LE for Male/Female national/non-national separately
- Answer the follow-up questions in the LE excel sheet

Day 2 (Tuesday Nov 21st 2023)

Subject
Death registries; corrections for number and causes of deaths
Mortality data in GCC countries; coverage and usability of data
BREAK
National experiences to improve coverage and quality of death registries
Analysis of causes of deaths; sample data
Review of the main findings of CoD analysis
Working with YLL template
Lunch Break
Calculating years of live lost (YLL) / Practical data analysis

Death registries; corrections for number and causes of deaths

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Mortality envelope

- The sum of deaths from all specific causes for any age and sex group must sum to the total number of deaths for that age and sex group.

- The number of deaths, by age and sex, provides the “envelope” which constrains individual disease and injury estimates of deaths.

Assessment of completeness, 1

- Direct methods of assessment
  - Matching deaths to a second source of mortality data
    - Independent representative sample of a household survey
    - Capture-recapture method

		Registration		Total
		Yes	No	
Survey	Yes	a=115	b=29	144
	No	c=22	d=6	28
Total		137	35	172

Completeness = 115/ 144 = 0.799

bc/a = (29*22)/115 = 5.5

Total = (144 + 137) – 115 + 5.5 = 171.5

Completeness = 137/171.5 = 0.799

Assessment of completeness, 2

- Indirect methods of assessment
  - **No second source** is available
  - Compare age-pattern of deaths with age-pattern of population at-risk of dying (death distribution methods); important assumptions:
    - Under-reporting of deaths is assumed to be constant by age
    - Stable population (constant birth and death rates, constant population growth rate, constant age structure; usually with no significant migration)
    - Closed population: closed to migration (negligible migration)

Brass Growth-Balance Method (indirect)

- *N(x)* is the population size at age *x*

$$\frac{N(x)}{N(x+)} = r + \frac{D(x+)}{N(x+)}$$

- *N(x+)* is the population size of all age groups at ages *x and above*
- *D(x+)* are the deaths at ages *x and above*
- birth rate - death rate = population growth rate
- Completeness (C) = 1/ K

$$\frac{N(x)}{N(x+)} = r + K\left(\frac{D(x+)}{N(x+)}\right)$$

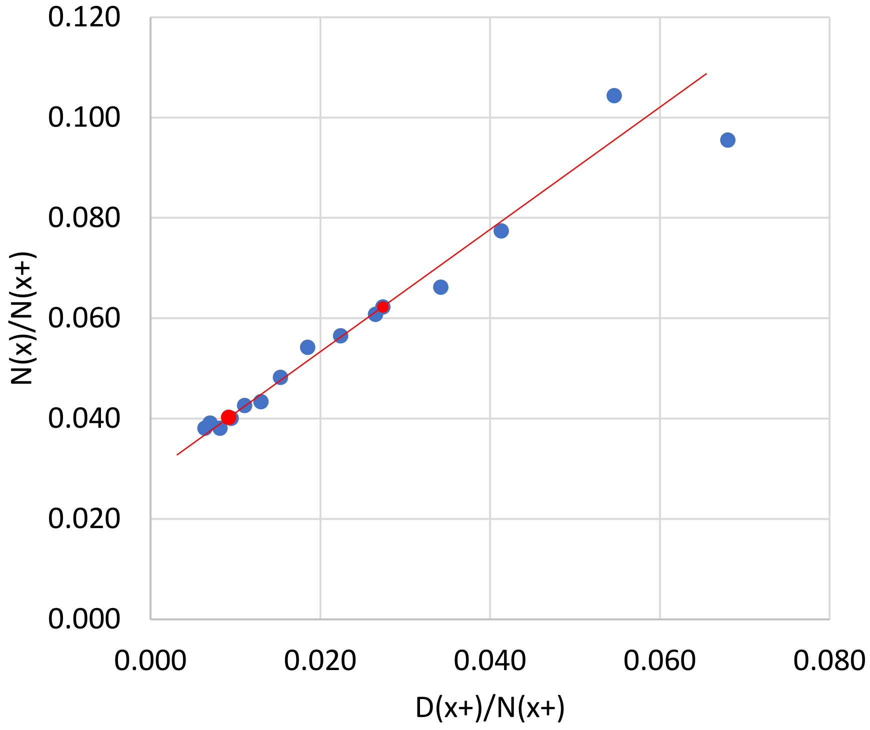
→ y = b + ax

Age X	Population At exact Age x: N(x)	Population Aged x And over: N(x+)	Registered Deaths over age x: D(x+)	Partial Death rate: D(x+)/N(x+)	Partial birth rate: N(x)/N(x+)
5	40 432	1 060 164	6 743	0.0064	0.0381
10	33 977	869 930	6 133	0.0070	0.0391
15	27 458	720 392	5 919	0.0082	0.0381
20	23 853	595 352	5 653	0.0095	0.0401
25	20 515	481 862	5 362	0.0111	0.0426
30	16 937	390 199	5 091	0.0130	0.0434
35	15 065	312 488	4 776	0.0153	0.0482
40	12 988	239 552	4 427	0.0185	0.0542
45	10 315	182 610	4 089	0.0224	0.0565
50	8 482	136 405	3 732	0.0274	0.0622
55	6 477	97 789	3 347	0.0342	0.0662
60	5 543	71 635	2 960	0.0413	0.0774
65	4 424	42 362	2 313	0.0546	0.1044
70	2 617	27 398	1 864	0.0680	0.0955

	X	Y
Set 1	X_1 = 0.0092	Y_1 = 0.0402
Set 2	X_2 = 0.0265	Y_2 = 0.0608

$$K = \frac{Y2 - Y1}{X2 - X1}$$

K=1.87, C=84.2%



The Bennett-Horiuchi Method (indirect)

- Data requirement
  - Two population census, preferably with 5-10 years interval
  - Calculates the ratio of the reported number of deaths in a particular age group to the estimated total number of future deaths to that age group as an estimate of the completeness of the registered deaths
  - A Synthetic Extinct Generations method
  - Stable population

Completeness of death registry (B-H method)

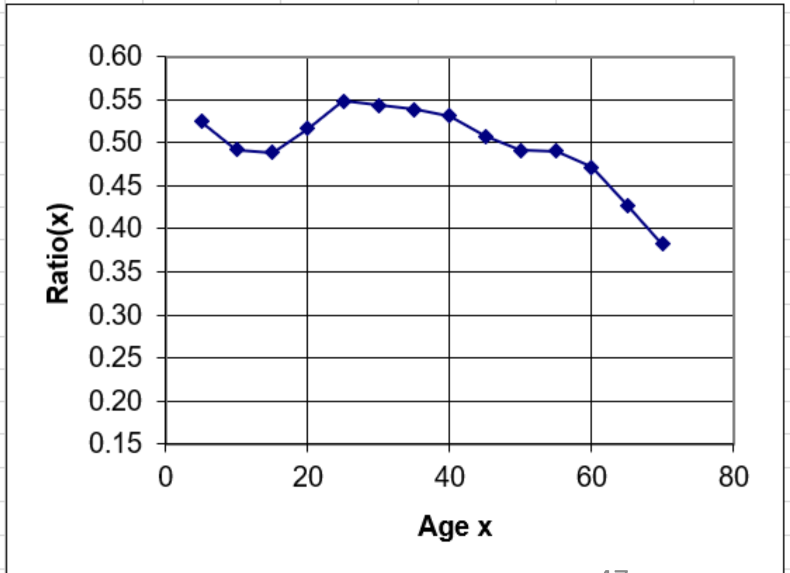
Extinct Generations (Bennett-Horiuchi) Method

		1	e75	6.24		
Sex	Male			Estimate	Error Indicator	Percent
Census 1	18-Aug-82	1982.630	Deaths adjustment factor	0.500	0.020	4.1
Census 2	18-Aug-92	1992.630				

Age Group (1)	Age x (2)	Population 1982.630 N1(x,5) (3)	Population 1992.630 N2(x,5) (4)	Inter-censal Deaths D(x,5) (5)	Age Specific Growth Rate r(x,5) (6)	Number Reaching Age x from Deaths N*(x) (7)	Number Reaching Age x from Age Dist N(x) (8)	Ratio N*(x)/N(x) (9)	Adjusted Deaths (10)	Adjusted Death Rate (11)
					2	6	7	8	9	10
0-4	0	644,716	791,447	46,743	0.020505	896,794	NA	NA	93,513	0.01309
5- 9	5	614,081	823,904	3,101	0.029393	764,998	1,457,648	0.525	6,204	0.00087
10-14	10	530,892	727,187	2,494	0.031463	657,560	1,336,491	0.492	4,989	0.00080
15-19	15	391,001	617,666	3,652	0.045724	559,539	1,145,275	0.489	7,306	0.00149
20-24	20	291,006	468,307	5,854	0.047578	441,929	855,824	0.516	11,711	0.00317
25-29	25	243,945	336,770	8,135	0.032246	343,171	626,106	0.548	16,275	0.00568
30-34	30	185,800	280,948	9,484	0.041350	284,566	523,587	0.543	18,973	0.00830
35-39	35	148,239	230,082	8,694	0.043961	222,864	413,518	0.539	17,393	0.00942
40-44	40	142,356	174,815	8,486	0.020540	171,098	321,959	0.531	16,976	0.01076
45-49	45	116,741	145,895	8,580	0.022293	146,338	288,229	0.508	17,166	0.01315
50-54	50	112,021	133,680	11,717	0.017676	122,787	249,847	0.491	23,441	0.01916
55-59	55	67,545	95,011	10,345	0.034120	101,190	206,332	0.490	20,695	0.02583
60-64	60	77,016	95,811	15,025	0.021836	75,821	160,892	0.471	30,059	0.03499
65-69	65	38,894	51,363	11,024	0.027808	53,751	125,790	0.427	22,055	0.04934
70-74	70	29,874	58,462	12,145	0.067139	36,490	95,369	0.383	24,297	0.05814
75+	75	39,495	52,190	13,348	0.027872	15,816	NA	NA	26,703	0.05882
Total		3,673,622	5,083,538	178,828					357,756	
	e75= 6.24		exp(r(75+)*e75) = T1 =		1.189960	3	Median	0.500		
			((r(75+)*e75)^2)/6 = T2 =		0.005041	4	0.5 * IQ Range	0.020		
			N(75)=D(75+)[T1 - T2] =		15,816	5	Percent	4.1		

x	Ratio
5	0.525
10	0.492
15	0.489
20	0.516
25	0.548
30	0.543
35	0.539
40	0.531
45	0.508
50	0.491
55	0.490
60	0.471
65	0.427
70	0.383

Order
Added MML



Using the completeness estimates to adjust mortality data

- Completeness (C)
- K = 1/C
- Adjusted number of deaths = K * registered number of deaths

  - C = 70% >> K = 1.43
  - Number of registered deaths= 8,500 >> Adjusted number = 12,155

Usual sources for causes of deaths data

- Vital Registration with Certification of Cause of Death
- Sample Registration Systems
- Household Surveys
- Verbal autopsy
- Population Surveillance Systems
- Epidemiological Estimates
- Burial/ Mortuary data
- Cause-of-Death Models
- Deaths In-Hospital: Should be avoided unless a very high percent of deaths are happening in hospitals
- Cancer Registries
- Police records: Usually only for injuries

ICD coding for causes-of-deaths

- ICD-11 codes: Around 17,000 diagnostic codes
  - Separate lists for mortality and morbidity
  - etiologies (such as infection or neoplasia)
  - organ systems (such as musculoskeletal or digestive)
  - Injuries: External causes or Nature of injuries
- ICD-10 or earlier versions: Mapping

ICD-11 Chapters

01 Certain infectious or parasitic diseases	15 Diseases of the musculoskeletal system or connective tissue
02 Neoplasms	16 Diseases of the genitourinary system
03 Diseases of the blood or blood-forming organs	17 Conditions related to sexual health
04 Diseases of the immune system	18 Pregnancy, childbirth or the puerperium
05 Endocrine, nutritional or metabolic diseases	19 Certain conditions originating in the perinatal period
06 Mental, behavioural or neurodevelopmental disorders	20 Developmental anomalies
07 Sleep-wake disorders	21 Symptoms, signs or clinical findings, not elsewhere classified
08 Diseases of the nervous system	22 Injury, poisoning or certain other consequences of external causes
09 Diseases of the visual system	23 External causes of morbidity or mortality
10 Diseases of the ear or mastoid process	24 Factors influencing health status or contact with health services
11 Diseases of the circulatory system	25 Codes for special purposes
12 Diseases of the respiratory system	26 Supplementary Chapter Traditional Medicine Conditions - Module I
13 Diseases of the digestive system	
14 Diseases of the skin	

An example of mapping ICD codes

10 Class Kind	Depth	icd10 Code	icd10 Chapter	icd10 Title	11 Class Kind	Depth	icd11 Code	icd11 Chapter	icd11 Title
block	1	B15-B19	I	Viral hepatitis	category	1	1E5Z	01	Viral hepatitis, unspecified
category	1	B18	I	Chronic viral hepatitis	category	1	1E51.Z	01	Chronic viral hepatitis, unspecified
category	2	B18.0	I	Chronic viral hepatitis B with delta-agent	category	2	1E51.2	01	Chronic hepatitis D
modifiedcategory	3	B18.00	I	Chronic viral hepatitis B with delta-agent : immune-tolerant phase	category	3	1E51.2	01	Chronic hepatitis D
modifiedcategory	3	B18.09	I	Chronic viral hepatitis B with delta-agent : other and unspecified phase	category	3	1E51.2	01	Chronic hepatitis D

Cause of death*

1

Report disease or condition directly leading to death on line a

Report chain of events i due to order (if applicable)

State the underlying cause on the lowest used line

	Cause of death*	Time interval between onset and death	
a	Direct cause of death **Cerebral haemorrhage**	**4 hours**	Immediate cause
b	Due to **Metastasis of the brain**	**4 months**	Intermediate cause(s)
c	Due to **Breast cancer**	**5 years**	Intermediate cause(s) / Underlying cause
d	Due to		

Underlying cause

2

Other singificant conditions contributing to death (time intervals can be included in brackets after the condition)

Arterial hypertension (3 years); Diabetes mellitus (10 years)

Contributory

**This does not mean the mode of dying. e.g. heart failure, respiratory failure. It means the disease, injury, or complicatiion that caused death.*

Age-Sex splitting for causes of deaths

- Optimally, the following age-groups should be used for cause of deaths:
  - Early neonatal period: 0-6 days
  - Late neonatal period: 7-28 days
  - Post neonatal infancy period: 29-364 days
  - 1-4 years
  - 5-year age groups
  - 85+ or 80+ as the last age group

Misclassification of causes of deaths

- Impossible or less probable causes of death: considering age and sex characteristics
  - Accidental errors
- Deliberate mis-certification
  - Associated with stigma or governance
  - Poisoning instead of suicide

Ill-defined and garbage codes

- No or minimal public health value
- ICD-11 Chapter 21: *Symptoms, Signs and Ill-defined Conditions*
- Unspecified causes in each chapter
  - ill-defined or very general conditions such as “heart failure” and “neoplasm with unknown primary site”
- Different with Misclassification

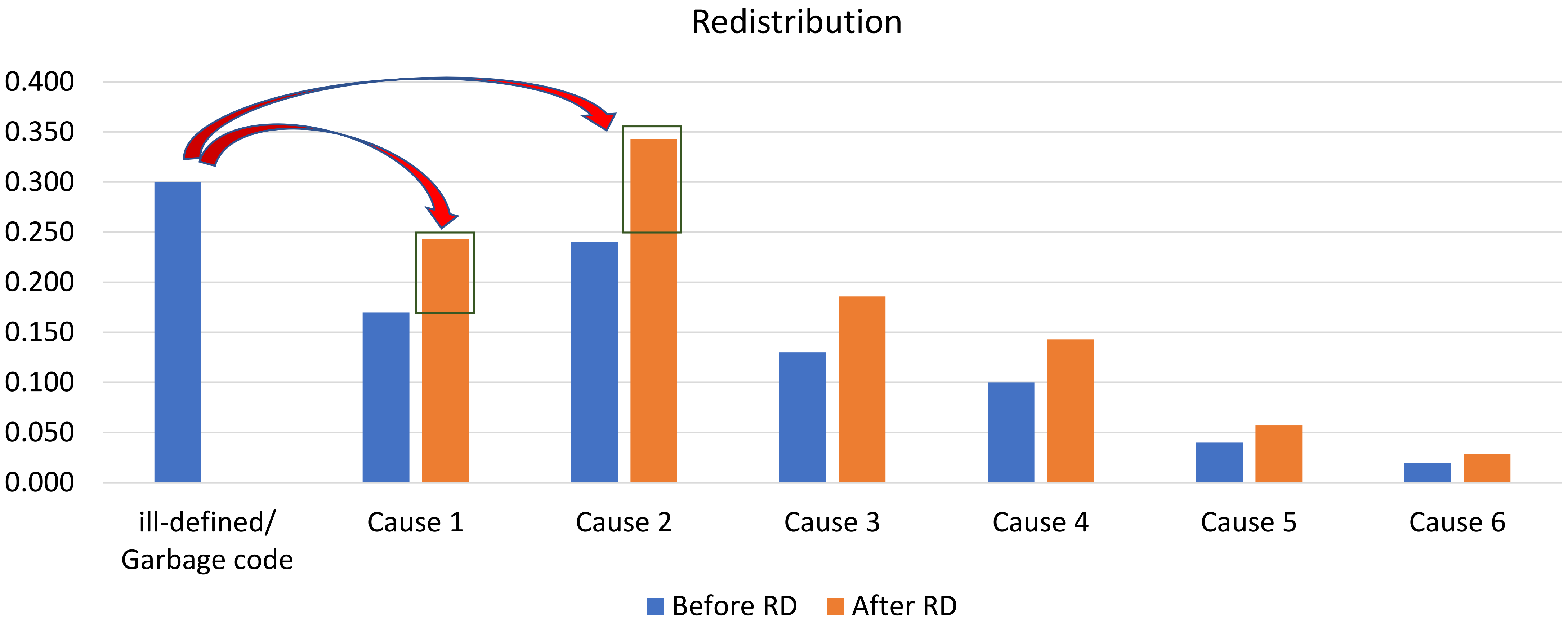
Ill-defined and garbage codes ICD-10 codes

i. Deaths classified as ill-defined (Chapter XVIII of ICD-10)

ii. Deaths classified to any one of the following vague or unspecific diagnoses:

1. A40-A41: Streptococcal and other septicaemia
2. C76, C80, C97: Ill-defined cancer sites
3. D65: Disseminated intravascular coagulation
4. E86: Volume depletion
5. I10: Essential (primary) hypertension
6. I269: Pulmonary embolism without mention of acute cor pulmonale
7. I46: Cardiac arrest
8. I472: Ventricular tachycardia
9. I490: Ventricular fibrillation and flutter
10. I50: Heart failure
11. I514: Myocarditis, unspecified
12. I515: Myocardial degeneration
13. I516: Cardiovascular disease, unspecified
14. I519: Heart disease, unspecified
15. I709: Generalized and unspecified atherosclerosis
16. I99: Other and unspecified disorders of circulatory system
17. J81: Pulmonary oedema
18. J96: Respiratory failure, not elsewhere classified
19. K72: Hepatic failure, not elsewhere classified
20. N17: Acute renal failure
21. N18: Chronic renal failure
22. N19: Unspecified renal failure
23. P285: Respiratory failure of newborn
24. Y10-Y34, Y872: External cause of death not specified as accidentally or purposely inflicted

Redistribution



Redistribution to specific causes

- Cancers of ill-defined digestive organs:
  - Redistribute proportionally to cancers of the digestive tract

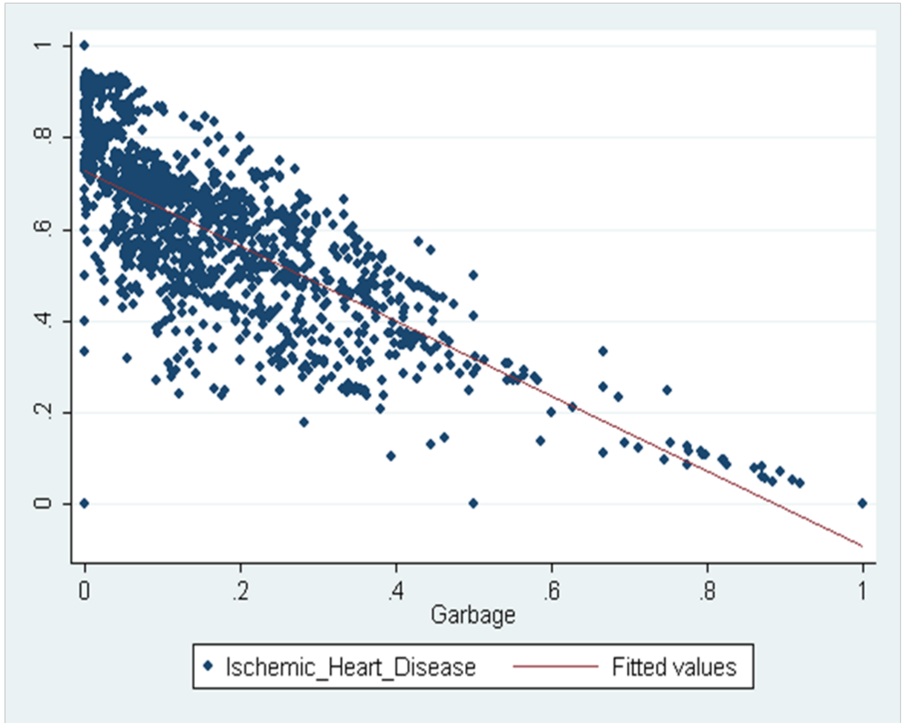
- Haemorrhage not elsewhere classified and Hypovolumic Shock
  - Redistribute according to pre-assigned proportions, separately for male and female

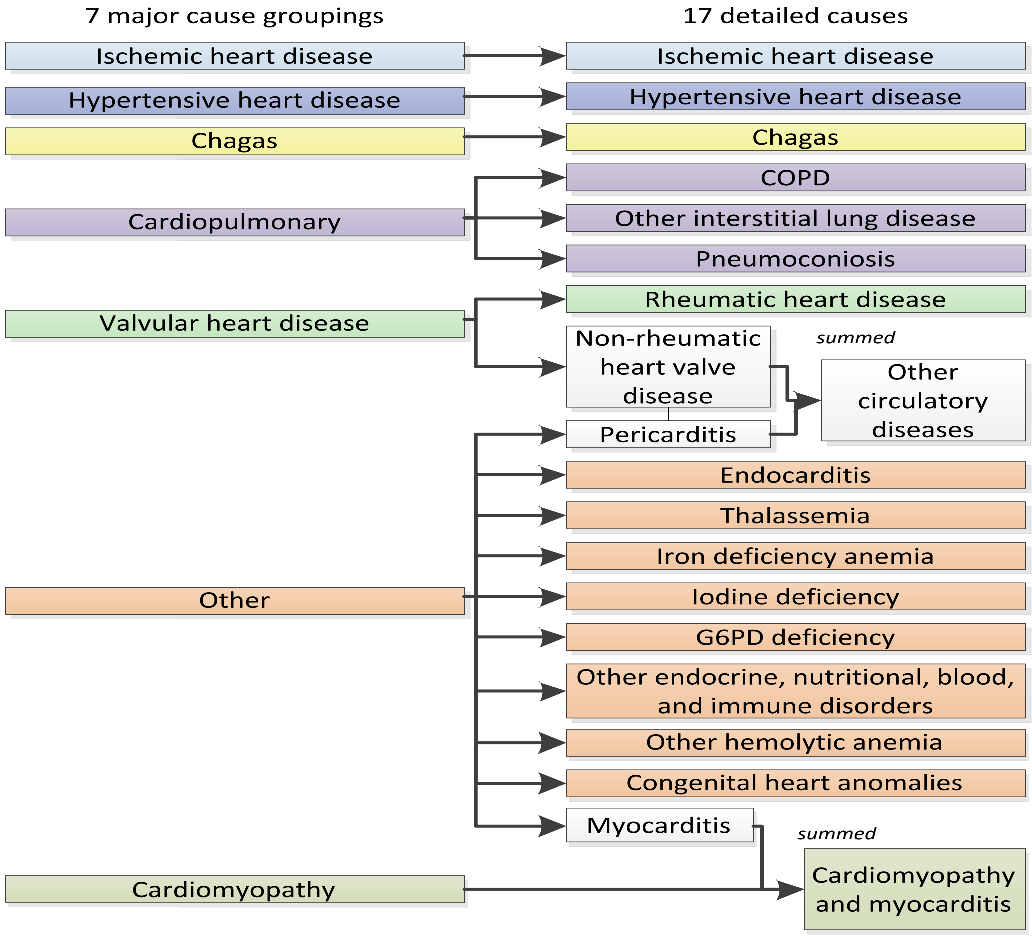
Target Codes	V01-V99	W00-W19	W20-W64	X73-X82	X93-Y04	X31-X35	O03-O07	O45	O63-O67	O72-O73	K25-K28
	Road Traffic Injury	Falls	Mechanical Injuries	Suicide	Assault	Forces of Nature and War	Abortion	Premature separation of placenta	Obstructed Labor	Postpartum Haemorrhage	Gastric ulcers w/ perforation
Prop. (M)	15%	15%	15%	15%	15%	15%	0%	0%	0%	0%	10%
Prop. (F)	10%	10%	10%	10%	10%	10%	8.75%	8.75%	8.75%	8.75%	5%

Redistribution to specific causes

- Heart Failure
  - Redistribute according to etiologic fraction analysis

Negative correlation between Ischemic Heart Disease and HF - developing country females >50





Health Information Systems Knowledge Hub
School of Population Health
University of Queensland

World Health Organization

HMN

ANACoD version 2.0
Analysing mortality level and cause-of-death data

About this version

Click on the buttons to select analysis

Step by step core analyses

Step0	Input data: raw mortality data by age, sex and ICD10 3 or 4 character codes; population by age and sex	**Step 6**	Distribution of deaths according to the Global Burden of Disease list
Step1	Basic check of input data	**Step 7**	Age pattern of broad groups of causes of deaths
Step 2	Crude death rates	**Step 8**	Leading causes of death
Step 3	Age- and sex-specific death rates	**Step 9**	Ratio of non-communicable to communicable causes of death
Step 4	Age distribution of deaths	**Step 10**	Ill-defined causes of death
Step 5	Child mortality rates	***Summary***	Summary of analyses

Supplementary analyses

S1	Age pattern of individual cause of death	**S2**	Age-specific death rates of individual cause of death

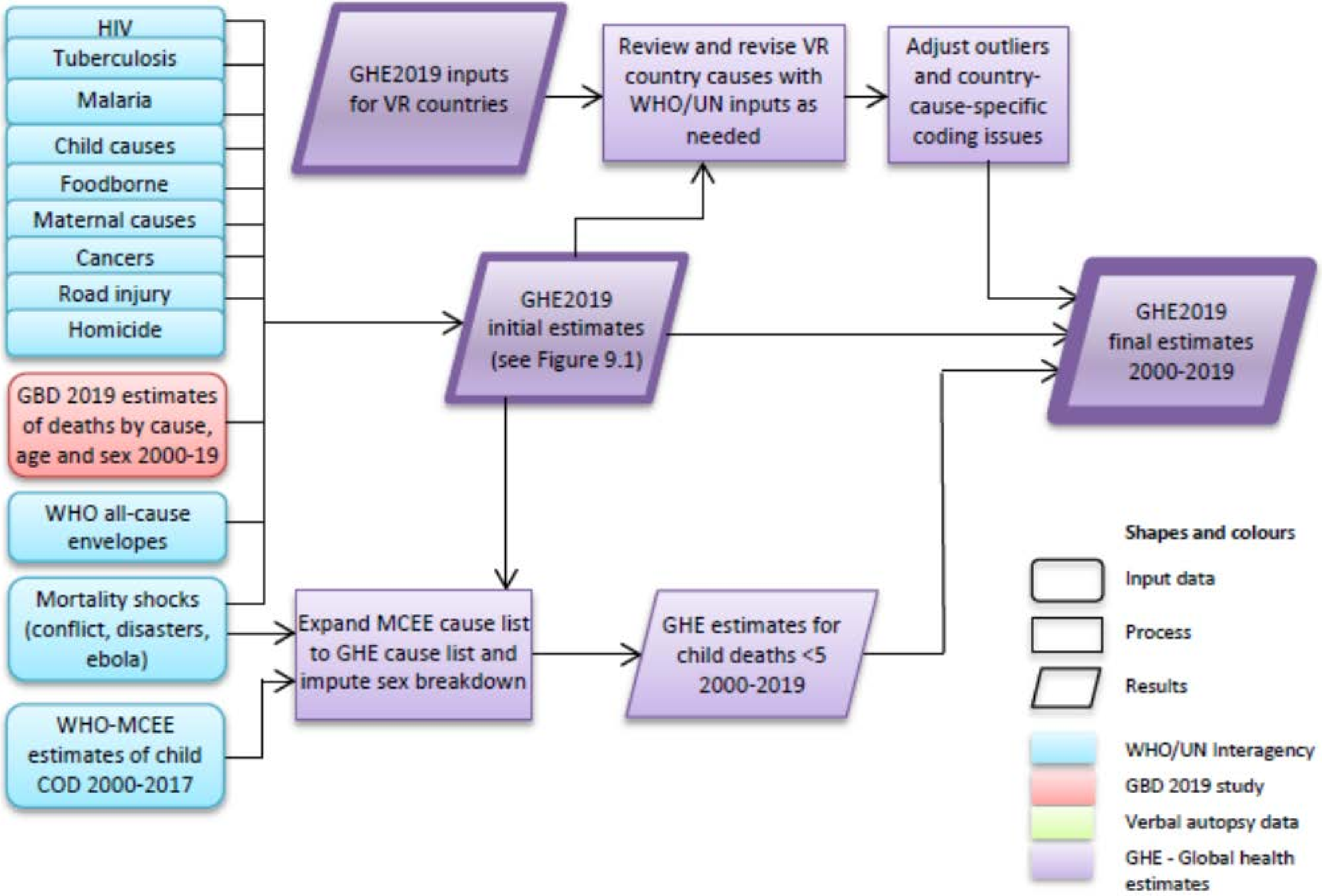
Background information

About	About the tool	**ICD10**	List of ICD-10 codes valid for underlying causes of death
GBD list	Global Burden of Disease cause categories and ICD-10 codes		

Mortality data in GCC countries; coverage and usability of data

Muscat – Nov 20 to 23 2023

WHO country-level causes of death (2000-2019)



WHO country-level causes of death (2000-2019)

Global Health Estimates (GHE)

Characteristics of country vital registration data and inclusion/exclusion

Country	Years of data in the WHO mortality database	Years of data used to compute the GHE	Quality	Completeness (ages 15 and over)		Usability[c]		Were data used for GHE?	Reason data or data-years were excluded
				Minimum	Maximum	Minimum	Maximum		
Bahrain	1998-2014		low	80%	81%	43%	53%	no	Low quality
Kuwait	1998-2017		high	100%	100%	76%	88%	no	Ad-hoc exclusion (see text)
Oman	2009-2010, 2014, 2016-2017		very low	58%	60%	23%	31%	no	Low quality
Qatar	2001, 2004-2017		very low	54%	57%	33%	40%	no	Low quality
Saudi Arabia	2009, 2012		very low	28%	29%	12%	13%	no	Low quality
United Arab Emirates	2005-2010, 2012, 2016, 2019		very low	57%	58%	22%	22%	no	Low quality

Usability (%) = Completeness (%) X (100 – Deaths assigned to garbage codes(%))

Ad-hoc exclusion of Kuwait data: high percentage of deaths with unknown age and in ill-defined cause categories

Non-national population in the GCC countries

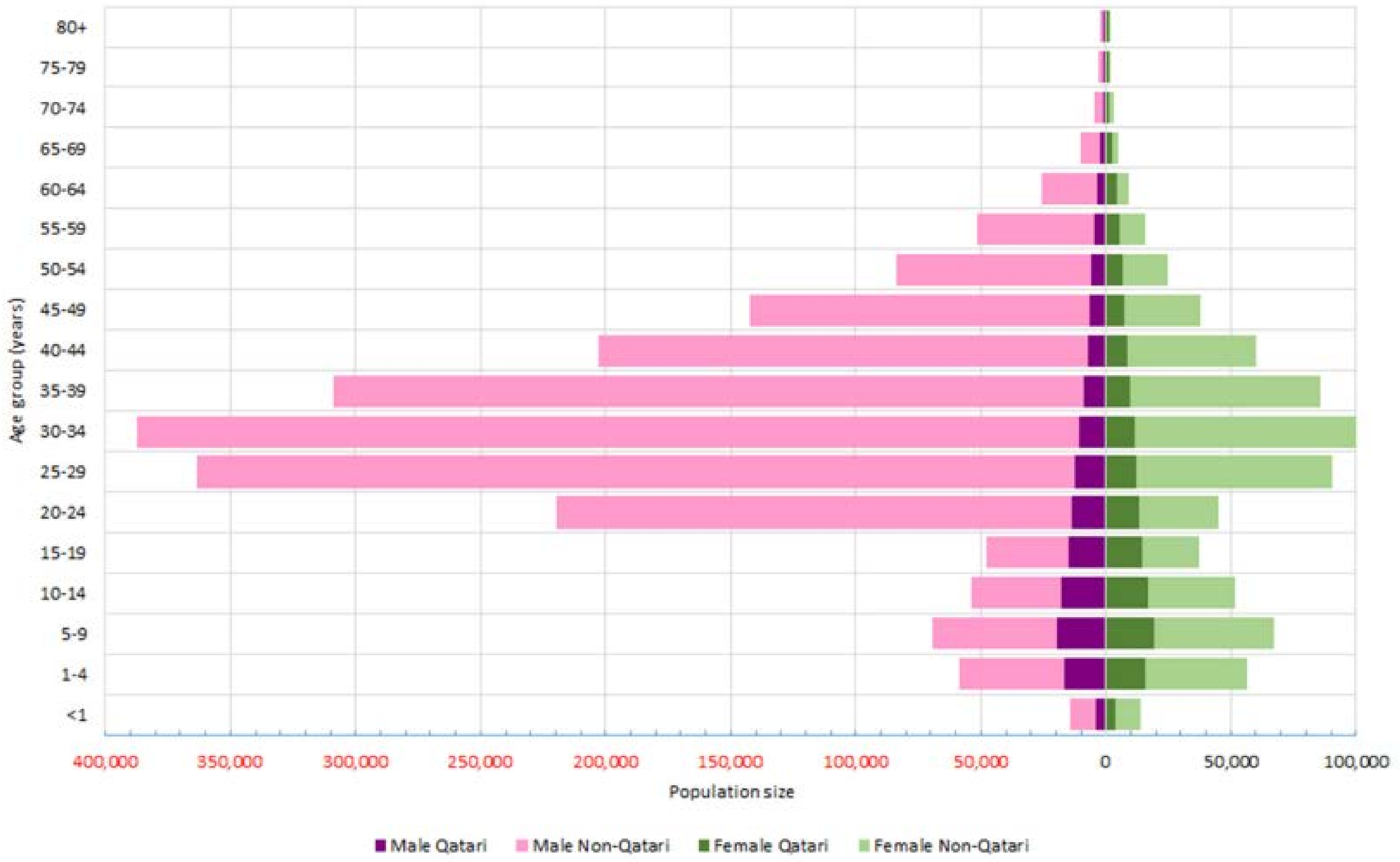


FIGURE 1
Population pyramid of Qatar by sex, age groups and nationality (2018).

Frontiers Public Health, 2023

Differential mortality in national and non-notional populations

Mortality rates per 100,000 population in Qatar by age-group, sex and nationality, 2018.

Age groups	Qatari			Non-Qatari			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
0–4	159.3	151.7	155.6	147.0	144.2	145.6	150.5	146.3	148.5
5–14	16.1	22.0	19.0	7.0	8.5	7.7	9.8	12.6	11.2
15–24	173.1	21.3	98.3	31.5	22.0	29.7	46.8	21.8	40.9
25–34	99.8	16.8	57.5	32.7	15.8	29.5	34.8	15.9	30.9
35–44	137.6	98.1	116.5	50.6	14.9	43.3	53.3	25.4	47.1
45–54	375.7	177.6	269.7	103.3	74.3	97.9	118.1	97.5	113.6
55–64	891.3	471.9	660.5	270.0	257.5	267.7	334.4	340.2	335.9
65–74	1,993.6	1,223.8	1,577.9	994.4	1,710.0	1,183.2	1,226.7	1,467.8	1,312.0
75+	6,397.0	4,942.0	5,636.6	3,724.0	4,840.8	4,130.9	4,892.1	4,901.2	4,896.1
All ages	299.9	192.1	245.1	66.9	64.7	66.4	84.1	92.7	86.3
Age-standardized	502.7	315.6	403.8	242.3	291.5	259.0	304.0	295.3	301.4

Frontiers Public Health, 2023

National experiences [and ideas] to improve coverage and quality of death registries

GROUP DISCUSSION

Muscat – Nov 20 to 23 2023

Analysis of causes of deaths & Review of the main findings of CoD analysis

Muscat – Nov 20 to 23 2023

Practical analysis of causes of deaths

- Use data for the most recent 2 population census in your country and number of deaths between the two censuses to estimate completeness of death registry (Only for nationals)
  - team-working/ use the online available data

- Use your estimate of completeness to update life table

- Calculate percentage of ill-defined and Garbage codes
  - Each participant: Select one of the numbers 1-24 of the ill-defined and garbage codes

- Redistribute your selected garbage code to all other causes (For this exercise, ignore that other causes might be an ill-defined or garbage code)

Working with YLL template

Muscat – Nov 20 to 23 2023

Calculating years of live lost (YLL) / Practical data analysis

Muscat – Nov 20 to 23 2023

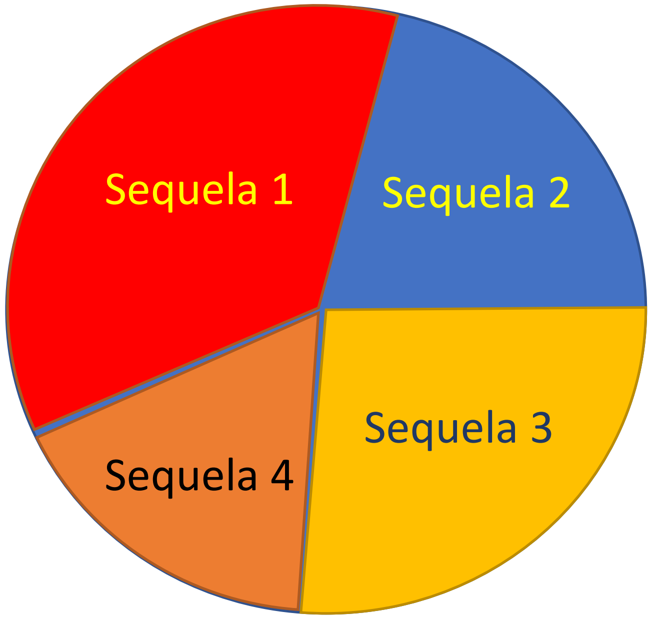
Day 3 (Wednesday Nov 22nd 2023)

Subject
Disease epidemiology indicators
Disease Modeling and DisMod
Review of available morbidity data in GCC countries
BREAK
Years Lived with Disabilities (YLD); valuing health conditions and disability weights
Working with YLD and DALY templates
Calculating YLD and DALYs / Practical data analysis
Burden attributable to risk factors
Lunch Break
Sullivan Healthy Life Expectancy approach

Disease epidemiology indicators

Muscat – Nov 20 to 23 2023

Disease (cause) and Sequelae



Disease A

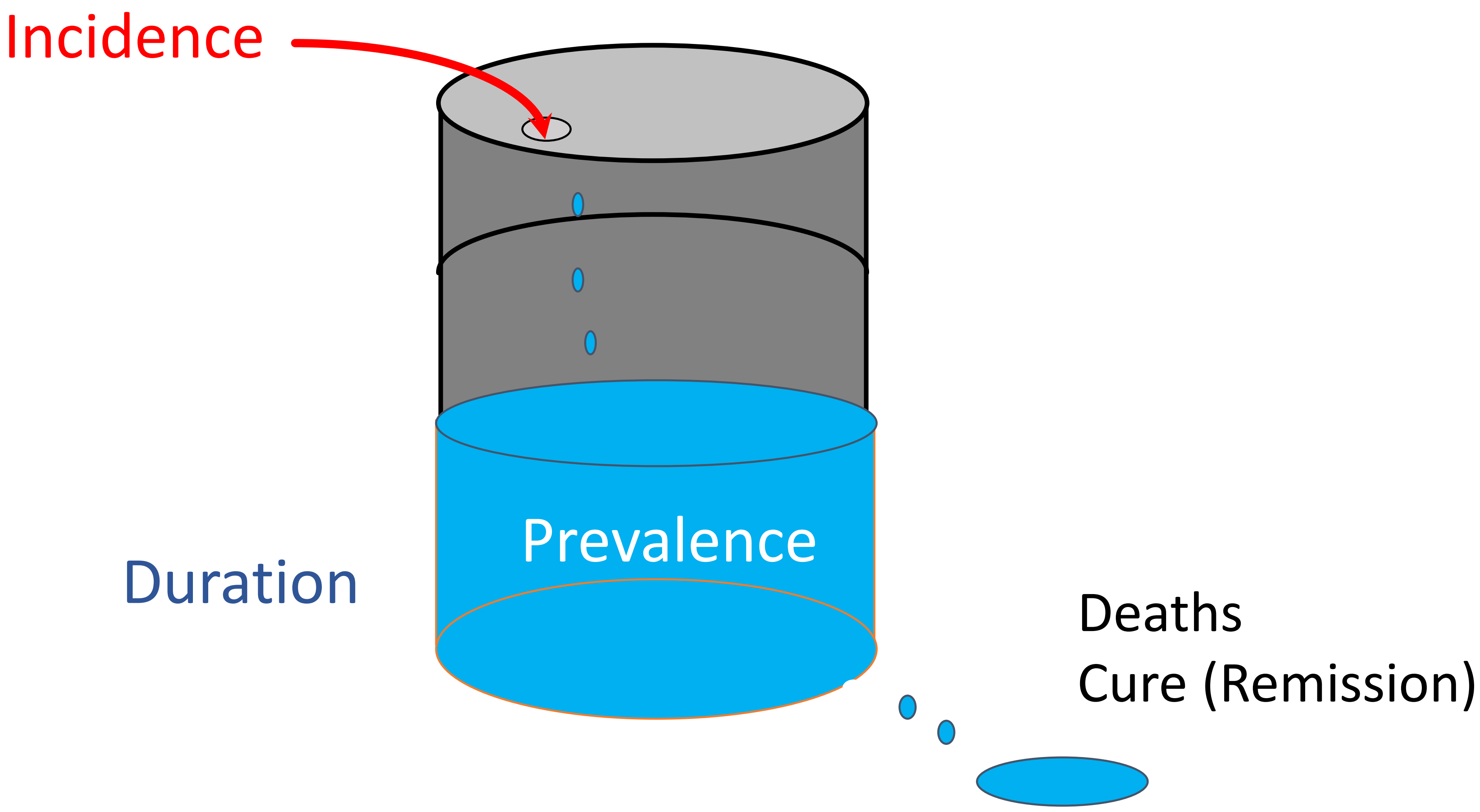
- GBD 2019
  - Diseases: 369
  - Sequela: 2118
    - Asymptomatic: 142
- Sequela
  - Mutually exclusive non-fatal conditions
  - Same diseases but different health states based on nature, duration and disability weight

$$YLDs_{\ disease} = \sum_{sequela=i}^{j} Prevalence_i * Disablity\ Weight_i$$

Stomach cancer: Sequela, health state names, lay description and disability weight

Sequela	Health state name	Health state lay description	Disability Weight
Diagnosis and primary therapy phase of stomach cancer	Cancer, diagnosis and primary therapy	has pain, nausea, fatigue, weight loss and high anxiety.	0.288 (0.193-0.399)
Controlled phase of stomach cancer	Generic uncomplicated disease: worry and daily medication	has a chronic disease that requires medication every day and causes some worry but minimal interference with daily activities.	0.049 (0.031-0.072)
Metastatic phase of stomach cancer	Cancer, metastatic	has severe pain, extreme fatigue, weight loss and high anxiety.	0.451 (0.307-0.6)
Terminal phase of stomach cancer	Terminal phase, with medication	has lost a lot of weight and regularly uses strong medication to avoid constant pain. The person has no appetite, feels nauseous, and needs to spend most of the day in bed.	0.54 (0.377-0.687)

General disease indicators



Measures of disease frequency

- Proportion = $\frac{\text{Cases}}{\text{Population}}$
  - such as prevalence

- Rate = $\frac{\text{Number of new events during a certain period}}{\text{Total number of person−years at risk}}$
  - such as incidence rate
  - Person time at risk: persons in the population contribute when alive and not-affected by the event

- Ratios = $\frac{\text{Rate of an event in diseased persons}}{\text{Rate of the same event in the reference group}}$
  - such as Incidence Rate Ratio

- Cumulative incidence= $\frac{\text{Number of new events during a certain period}}{\text{Total number of persons at-risk at the start of period}}$

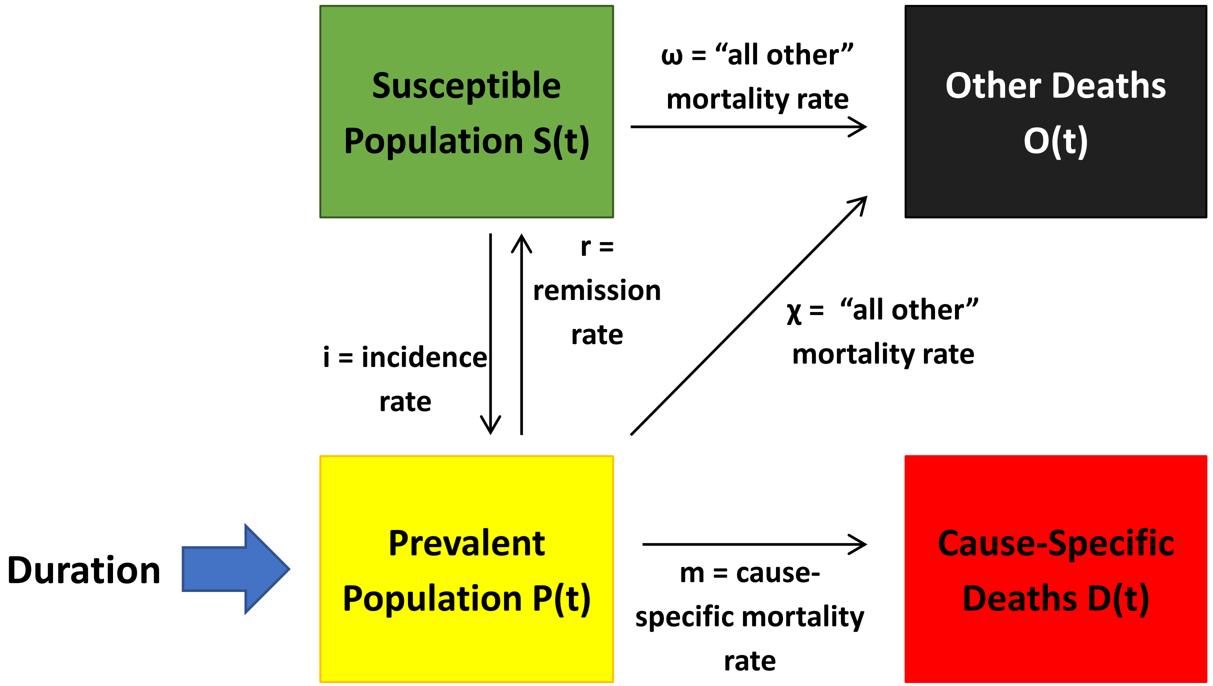
  - A probability, not a rate
  - Also known as ‘risk’, ‘incidence proportion’ and ‘attack rate’

  - Can be converted to an approximation of incidence rate using the rate equation:
    - $p = 1 - exp^{-rt}$
    - $r = -\frac{\ln(1-p)}{t}$
  - Probabilities range from 0 to 1 and rates range from 0 to ∞.

  - For modelling purposes, rates are the preferred way to express the transition from one state to another.

- Most remission data is reported as cumulative

Generic Compartmental Disease Model



For those who are interested in the differential equations:

$$\frac{dS(t)}{dt} = -(i+\omega)S(t)$$

$$\frac{dO(t)}{dt} = \omega\big(S(t)+P(t)\big)$$

$$\frac{dP(t)}{dt} = iS(t) - (r+m+\chi)P(t)$$

$$\frac{dD(t)}{dt} = mP(t)$$

DisMod & epidemiologic measures

- Prevalence
- Incidence
- Remission
- Cause-specific mortality
- Case fatality
- Relative Risk (RR) of mortality
- Duration

DisMod-MR also accepts other types of input data such as excess mortality, standardized mortality ratio (SMR) and with-condition mortality

Prevalence

- Point prevalence = $\frac{\text{Number of people with disease at a given point in time}}{\text{Total number of people in the population}}$
  - A proportion, not a rate
  - Useful for DisMod models

- Period prevalence
  - Number of people with disease in a period of time is considered
  - Usual periods of time: 1-year, 6-month, 3-month
  - Careful conversion to point prevalence

- Long-life prevalence
  - Not-useful in general for DisMod models

Rates as inputs of DisMod

- Prevalence
- Incidence
- Remission
- Cause-specific mortality
- Case fatality
- Relative Risk (RR) of mortality
- Duration

All these indicators are used as RATE in DisMod.

If they are in a different format, they need to be converted to rates

Example:

- In a population of 10,000 individuals, 100 new cases of a an infectious disease happened in the reference Year. Among the 100 cases, 10 individuals died and the other 90 cases had recovery. Average duration of disease was 1 month.
    - Assumption: No mortality due to other causes
    - Incidence (rate) = $\frac{100}{10,000}$ = 1%
    - Death proportion = 10%
    - Case fatality (rate) = $\frac{10}{\frac{1}{12} * 100}$ = 1.2 death per 1 person-year of disease
    - Remission proportion = 90%
    - Remission (rate) = $\frac{90}{\frac{1}{12} * 100}$ = 10.8 recovered person per 1 person-year of disease

RR of mortality versus Standardized Mortality Ratio (SMR)

$$RR = \frac{Mortality\ rate\ of\ diseased}{Mortality\ rate\ of\ non-diseased}$$

$$SMR = \frac{Mortality\ rate\ of\ diseased}{Mortality\ rate\ of\ entire\ population}\ [= RR\ of\ Mortality\ (in\ DisMod\ II)]$$

- When a disease is rare, RR and SMR are very similar and when it is common, they are very different
- In DisMod II, SMR was named RR of mortality which might be confusing for users
- In DisMod-MR, it was renamed as SMR

RR of mortality versus Case Fatality

$$RR = \frac{Mortality\ rate\ of\ diseased}{Mortality\ rate\ of\ entire\ population} = \frac{General\ Mortality + Case\ Fatality}{General\ Mortality}$$

$$RR = \frac{M+C}{M} \quad >>> \quad C = RR.M - M = M\ (RR - 1)$$

Duration, Remission and Case Fatality

$$Duration = \frac{1}{Remission + Case\ fatality}$$

Back-calculation of our example:

$$Duration = \frac{1}{10.8+1.2} = \frac{1}{12} \text{ (year)} = \text{ 1 month}$$

Example:

- In a population of 10,000 individuals, 100 new cases of a an infectious disease happened in the reference Year. Among the 100 cases, 10 individuals died and the other 90 cases had recovery. Average duration of disease was 1 month.
  - Assumption: No mortality due to other causes
  - Incidence (rate) = $\frac{100}{10,000}$ = 1%
  - Death proportion = 10%
  - Case fatality (rate) = $\frac{10}{\frac{1}{12} * 100}$ = 1.2 death per 1 person-year of disease
  - Remission proportion = 90%
  - Remission (rate) = $\frac{90}{\frac{1}{12} * 100}$ = 10.8 recovered person per 1 person-year of disease

Working with DisMod

Muscat – Nov 20 to 23 2023

Years Lived with Disabilities (YLD); valuing health conditions and disability weights

Muscat – Nov 20 to 23 2023

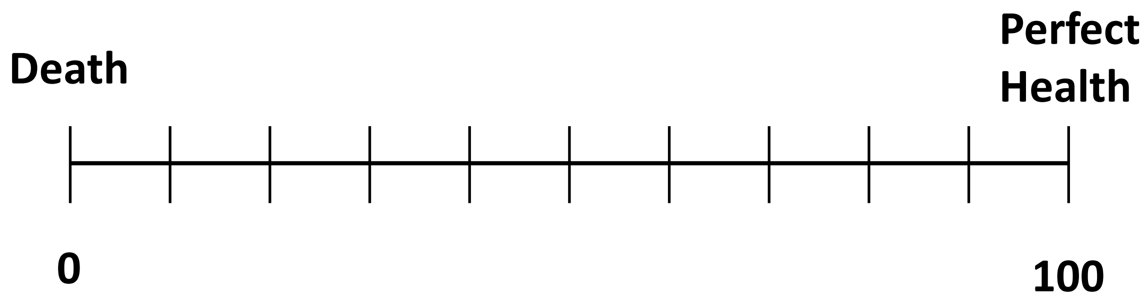
Valuation Techniques

Most frequent methods for valuation of health conditions:

- Rating and Visual analogue scales
- Standard gamble
- Time trade-off (TTO)
- Person trade-off (PTO)

Rating Scales / Visual Analogue Scale

Respondents position each health state on a scale from 0 (least desirable or death) to 100 (most desirable or perfect health)



Advantages

- easy to understand for most people
- cognitive burden is relative low

Disadvantages

- difficulty in assigning numbers to feelings about health states
- avoidance of extreme categories, clustering of values

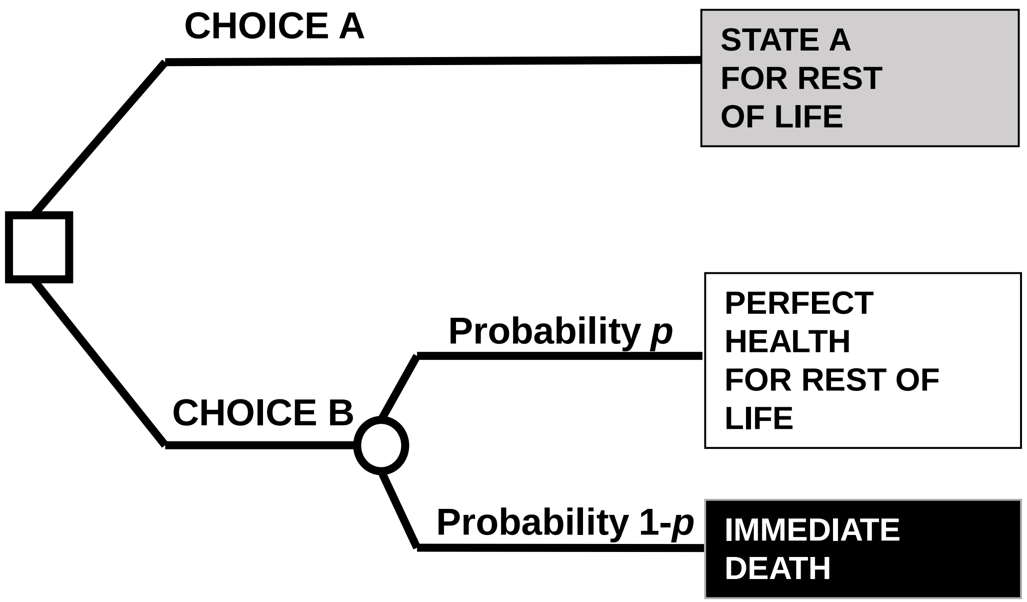
Standard Gamble

- Respondents compare 2 choices:

  1. Living with state A for the rest of life

  2. Choice B which has a probability of ***P*** for **complete recovery** and probability of **1-*P*** of **immediate death**

  - The question will be repeated by decreasing or increasing values of P, based on the respondent's initial choice, until the **point of indifference** is reached.



Standard Gamble

Advantage

- related to choices under uncertainty

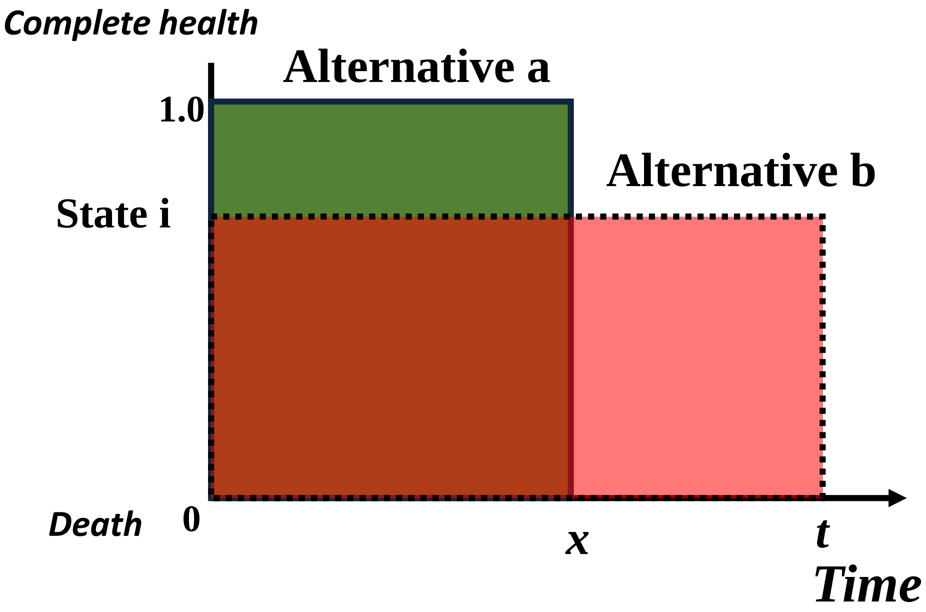
Disadvantage

- cognitively demanding
- does not correspond to typical decision making as choice between life and death are not real life scenarios
- variation between individuals in propensity to take risks

Time Trade-Off

- Respondents compare 2 choices:
  1. Living with **health condition *i*** for ***t*** years
  2. Living in **complete health** for ***x*** years (where x is shorter than *t*)

  In essence, respondents consider trading (t-x) years of life to enjoy full health instead of living with a health condition for a longer time. The question is repeated, by increasing or decreasing x until reaching the point of indifference.



Time Trade-Off

Advantage

- choice between two certain outcomes

Disadvantage

- seems to confound preferences for health states with time preference
- respondents are likely to include other (social) considerations than only health

Person Trade-Off

- Respondents compare 2 choices:
  1. Intervention A that prevents **deaths** in **x** (say 1,000) healthy individuals
  2. Intervention B that prevents **health condition B** in **y** (say 2000) healthy individuals
  - By choosing one intervention, respondent will lose the opportunity to implement the other intervention
  - Depending on the selected choice of respondent, number of y is increased or decreased to reach the point of indifference

Person Trade-Off

Advantage

- closely related to resource allocation question (position of a policy-maker)

Disadvantage

- respondents are reluctant to make such choices
- valuation exercise mixes health and distributive preferences

Disability weight lists

- Disability weight for each sequela
- Sometimes different for treated and non-treated cases
- Might be different based on severity

Disease sequelae	DW (uncertainty interval)
Mild diarrheal diseases	0.074 (0.049-0.104)
Moderate diarrheal diseases	0.188 (0.125-0.264)
Severe diarrheal diseases	0.247 (0.164-0.348)

- Severity distribution in different countries>> Different average DW
- Uncertainty interval

Disability weights and co-morbid conditions

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Co-morbidity

- Simultaneous presence of 2 (or more) causes of morbidity in one person
- Certain subpopulations, such as the elderly, are more susceptible to clustering comorbid conditions
- Neglecting comorbidity often leads to an overestimation of disabilities for common comorbid conditions.
- By ignoring comorbidity, disability weights (DWs) could potentially exceed 1, which is incongruent with the assumption that death represents the worst health condition.

Dealing with DW for Co-morbid conditions

Three general approaches:

- Maximum limit approach
  - disease with the highest overall DW
- Additive approach
  - comorbid disease simply adds to the utility loss of the primary disease
- Multiplicative approach
  - increases the utility loss of a patient, though it is less than the sum of the utility loss of both diseases independently

Multiplicative vs. Additive approaches

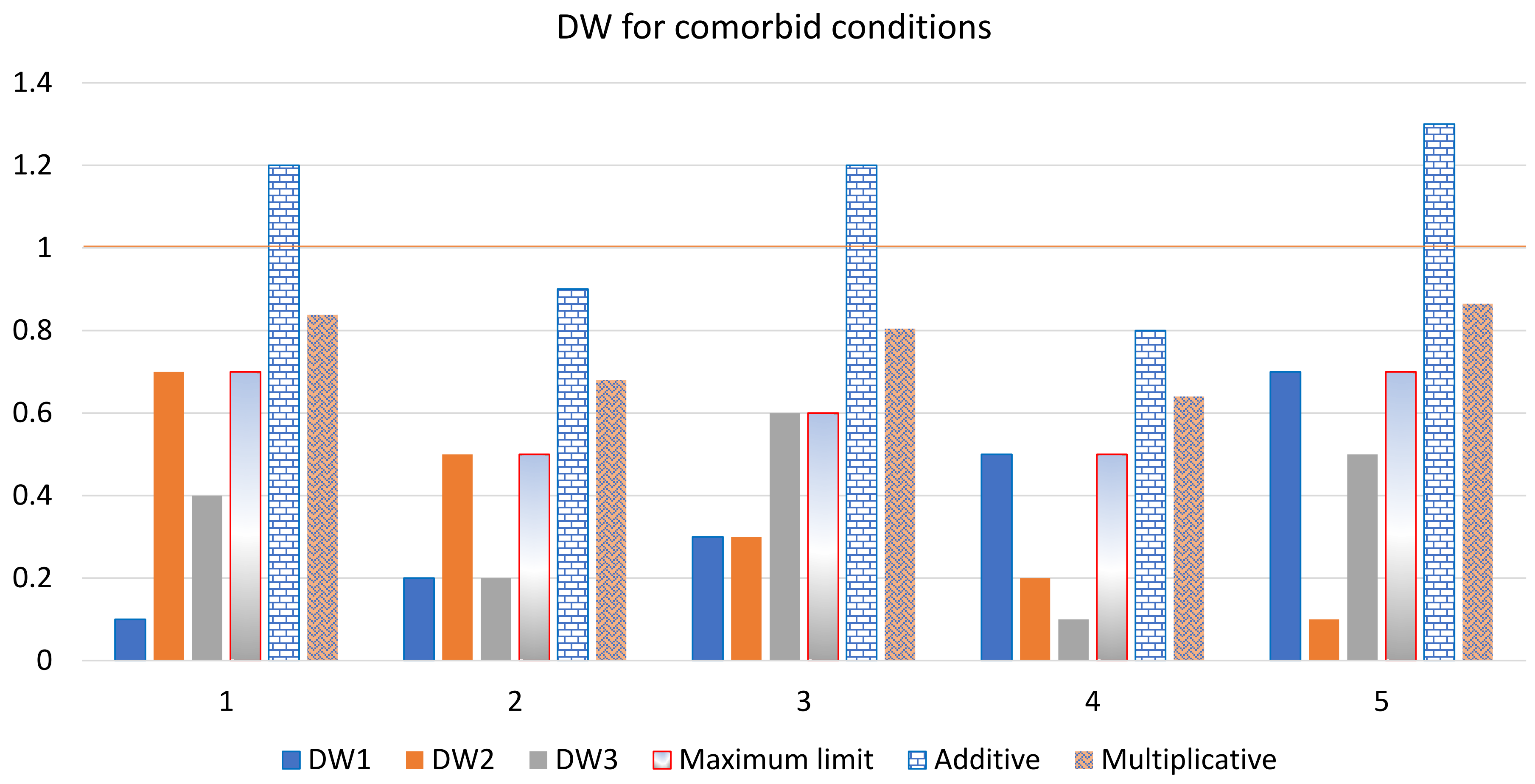
- For DW_1, DW_2, …, DW_n:

Multiplicative:

Comorbid DW = 1 -$\Pi\ (1 - DWi) = 1 - (1 - DW_1)(1 - DW_2) \ldots (1 - DWn)$

Additive:

Comorbid DW = ΣDW_i


DW for comorbid conditions
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
DW1
DW2
DW3
Maximum limit
Additive
Multiplicative

Simulation

- Pattern of comorbidity
  - Considering all conditional probabilities of comorbidities
    - Baseline evidence?
    - Feasibility?
- Simulation of comorbidities
  - Simulate a population with a structure similar to the reference population with estimated disease prevalence
  - Assume that prevalence of different diseases are independent
  - Simulation method has been used in the recent rounds of GBD

Working with DisMod

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Working with YLD and DALY templates

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Comparative Risk Assessment (CRA)

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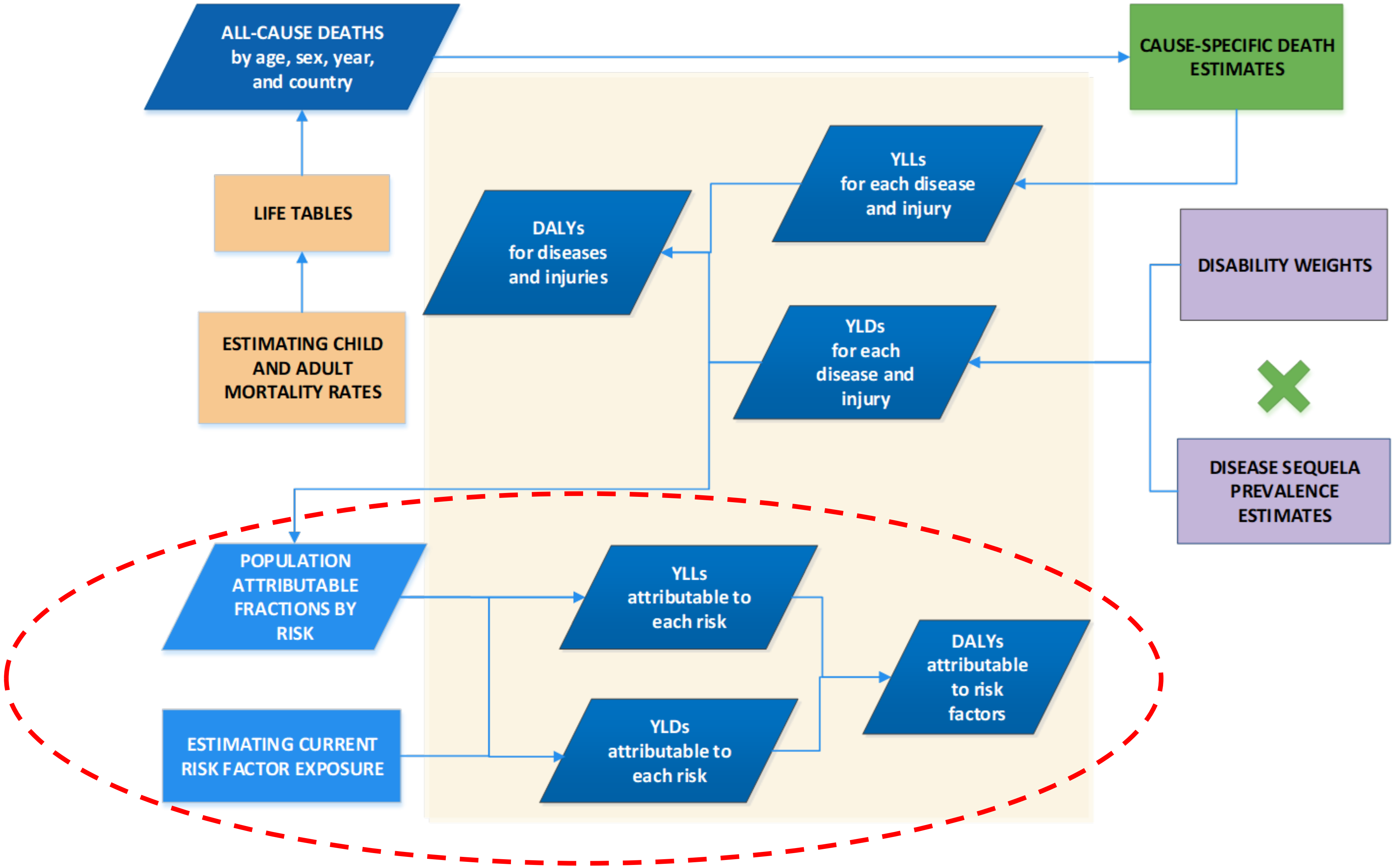
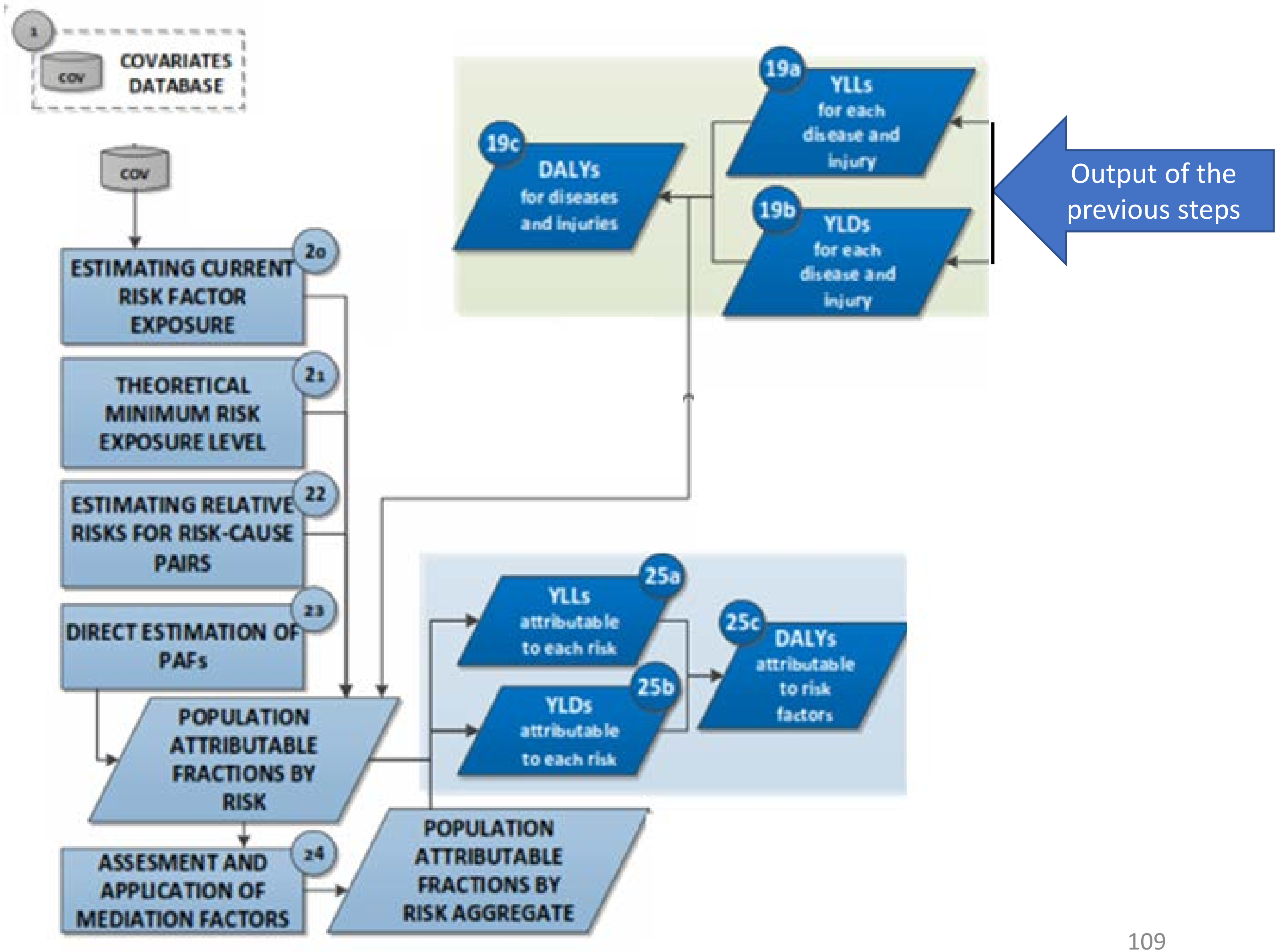
Simplified GBD flow chart



Estimating burden attributable to risk factors

- Select risk–outcome pairs
- Estimate exposure distributions to each risk factor in the population
- Estimate relative risk per unit of exposure for each risk–outcome pair
- Choose a counterfactual exposure distribution: theoretical minimum risk exposure distribution (TMRED)
- Compute attributable burden

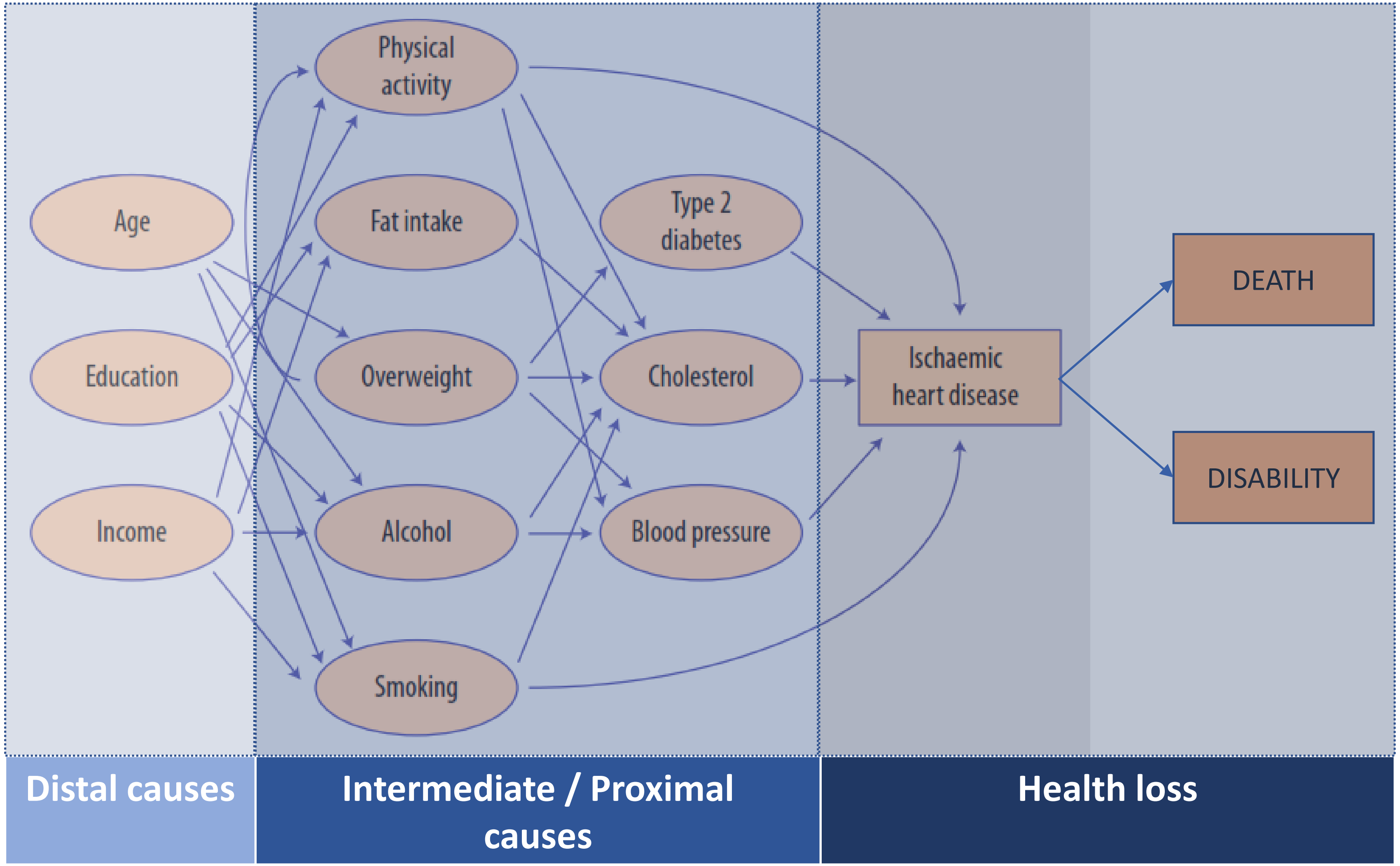


Risk factor- disease selection criteria

The World Cancer Research Fund grading system

Convincing evidence	• Based on epidemiological studies showing consistent associations between exposure and disease, with little or no evidence to the contrary • Based on a substantial number of studies including prospective observational studies and where relevant, RCTs of sufficient size, duration, and quality showing consistent effects • Biologically possible association
Probable evidence	• Based on epidemiological studies showing fairly consistent associations between exposure and disease, but for which there are perceived shortcomings in the available evidence or some evidence to the contrary, which precludes a more definitely judgment • Biologically possible association
Possible evidence	• Based mainly on findings from case-control and cross-sectional studies; insufficient RCTs, observational studies, or non-randomized controlled trials • Non-epidemiological study evidence (clinical, lab) is supportive
Insufficient evidence	• Based on findings of a few studies which are suggestive, but insufficient to establish an association • Little or no evidence from RCTs

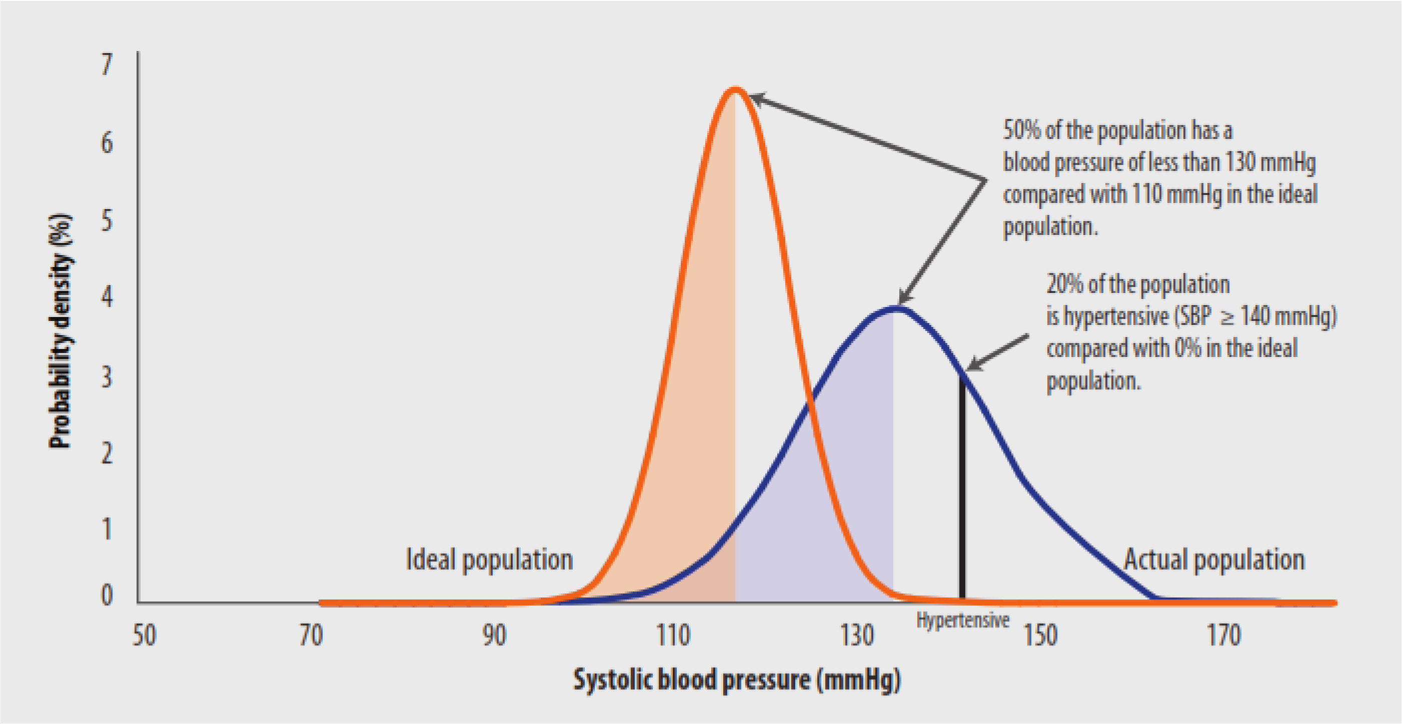
Distal and proximal causes of health loss



Comparative Risk Assessment (CRA)

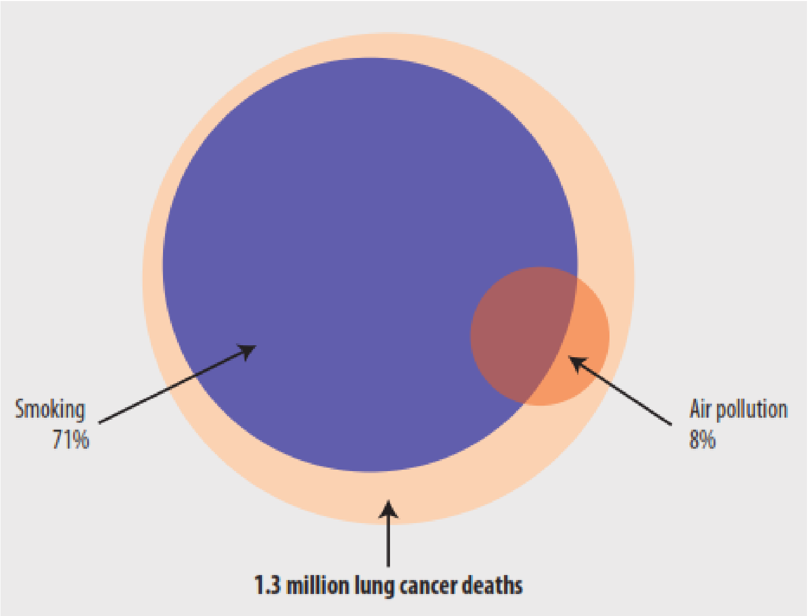
Systematic evaluation of the changes in burden of disease by modifying the population distribution of exposure to a theoretical risk factor distribution that implies minimum health loss (Theoretical Minimum Risk Exposure Distribution).

Comparative Risk Assessment



Distribution of current exposure, compared to the TMRED (ideal population)

Counterfactual analysis



Distribution of exposure

Dichotomous

- Obesity (Y/N)
- Hypertension (Y/N)

Categorical or Polychotamous

- Underweight, Normal weight, Overweight, Obese, Morbidly obese
- Hypotensive, Normotensive, Mildly hypertensive, Moderately hypertensive, Severely hypertensive

Continues

- Body Mass index
- Systolic blood pressure

Health effects of a risk factor

Population Attributable Fraction (PAF)

- PAF defines the percentage reduction in disease burden or death if there had been no exposure to the risk factor

$$PAF = \frac{P(RR-1)}{P(RR-1)+1}$$

- Prevalence of exposure
- RR: Relative Risk of disease in the exposed individuals compared to the non-exposed individuals (For a risk factor, RR is more than 1)

Health effects of a risk factor (ctd)

$$PIF = \frac{\int_l^h RR(x)P(x)dx - \int_l^h RR(x)P^*(x)dx}{\int_l^h RR(x)P(x)dx}$$

- PIF is the potential impact fraction (PIF) and is used instead of PAF where the counterfactual is not zero. In many cases, PIF is called PAF by epidemiologists.
  - P: Prevalence of exposure
  - RR: Relative Risk
  - dx (first formula): denotes that the integration is done with respect to *x* and *l* and *h* are the integration boundaries (lowest and highest exposure levels)

$$PIF = \frac{\sum_{i=1}^{n} P_i \, RR_i - \sum_{i=1}^{n} P_i' RR_i}{\sum_{i=1}^{n} P_i \, RR_i}$$

$$PAF = \frac{\sum_{i=1}^{k} P_i (RR_i - 1)}{\sum_{i=0}^{k} P_i (RR_i - 1) + 1}$$

Relative risk example

DISEASE	RISK FACTOR	SEX	Morbidity/ Mortality	Relative Risk (Uncertainty), all ages
Diarrheal diseases	Unimproved, untreated	Both	Both	11.084 (4.287 to 22.867)
Diarrheal diseases	Unimproved, chlorinated	Both	Both	8.024 (3.203 to 16.486)
Diarrheal diseases	Unimproved, filter	Both	Both	5.331 (2.153 to 10.887)
Diarrheal diseases	Improved, untreated	Both	Both	8.986 (3.898 to 17.446)
Diarrheal diseases	Improved, chlorinated	Both	Both	6.505 (2.905 to 12.528)
Diarrheal diseases	Improved, filtered	Both	Both	4.322 (1.954 to 8.243)
Diarrheal diseases	Piped, untreated	Both	Both	6.880 (3.104 to 13.016)
Diarrheal diseases	Piped, chlorinated	Both	Both	4.980 (2.320 to 9.296)
Diarrheal diseases	Piped, filtered	Both	Both	3.309 (1.564 to 6.129)
Diarrheal diseases	High quality (HQ) piped, untreated	Both	Both	2.079 (1.788 to 2.409)
Diarrheal diseases	HQ piped, chlorinated	Both	Both	1.505 (1.418 to 1.594)
Diarrheal diseases	HQ piped, filtered	Both	Both	1.000 (Reference group)

Population distribution of exposure to risk factors

- Systematic review, compile and critical appraisal of available data sources on exposure
- Critically assess : population representativeness of prevalence studies, study design and study quality
- Identify the best available data sources for population distribution of exposure for age-sex groups and by region
- Common sources of exposure data:
  - Ecological/environmental measurements
  - Household surveys/measurements
  - Indirect methods

Attributable burden

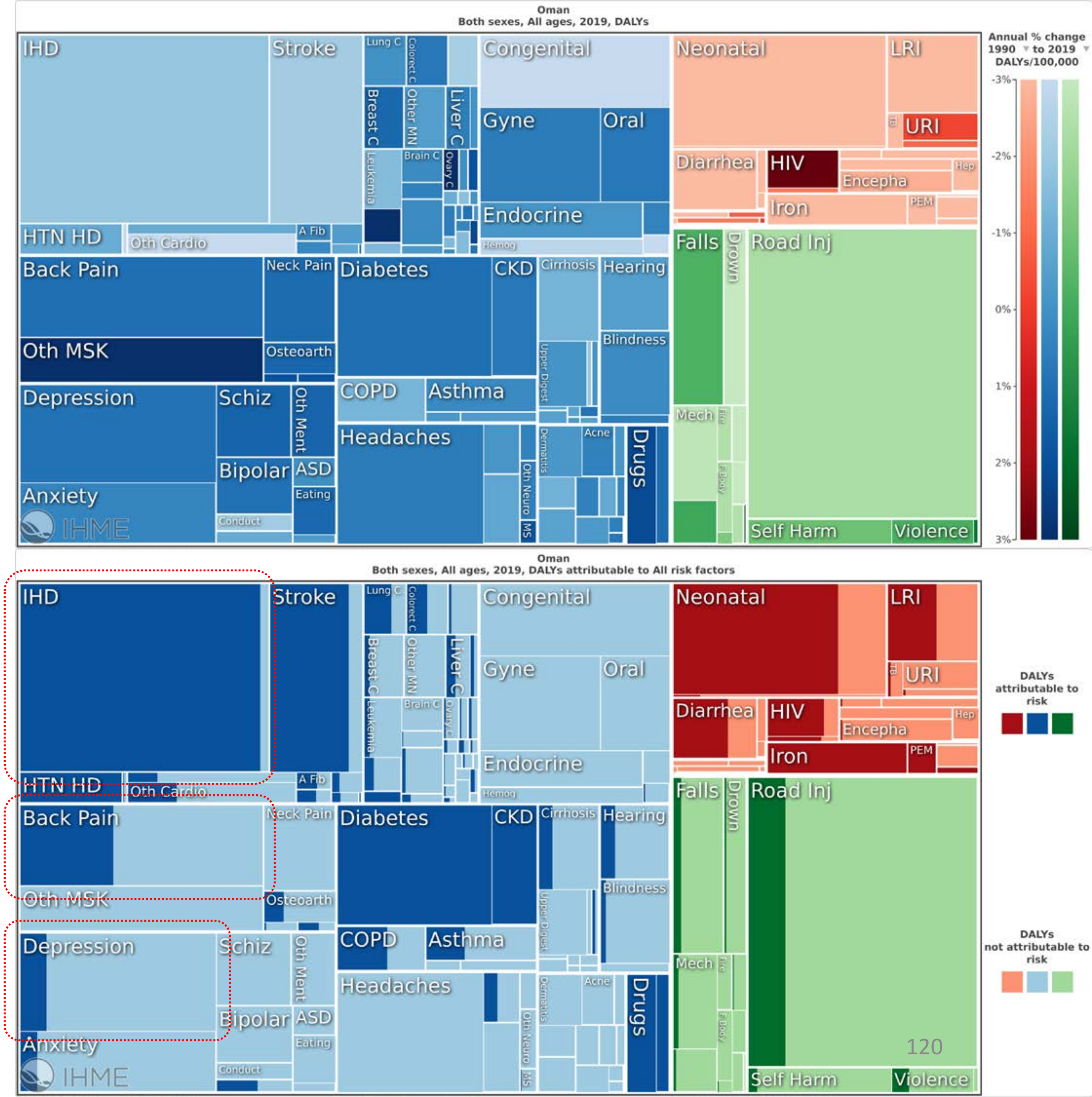
- Attributable Burden = PAF * B
  - PAF: Population Attributable Fraction
  - B: Estimated burden (DALYs or a component of burden, such as YLL, YLD or deaths)

- Zinc deficiency AND Diarrheal disease
  - In 1-4 year-old children: RR = 1.14, for both mortality and morbidity
  - Prevalence of Zinc deficiency in 1-4y: 30%
  - Diarrheal disease (<5y): 2,200 DALYs
    - PAF = $\frac{0.3(1.14-1)}{0.3(1.14-1)+1}$ = 0.04 >> Attributable burden = 0.04 * 2200 = 88 DALYs

$$PAF = \frac{P(RR-1)}{P(RR-1)+1}$$

Total PAF of the disease attributable to all included risk factors

$$Joint\ \mathrm{PAF} = 1 - \prod_{i=1}^{n}(1 - PAF_i)$$



Joint effects of risk factors

- Joint effect of six risk factors on ischemic heart disease in 70-79 year old males:

Risk factor	PAF
High Blood pressure	0.55
Hypercholesterolemia	0.42
Tobacco use	0.06
High BMI	0.14
Low Fruit & vegetables consumption	0.05
Low physical activity	0.20

$$Joint\ \mathrm{PAF} = 1 - \prod_{i=1}^{n}(1 - PAF_i)$$

Joint PAF = 1- [(1-0.55)(1-0.42)(1-0.06)(1-0.14)(1-0.05)(1-0.20)] = 0.8396

Attributable burden to air pollution

- AirQ+
- Inputs
  - Air quality data:
    - Average concentration (for long-term exposure effects)
    - Detailed concentration (frequency of days with particular pollutant concentration values), for short-term exposure effects
  - Data for population at risk
  - Health data, such as baseline rates of health outcomes in the population studied
  - A cut-off value for consideration (for example 10 µg/m3 for PM2.5)
  - RR values (if different from the AirQ+ default values)
  - Population and mortality data, both stratified by age, when using the life table analysis.

Health outcome		ICD-10	Exposure									
			Ambient air pollution									Household air pollution
			Long-term					Short-term				Long-term
			$PM_{2.5}$	PM_{10}	NO_2	O_3	BC	$PM_{2.5}$	PM_{10}	NO_2	O_3	Solid fuel use
Mortality	Mortality, all (natural) causes		x		x		x	x		x	x	
	Mortality, ALRI (children 0-4)	J10-J22	x									x
	Mortality, COPD (adults 30+)	J40–J44, J47	x									
	Mortality, COPD (women 30+)	J40–J44, J47										x
	Mortality, COPD (men 30+)	J40–J44, J47										x
	Mortality, IHD (adults 25+)	I20–I25	x									
	Mortality, IHD (women 25+)	I20–I25										x
	Mortality, IHD (men 25+)	I20–I25										x
	Mortality, LC (adults 30+)	C33-C34, D02.1-D02.2, D38.1	x									
	Mortality, LC (women 30+)	C33-C34, D02.1-D02.2, D38.1										x
	Mortality, LC (men 30+)	C33-C34, D02.1-D02.2, D38.1										x
	Mortality, Stroke (adults 25+)	I60-I63, I65-I67, I69.0-I69.3	x									
	Mortality, Stroke (women 25+)	I60-I63, I65-I67, I69.0-I69.3										x
	Mortality, Stroke (men 25+)	I60-I63, I65-I67, I69.0-I69.3										x
	Mortality, respiratory diseases	J00-J99				x					x	
	Mortality, CVDs	I00-I99									x	
	Postneonatal infant mortality, all-cause			x								
Prevalence/ incidence	Prevalence of bronchitis in children			x								
	Prevalence of bronchitis symptoms in asthmatic children aged 5-14				x							
	Incidence of chronic bronchitis in adults			x								
	Incidence of asthma symptoms in asthmatic children								x			
Hospital admissions	Hospital admissions: CVD (including stroke)							x				
	Hospital admissions, CVD (without stroke)										x	
	Hospital admissions: respiratory diseases							x		x	x	
RADs/work days lost	Work days lost, working age population only							x				
	Restricted activity days (RADs)							x				
	Minor restricted activity days (MRADs)										x	

Acronyms: International Classification of Diseases (ICD); Acute lower respiratory disease (ALRI), chronic obstructive pulmonary (COPD), Ischaemic heart disease (IHD), lung cancer (LC), cardiovascular diseases (CVD), restricted activity days (RADs), minor restricted activity days (MRADs), particulate matter less than 2.5 microns ($PM_{2.5}$), particulate matter less than 10 microns (PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), black carbon (BC)

Default values available:

To facilitate calculations, AirQ+ includes default values for:

- RRs for selected pollutant health end-points pairs;
- conversion factors between PM2.5 and PM10
- worldwide solid fuel use statistics at the national level

Calculating healthy life expectancy; Sullivan method

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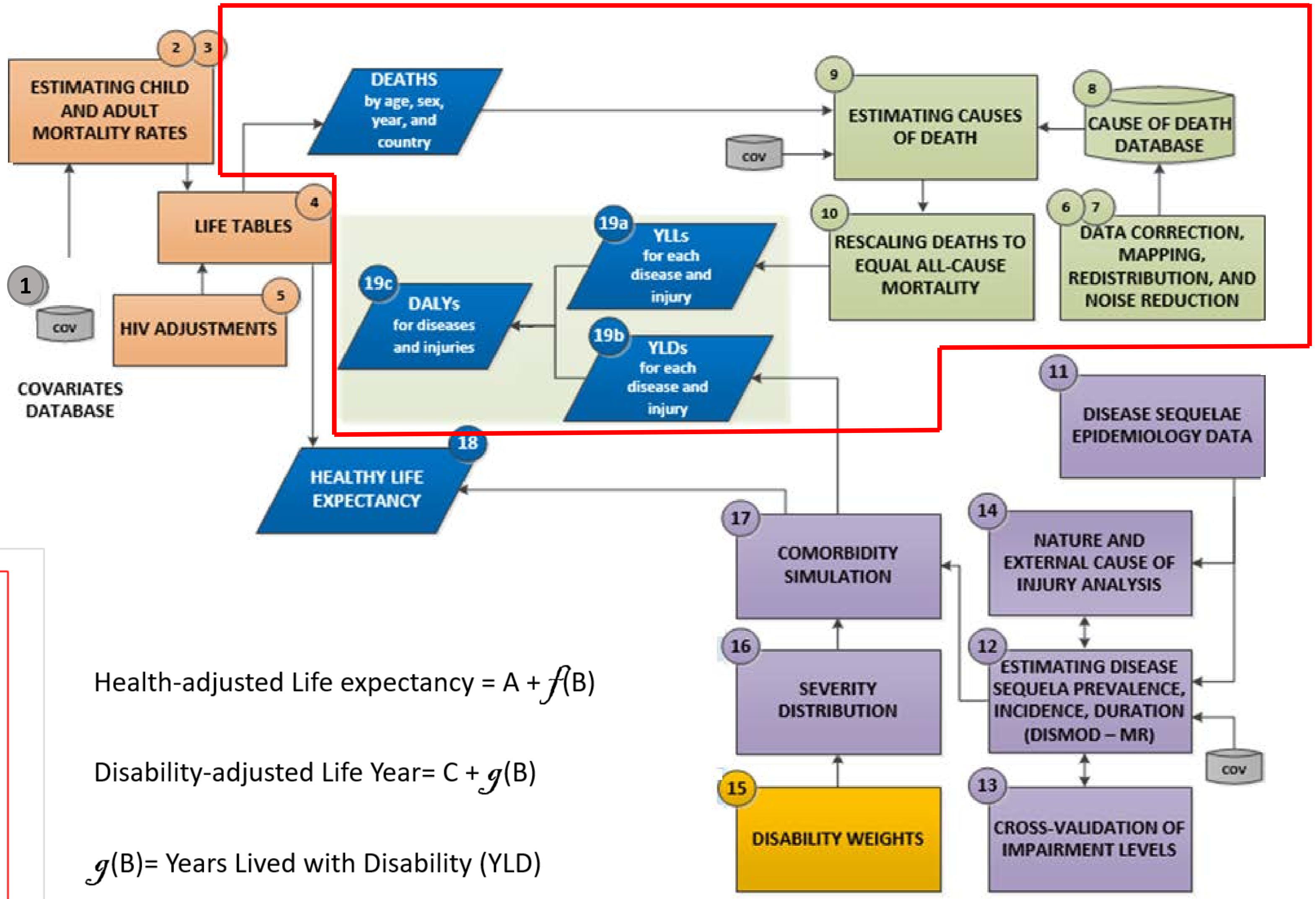
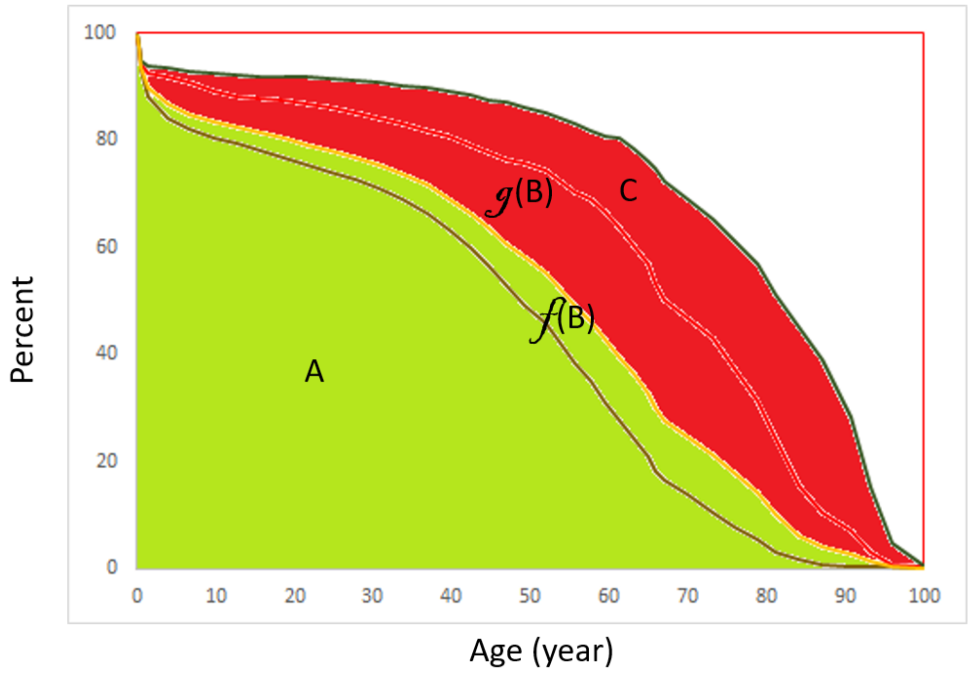
HALE

A review of what we're looking for





Health-adjusted Life expectancy = A + f(B)

Disability-adjusted Life Year= C + g(B)

g(B)= Years Lived with Disability (YLD)

Life expectancy - g(B) = HALE

A Single Index of Mortality and Morbidity

DANIEL F. SULLIVAN

A CONTINUING interest of the National Center for Health Statistics is the development and evaluation of new health indices suited to diverse specific purposes. No one index can reflect all aspects of health, but there is considerable agreement that an index which measures some aspects of nonfatal illness as well as mortality would be desirable. A rationale for using both mortality and disability rates as the components of such an index has already been published (*1*).

matical models of illness frequency, illness duration, and mortality (*2*). Moriyama has discussed criteria desired in an index of health and, in view of these, reviewe
some approaches proposed in t
literature (*3*). A description a
evaluation of disability concep
and measures being considered
the basis of the morbidity co
ponent of a mortality-morbidi
index appeared in a recent rep
(*4*).

Another technique for mergi
death rates with illness rates, a
some illustrative results are d

studies by those in a position to conduct related research.

Some preliminary index values based upon the techniques pre-

Table 3. Computation of the approximate expectation of life free of disability ($\mathring{e}_x\dagger$) for white males, civilian resident population, United States, mid-1960's

Age group	Exact initial age x	1965 abridged life table values [1] l_x	1965 abridged life table values [1] L_x	Disability weighting factor I_x [2]	Life table values, weighted for disability [3] $L_x\dagger$	$T_x\dagger$	$\mathring{e}_x\dagger$
Under 15	0	100, 000	1, 457, 411	0. 967	1, 409, 316	6, 252, 782	62. 5
15–44	15	96, 767	2, 830, 657	. 964	2, 728, 753	4, 843, 466	50. 1
45–64	45	90, 639	1, 623, 962	. 915	1, 485, 925	2, 114, 713	23. 3
65–74	65	65, 901	532, 960	. 802	427, 434	628, 788	9. 5
75 and over	75	39, 665	318, 095	. 633	201, 354	201, 354	5. 1

[1] Reference 10.

[2] For each age group, the weighting factor is

$$I_x = 1 - \frac{w_x}{365}$$

where w_x is the total number of disability days per person per year in the designated age group.

[3] The dagger symbol, †, is used in this paper to distinguish weighted life table values from the corresponding values denoted by conventional notation.

HSMHA Health Reports, 1971

Sullivan Method

- Sullivan Health expectancy: the number of remaining years, at a particular age, which an individual can expect to live in a healthy state
    - Disability-free life expectancy (in Sullivan's original paper)
        - Disability
            - Days in health institutions
            - Days unable to carry on major activities
            - Days of restricted activity (not elsewhere included)
- Health may be defined differently

Calculation of Disability-Free Life Expectancy (DFLE) by the Sullivan method using a single-year life table (method 1)

[1]	*[2]*	*[3]*	[4]	[5]	[6]	[7]	[8]	[9]	*[10]*	[11]	[12]	[13]	[14]
Age	***Mid-year population***	***No. deaths***	**Central Death rate**	**Conditional probability of death**	**Numbers surviving to age x**	**Person years lived at age x**	**Total number of years lived from age x**	**Total Life Expectancy**	***Proportion with disability***	**Person years lived without disability at age x**	**Total years lived without disability from age x**	**Disability-free life expectancy**	**Prop. of life spent disability free**
X	P_x	D_x	m_x	q_x	ℓ_x	L_x	T_x	e_x	π_x	$[1-\pi_x]L_x$	$\Sigma[1-\pi_x]L_x$	$DFLE_x$	$\%DFLE/e_x$
0	*54795.5*	*202*	0.003686	0.003606	100000.00	99711.50	8141517.37	81.4	*0*	99711.50	6657315.85	66.6	81.8
1	*54818*	*21*	0.000383	0.000383	99639.37	99620.29	8041805.87	80.7	*0.048*	94838.52	6557604.35	65.8	81.5
2	*55665.5*	*11*	0.000198	0.000198	99601.21	99591.37	7942185.57	79.7	*0.048*	94810.99	6462765.83	64.9	81.4
3	*55969.5*	*8*	0.000143	0.000143	99581.53	99574.41	7842594.20	78.8	*0.048*	94794.84	6367954.85	63.9	81.2
4	*55805.5*	*12*	0.000215	0.000215	99567.30	99556.59	7743019.79	77.8	*0.048*	94777.88	6273160.00	63.0	81.0
5	*56401.5*	*8*	0.000142	0.000142	99545.89	99538.83	7643463.19	76.8	*0.030*	96552.67	6178382.13	62.1	80.8
…..	.....	.....	.....	.....	.....	.....	.....	.....					
80	*41393.5*	*2049*	0.049501	0.048305	65741.36	64153.54	571593.91	8.7	*0.431*	36503.37	302397.46	4.6	52.9
81	*36644*	*1765*	0.048166	0.047033	62565.73	61094.39	507440.37	8.1	*0.431*	34762.71	265894.10	4.2	52.4
82	*32714*	*1435*	0.043865	0.042924	59623.05	58343.43	446345.98	7.5	*0.431*	33197.41	231131.39	3.9	51.8
83	*28395*	*1038*	0.036556	0.035900	57063.81	56039.53	388002.55	6.8	*0.431*	31886.49	197933.98	3.5	51.0
84	*20277.5*	*1201*	0.059228	0.057525	55015.25	53432.88	331963.02	6.0	*0.431*	30403.31	166047.49	3.0	50.0
85+	*125152*	*23298*	0.186158		51850.51	278530.14	278530.14	5.4	*0.513*	135644.18	135644.18	2.6	48.7

Jagger et. al. 2014, Institute for Ageing

Age-specific prevalence of disability for females in Belgium, 2004

Age at start of interval	Age group	Numbers surviving to age x	Person years lived in age interval	Total number of years lived from age x	Total Life Expectancy	*Proportion with disability*	Person years lived without disability in age interval	Total years lived without disability from age x	Disability-free life expectancy	Proportion of remaining life spent disability-free
x	x – x+n	ℓ_x	${}_nL_x$	T_x	e_x	π_x	$[1-\pi_x]_nL_x$	$\Sigma[1-\pi_x]_nL_x$	$DFLE_x$	$\%DFLE_x/e_x$
0	0	100000.00	99711.50	8141517.37	81.4	*0*	99711.50	6657315.85	66.6	81.8
1	1-4	99639.37	398342.67	8041805.87	80.7	*0.048*	379222.22	6557604.35	65.8	81.5
5	5-9	99545.89	497564.90	7643463.19	76.8	*0.03*	482637.95	6178382.13	62.1	80.8
10	10-14	99484.13	497298.40	7145898.30	71.8	*0.072*	461492.91	5695744.17	57.3	79.7
15	15-19	99423.34	496854.73	6648599.90	66.9	*0.098*	448162.96	5234251.26	52.6	78.7
20	20-24	99291.64	496050.19	6151745.17	62.0	*0.087*	452893.83	4786088.30	48.2	77.8
25	25-29	99128.49	495178.43	5655694.98	57.1	*0.096*	447641.31	4333194.47	43.7	76.6
30	30-34	98940.69	494180.05	5160516.54	52.2	*0.089*	450198.02	3885553.16	39.3	75.3
35	35-39	98714.90	492642.40	4666336.50	47.3	*0.142*	422687.18	3435355.14	34.8	73.6
40	40-44	98324.09	490188.26	4173694.09	42.4	*0.122*	430385.29	3012667.96	30.6	72.2
45	45-49	97718.05	486353.79	3683505.83	37.7	*0.195*	391514.80	2582282.67	26.4	70.1
50	50-54	96729.47	479719.40	3197152.04	33.1	*0.161*	402484.57	2190767.87	22.6	68.5
55	55-59	95034.89	470131.64	2717432.64	28.6	*0.298*	330032.41	1788283.29	18.8	65.8
60	60-64	93038.01	458117.83	2247301.01	24.2	*0.234*	350918.26	1458250.88	15.7	64.9
65	65-69	90062.67	440571.98	1789183.18	19.9	*0.257*	327344.98	1107332.62	12.3	61.9
70	70-74	85687.67	412410.98	1348611.20	15.7	*0.345*	270129.19	779987.64	9.1	57.8
75	75-79	78786.43	364606.31	936200.22	11.9	*0.431*	207460.99	509858.45	6.5	54.5
80	80-84	65741.36	293063.77	571593.91	8.7	*0.431*	166753.28	302397.46	4.6	52.9
85	85+	51850.51	278530.14	278530.14	5.4	*0.513*	135644.18	135644.18	2.6	48.7

Age group (years)	Prevalence of disability (%)
1-4	4.8
5-9	3.0
10-14	7.2
15-19	9.8
20-24	8.7
25-29	9.6
30-34	14.2
35-39	12.2
40-44	19.5
45-49	16.1
50-54	29.8
55-59	14.2
60-64	23.4
65-69	25.7
70-74	34.5
75-79	43.1
80-84	43.1
85+	51.3

Day 4 (Thursday Nov 23rd 2023)

Subject
Calculating health-adjusted life expectancy (HALE); GBD approach
Calculating Sullivan HLE / Practical data analysis
GBD visualization tools/ GBD Compare
BREAK
GBD visualization tools/ GBD Results tool
Review of GBD results; national findings of GCC countries
Wrap-Up, feedback, and building connections!
Lunch Break
Conclusion and Final remarks

Calculating health-adjusted life expectancy (HALE) – GBD Approach

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Step-by-step in GBD, 1

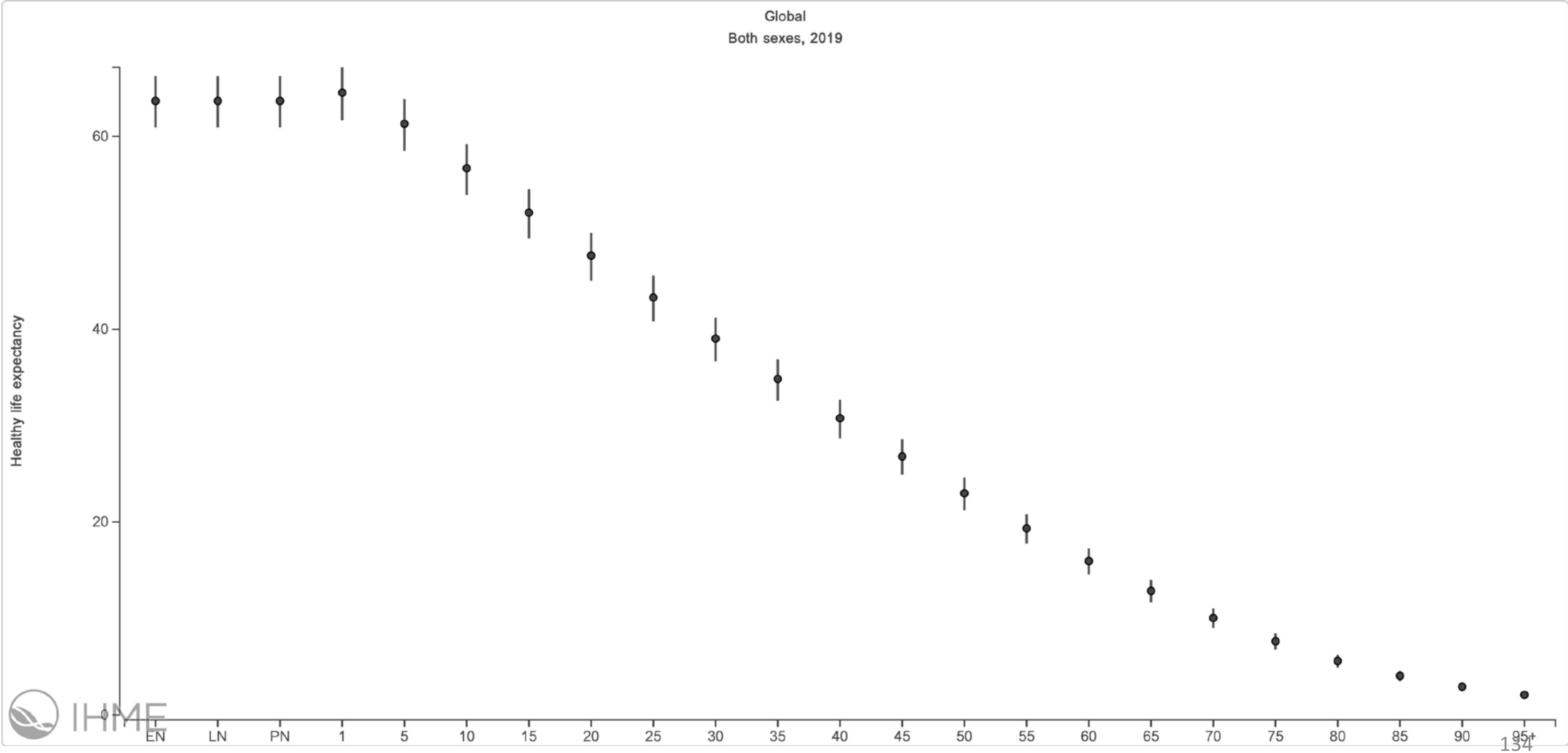
- Computing average health of individuals for every age group
  - Prevalences for all sequelae and their associated DW
  - Accounted for comorbidity with a Monte Carlo simulation approach.
  - A simulated population with possible multi-morbidities, consistent with the underlying estimates of prevalence.
  - Defining “1 minus the DW” as the positive health associated with each sequela
  - Average health values are computed as “1 minus the YLD per person in a population”
  - Computing health adjusted person years.

Step-by-step in GBD, 2

- Using the average health values into the life table using Sullivan's method
  - the nLx (average person-years lived within an age interval starting at age x) is multiplied by the corresponding average health value in that interval
  - Recalculating the rest of the life table using the adjusted nLx values
  - Generating health adjusted person years lived above a certain age (adjusted Tx) for each age group
  - HALE is calculated by dividing the adjusted Tx for each age group by the proportion of hypothetical birth cohort still alive at age x

HALE by age

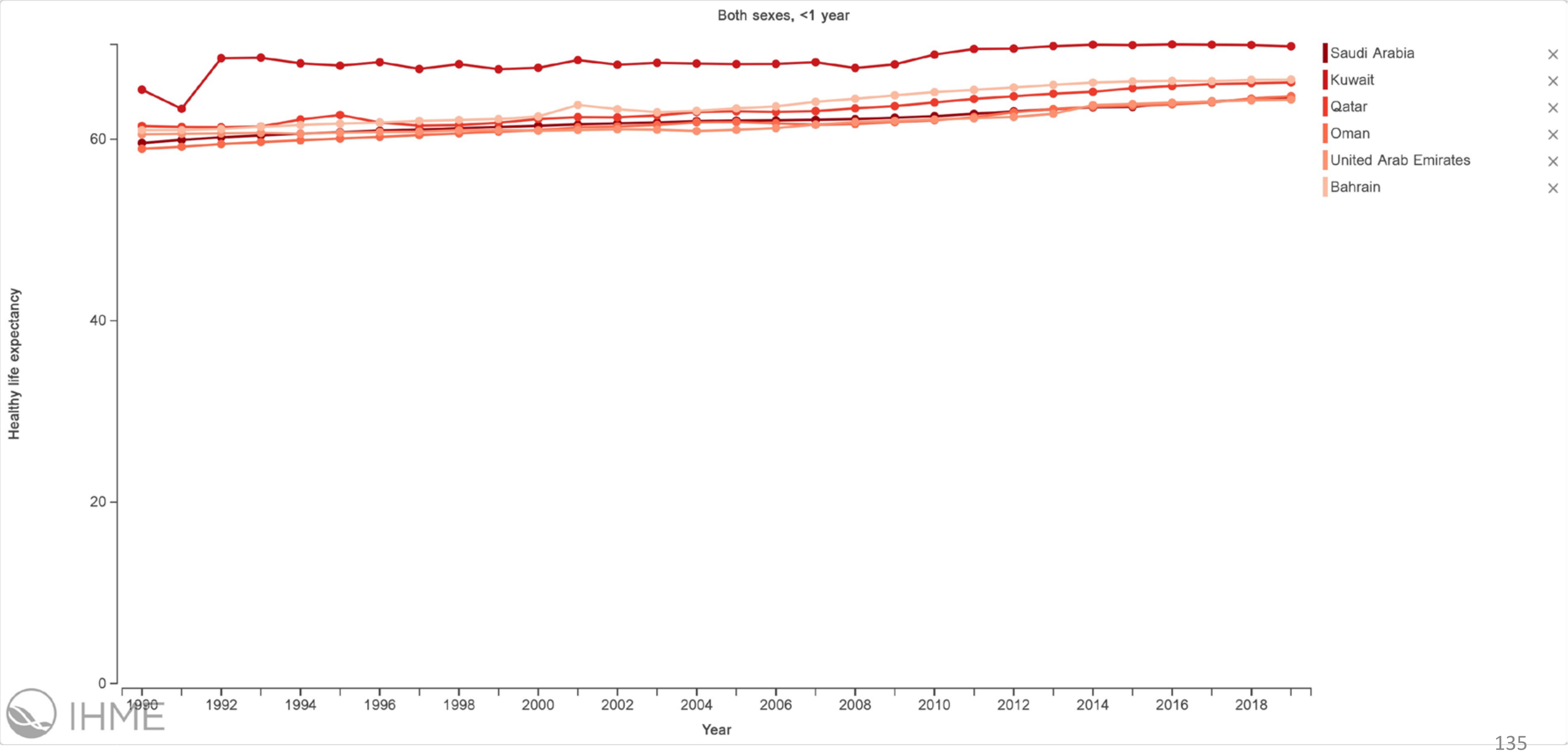
Global, Both Sexes, 2019, GBD



http://ihmeuw.org/68j0

HALE at birth

GCC countries, Both Sexes, 2019, GBD



http://ihmeuw.org/68iz

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Calculating Sullivan HALE / Practical session

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GBD visualization tools

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Conclusion

A quick review and suggestions for the next steps!

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What we discussed:

- General process and data requirements
- All-cause mortality, completeness, mortality envelope, life tables and LE
- Causes of death and corrections
- All-cause and disease-specific YLL
- Challenges of morbidity data
- Disease modeling
- Disability weights for single and comorbid health conditions
- Calculation of YLD and DALYs
- Calculation of HALE, Sullivan method and GBD approach

Suggestions for the next steps

Sources:

- WHO Burden of disease materials for BoD studies
- GBD course: Institute for Health Metrics and Evaluation (IHME)
- GBD course: University of Queensland
- GBD visualization tools and other GBD resources
- GBD study protocol and capstone papers
- Newcastle University: Health Expectancy Calculation by the Sullivan Method: A Practical Guide

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