Supplementary Material

Supplementary Table S1: Data inputs and sources [17-27]

Source	Information	Detail
Kent Household population projections, 2001-2037	Population data	Household population, migration and death estimates and projections: counts by age, sex, and local authority
ONS annual deaths, 2001-2016	Deaths	counts by age, cause of death, sex, and local authority
KiD	Number of A&E attendances	counts by cohort, age group and CCG
	Number of patients admitted to hospital (emergency)	counts by cohort, age group and CCG
	Number of GP appointments	counts by cohort, age group and CCG
	Number people supported by domiciliary care	counts by cohort, age group and CCG
	Number of people resident in a residential care home	counts by cohort, age group and CCG
	Number of people resident in a nursing home	counts by cohort, age group and CCG
Health Survey for England - 1999-2014	Lipid-lowering drugs	Prevalence of never having had angina or heart attack and currently taking lipid lowering drugs prescribed by a doctor
	Hypertension treatment	Prevalence of never having had angina or heart attack currently taking medication specifically prescribed to treat high blood pressure
	Smoking cessation	Prevalence healthy and a current smoker
	Weight management	Prevalence healthy and overweight or obese
General Lifestyle Survey and General Household Survey – 2005-2017	Alcohol consumption	Prevalence mean weekly alcohol consumption, None, low, hazardous or harmful
NHS England	Breastfeeding initiation	Breast feeding initiation percent (2013/14, 2014/15 & 2015/16 average)
	Smoking during pregnancy	Smoking during pregnancy percent (2014/15, 2015/16 & 2016/17 average)
National Child Measurement Programme,	Child Obesity	Child obesity prevalence, 11 year olds (2012/13 to 2015/16 average)

IMD 2010 (Index of Deprivation Affecting Children 0-15 years)	Fuel Poverty	Percent of children classed as living in child poverty (proxy for fuel poverty)
Millennium Cohort Study, 2017	Adverse Childhood Experiences (ACE)*	Percent of children with 1+ ACE (indirect), age groups and Percent of children with 3+ ACE (indirect / direct), at 15
Health Survey for England (HSfE) - 1999-2009	Current cigarette smoking	Self-reported status
	SBP (mmHg)	Mean SBP from 2nd and 3rd reading
	Body Mass Index	Valid height and weight measurements
	Total cholesterol (mmol/l)	Those reporting taking lipid lowering drugs were included
Health Survey for England (HSfE) - 1999-2004, 2006, 2008, 2009	Physical inactivity	Low or no activity levels
Health Survey for England (HSfE) - 2005-2017	Alcohol consumption	Self-reported status

Supplementary Table S2: Children and young people cohort definitions

Segmentation Cohort	Long-term conditions	Definition	KID definition
Health Conditions	Enduring physical health	Cystic Fibrosis, Cerebral Palsy, Other disorders of the nervous system, Diabetes Type 1, Epilepsy, Spina Bifida, Chronic Kidney Disease	Cerebral_Palsy, Parkinsons, Carpal_Tunnel_Syndrome, MS, Diabetes1, Eplisepsy, Spina_Bifida, CKD
	Enduring mental health	Schizophrenia, Psychoses, Bipolar	MH, OCD, Tourette
	Non-enduring physical health	Cancers, Cardiac, Asthma	Cancers, Cardiac, Asthma
	Non-enduring mental health	Mild Depression, Anxiety, Eating Disorder	Anorexia_Bulimia, Depression, Anxiety
	Learning disability	Downs Syndrome, other learning disability	Chromosome_inc_Downs, LD
	ADHD	ADHD	ADHD
	Autism	Autism	ASD
Healthy	None of the above	None of the above	None of the above

Supplementary Table S3: Adult cohort definitions

Segmentation Cohort	Cohort group	Long-term conditions	Definition	KID definition
Severe frailty	Severe frailty	Severe frailty	Electronic frailty index severe frailty (eFi:>0.36)	Electronic Frailty Index severe frailty (Frailty index > 2)
Multiple conditions and complex needs	Single conditions with high levels of need	Serious Mental Illness	Schizophrenia, psychoses, bipolar	MH
		Severe Learning Disability	Learning disability	LD
		Dementia	Diagnosed Dementia	Dementia
		Neurological Conditions	Diagnosed Parkinsons	Parkinsons
	Multiple conditions	Multiple conditions	2 or more of the single condition health cohorts, but excluding people already identified as severely frail or with a high need single condition	
Single Conditions	Single Conditions	Asthma	QoF definition	Asthma
		Coronary Heart Disease	QoF definition	CHD
		Chronic Obstructive Pulmonary Disease	QoF definition	COPD
		Type 2 Diabetes	QoF definition	Diabetes2
		Heart Failure	QoF definition	HF
		Stroke	QoF definition	Stroke
		Moderate frailty	Electronic Frailty Index moderate frailty (eFi: 0.24-0.36)	Electronic Frailty Index moderate frailty (Frailty index < 2)
Healthy	Healthy	Healthy	None of the above	None of the above

Supplementary Table S4: Prevalence of Children and Young people long-term conditions (2017) [17]

Cohorts	Age group (years)					
	0-1	2-4	05-10	11-15	16-17	18-24
Healthy	99.9	98.4	93.9	88.5	85.9	
ADHD	0.0	0.0	0.1	0.3	0.3	
Autism	0.0	0.1	0.5	0.6	0.4	
Mental Health Not Enduring	0.0	1.1	4.5	7.8	8.8	
Physical Not Enduring	0.0	0.0	0.2	1.2	2.8	
LD	0.0*	0.0*	0.0*	0.1	0.2	0.4
Mental Health Enduring	0.1	0.2	0.3	0.3	0.4	0.3
Enduring physical condition	0.0	0.2	0.6	0.9	1.2	1.4

Supplementary Table S5: Prevalence of Adult long-term conditions (2012) [17, 31]

	Age groups (years)					
Cohorts	**18-49**	**50-59**	**60-64**	**65-74**	**75-84**	**85+**
Healthy	89.6	76.8	70.2	58.8	43.2	31.8
Asthma	7.0	8.5	7.0	6.3	4.1	2.9
CHD	0.2	1.6	3.0	5.2	8.3	5.6
COPD	0.2	1.1	2.3	1.7	1.4	1.0
Diabetes type 2	1.0	3.9	5.7	5.5	5.3	4.6
HF	Contained within higher order cohorts, e.g. multiple and severe frail					
Stroke	0.1	0.5	1.0	1.7	2.9	2.1
Moderately Frail	0.0	1.8	2.2	2.6	5.2	6.0
Multiple LTC	0.9	4.3	6.6	8.7	12.7	11.8
Severe mental health	0.6	0.8	0.5	0.2	0.0	0.0
Neuro	0.0	0.1	0.7	0.4	0.9	0.2
Dementia	0.0	0.3	0.5	0.4	1.7	1.9
LD	0.3	0.3	0.3	0.2	0.1	0.0
Severe Frail	0.0	0.0	0.0	8.5	14.2	32.2

Supplementary Table S6: Adult percentage prevalence of single condition long-term conditions within multiple and frail cohorts (2012) [31]

Cohort	Multiple conditions	Frail
Asthma	43.8	4.5
CHD	40.1	6.9
COPD	35.1	4.4
Type 2 Diabetes	40.4	8.1
Heart Failure	4.8	0.6
Stroke	25.9	8.0
Frail moderate	38.5	25.3
Severe mental health	0.0	0.5
Parkinsons	0.0	4.5
Dementia	0.0	12.2

Supplementary Table S7: Incidence per 1000 population age 18 and over (2017)

Cohort CYP	Incidence, rate per 1000, age group (years)						
	0	**0-1**	**2-4**	**5-10**	**11-15**	**16-17**	**18-24**
From healthy	0.09	0.09	0.11	0.10	0.11	0.11	0.07
Health conditions							
From healthy	0.00	0.05	0.41	0.68	0.85	1.62	0.55

Supplementary Table S8: Incidence and mortality rates per 1000 population age 18 and over (2012) [17, 31]

Cohort	Healthy to cohort	Single to multiple	Frail to severe	Death rate
Healthy	0.0	0.5	2.0	4.0
Asthma	1.5	10.7	2.4	3.7
CHD	1.6	25.3	8.0	24.0
COPD	1.1	43.6	25.8	36.9
Diabetes type 2	2.2	33.6	10.3	14.5
HF	0.0	0.0	0.0	0.0
Stroke	1.0	58.3	22.9	23.0
Moderately Frail	2.1	8.5	54.2	50.7
Multiple LTC	4.1		38.9	37.3
Severe mental health	0.1		10.5	8.0
Neuro	0.3		47.6	64.3
Dementia	0.6		65.6	73.8
LD	from CYP model		8.0	
Severe Frail				140.1

Supplementary Table S9: Cause of death percent aged 50 and over (2012) [31]

	Cause of death (%)			
Cohort	**Cancer**	**CVD**	**Respiratory**	**Other**
Healthy	40.7	25.5	7.3	26.5
Asthma	41.7	33.3	8.3	16.7
CHD	31.0	45.2	3.6	20.2
COPD	0.0	71.4	28.6	0.0
Diabetes type 2	48.3	20.0	8.3	23.3
Heart failure	0.0	0.0	0.0	0.0
Stroke	50.0	12.5	25.0	12.5
Moderate frailty	8.8	28.4	42.2	20.6
Multiple LTC	25.9	36.1	17.0	21.0
Severe mental health	100.0	0.0	0.0	0.0
Parkinson's	16.7	0.0	0.0	83.3
Dementia	12.5	26.8	0.0	60.7
Frail severe	19.5	25.9	20.0	34.6
All persons	28.3	29.3	14.3	28.1

Supplementary Table S10: ONS Mortality by main cause of death (2012) [19]

Age group	CVD	Cancer	Respiratory	Other	Total	Percent
15-24	0	0	0	15	15	0%
25-34	0	0	0	18	18	0%
35-44	6	34	0	55	95	1%
45-54	79	199	6	142	426	3%
55-64	215	484	61	200	960	7%
65-74	570	963	253	328	2114	16%
75-84	1170	1254	587	873	3884	30%
85+	1837	915	1036	1849	5637	43%
Total	3877	3849	1943	3480	13149	100%
Percent	29%	29%	15%	26%	100%	

Supplementary Table S11: Adult percentage prevalence of long-term conditions by social grade (2012) [31]

Cohorts	Prevalence by social grade					
	DE	Average	Diff	Diff social class adj	Prevalence adj	Prevalence ratio
Healthy	55.84	63.11	-7.27	1.40	64.51	1.02
Asthma	6.25	5.96	0.30	-0.06	5.90	0.99
CHD	4.24	3.94	0.30	-0.06	3.88	0.99
COPD	1.95	1.53	0.42	-0.08	1.44	0.95
Diabetes type 2	6.40	5.45	0.95	-0.18	5.27	0.97
HF	0.03	0.04	-0.01	0.00	0.04	1.00
Stroke	1.53	1.27	0.26	-0.05	1.22	0.96
Moderately Frail	3.26	2.69	0.57	-0.11	2.58	0.96
Multiple LTC	10.37	8.09	2.28	-0.44	7.66	0.95
Severe mental health	0.60	0.43	0.17	-0.03	0.40	0.93
Neuro	0.46	0.42	0.04	-0.01	0.41	0.98
Dementia	0.94	0.86	0.09	-0.02	0.84	0.98
LD	n/a		0.00	0.00	0.00	1.00
Severe Frail	8.13	6.22	1.91	-0.37	5.85	0.94

Supplementary Table S12: Observed risk factor levels in 1999 and 2009 by social class [21]

	Professional		Managerial and skill non-manual		Manual skilled		Unskilled manual		England	
Year	**1999**	**2009**	**1999**	**2009**	**1999**	**2009**	**1999**	**2009**	**1999**	**2009**
Smoking prevalence, %	13.6	8.4	22.1	18.3	32.6	28.5	34.6	33.6	26.3	22.1
Physical inactivity, %	34.7	23.9	37.1	33.7	38.0	37.4	38.6	39.9	37.4	34.6
Systolic blood pressure, mmHg	134.9	131.1	134.2	129.9	136.2	132.8	138.5	134.2	135.3	131.2
Cholesterol, mmol/l	5.48	5.41	5.49	5.46	5.56	5.36	5.60	5.45	5.53	5.42
Body mass index, kg/m^2	26.1	26.7	26.3	27.2	26.7	27.5	27.0	28.0	26.3	27.2

Supplementary Table S13: Variable definitions for adult risk factors [21]

Risk factor HSfE survey	HSfE survey years	Description
Current cigarette smoking	1999-2009	Self-reported status
SBP (mmHg)	1999-2009	Mean SBP from 2nd and 3rd reading
Body Mass Index	1999-2009	Valid height and weight measurements
Total cholesterol (mmol/l)	1999-2009	Those reporting taking lipid lowering drugs were included
Physical inactivity	1999-2004, 2006, 2008, 2009	Low or no activity levels
Alcohol consumption	2005-2017	Self-reported status

Supplementary Table S14: Beta coefficients for major risk factors: Systolic blood pressure [33]

Estimated β coefficients from multiple regression analyses for the relationship between absolute changes in population mean risk factors and percentage changes in coronary heart disease mortality for men and women, stratified by age.

Systolic Blood pressure					
	Age group				
	25-44	**45-54**	**55-64**	**65-74**	**75+**
Men (hazard ratio per 20 mmHg)	0.49	0.49	0.52	0.58	0.65
Men (log hazard ratio per 1 mmHg)	-0.036	-0.035	-0.032	-0.027	-0.021
Minimum	-0.029	-0.028	-0.026	-0.022	-0.017
Maximum	-0.043	-0.042	-0.039	-0.032	-0.025
Men (hazard ratio per 20 mmHg)	0.4	0.4	0.49	0.52	0.59
Men (log hazard ratio per 1 mmHg)	-0.046	-0.046	-0.035	-0.032	-0.026
Minimum	-0.037	-0.037	-0.028	-0.026	-0.021
Maximum	-0.055	-0.055	-0.042	-0.039	-0.031

Supplementary Table S15: Beta coefficients for major risk factors: Body mass index [34-35]

Estimated β coefficients from multiple regression analyses for the relationship between absolute changes in population mean risk factors and percentage changes in coronary heart disease mortality for men and women, stratified by age.

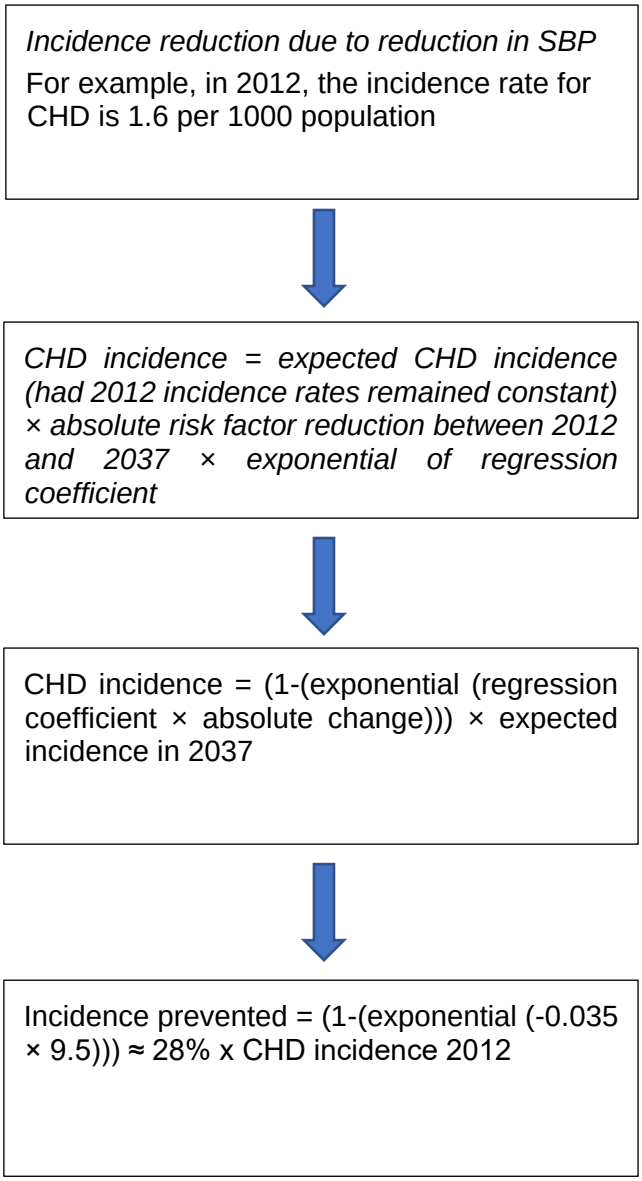
Body Mass Index (BMI)					
	Age group				
	<44	**45-59**	**60-69**	**70-79**	**80+**
Hazard ratio	0.89	0.91	0.95	0.96	0.97
Risk reduction per 1kg/m^2	0.11	0.09	0.05	0.04	0.03
Age gradient (45-59 as reference)	1.22	1	0.56	0.44	0.33
Relative risks, CHD deaths per 5 BMI units (1kg/m^2)		1.16			
Relative risks, CHD deaths per 1kg/m^2 applying age gradients from James et al	1.04	1.03	1.02	1.01	1.01
Log coefficients	0.0363	0.0297	0.0165	0.0132	0.010
Minimum	0.0255	0.0209	0.0116	0.0093	0.007
Maximum	0.0466	0.0381	0.0212	0.0169	0.0127

Supplementary Table S16: Beta coefficients for major risk factors: Cholesterol [36]

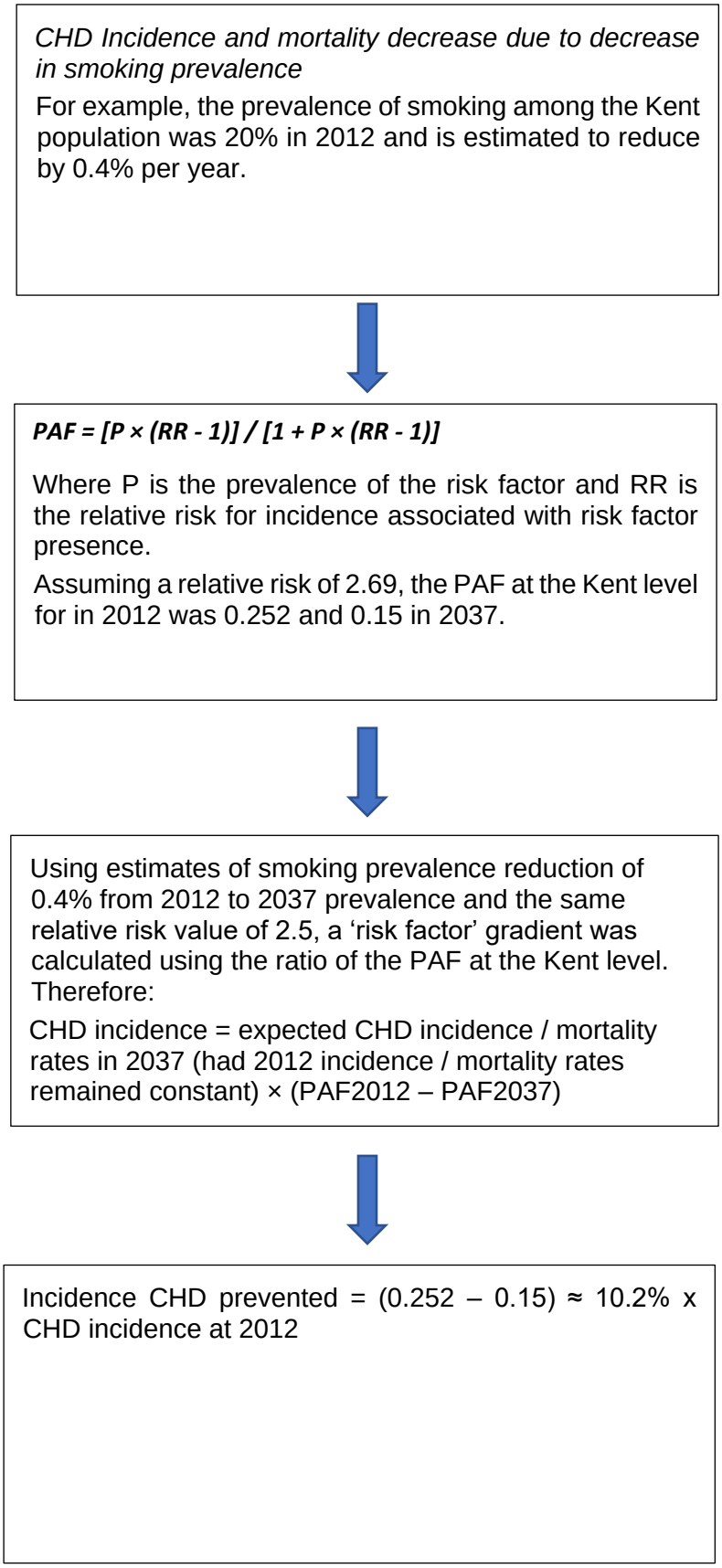
Estimated β coefficients from multiple regression analyses for the relationship between absolute changes in population mean risk factors and percentage changes in coronary heart disease mortality for men and women, stratified by age.

Cholesterol						
	Age group					
	25-44	45-54	**55-64**	**65-74**	**75-84**	**85+**
Mortality reduction per 1 mmol/l						
Men	0.55	0.53	0.36	0.21	0.21	0.21
Women	0.57	0.52	0.35	0.23	0.23	0.23
Log coefficient						
Men	-0.799	-0.755	-0.446	-0.236	-0.117	-0.083
Minimum	-0.639	-0.604	-0.357	-0.189	-0.093	-0.067
Maximum	-0.958	-0.906	-0.536	-0.283	-0.140	-0.100
Women	-0.844	-0.734	-0.431	-0.261	-0.174	-0.051
Minimum	-0.675	-0.587	-0.345	-0.209	-0.139	-0.041
Maximum	-1.013	-0.881	-0.517	-0.314	-0.209	-0.062

Supplementary Figure S1: Estimation of risk factor changes using regression method.



Supplementary Figure S2: Estimation of incidence and mortality changes from risk factor changes using the PAF method.



Supplementary Table S17: Relative risk for underlying risk, incidence and mortality: smoking in adults [37]

			Men		Women		Both	
		Age	**Current**	**Ex**	**Current**	**Ex**	**Current**	**Ex**
Cancers	lung	35+	23.26	8.70	12.69	4.53	17.98	6.62
	upper respiratory	35+	10.89	3.40	5.08	2.29	7.99	2.85
	oesophagus	35+	6.76	4.46	7.75	2.79	7.26	3.63
	larynx	35+	14.60	6.34	13.02	5.16	13.81	5.75
	cervical	35+	1.00	1.00	1.59	1.14	1.30	1.07
	bladder	35+	3.27	2.09	2.22	1.89	2.75	1.99
	kidney and renal pelvis	35+	2.50	1.70	1.40	1.10	1.95	1.40
	stomach	35+	1.96	1.47	1.36	1.32	1.66	1.40
	pancreas	35+	2.31	1.15	2.25	1.55	2.28	1.35
	unspecified	35+	4.40	2.50	2.20	1.30	3.30	1.90
	myeloid leukaemia	35+	1.80	1.40	1.20	1.30	1.50	1.35
Respiratory	COPD*	35+					6.50	3.00
	Chronic airways disease	35+	10.58	6.80	13.08	6.78	11.83	6.79
	Pneumonia	35-64	2.50	1.40	4.30	1.10	3.40	1.25
	Pneumonia	65+	2.00	1.40	2.20	1.10	2.10	1.25
	Pneumonia	35+	2.25	1.40	3.25	1.10	2.75	1.25
Circulatory	Other Heart		1.78	1.22	1.49	1.14	1.64	1.18
	CHD	35+	2.48	1.50	2.90	1.53	2.69	1.51
	Other arterial	35+	2.07	1.01	2.17	1.12	2.12	1.07
	Stroke	35-54	4.40	1.10	5.40	1.30	4.90	1.20
	Stroke	55-64	3.10	1.10	3.70	1.30	3.40	1.20
	Stroke	65-74	2.20	1.10	2.60	1.30	2.40	1.20
	Stroke	75+	1.60	1.10	1.30	1.00	1.45	1.05
	Stroke	35+	2.83	1.10	3.25	1.23	3.04	1.16
	aortic aneurism	35+	6.20	3.07	7.07	2.07	6.64	2.57
	Atherosclerosis	35+	2.44	1.33	1.83	1.00	2.14	1.17
Digestive disease	Stomach ulcer	35+	5.40	1.80	5.50	1.40	5.45	1.60
	Crohn's disease	35+	2.10	1.00	2.10	1.00	2.10	1.00
	Periodontal/Periodontitis	35+	3.97	1.68	3.97	1.68	3.97	1.68
Total death rate							3.84	1.43

Supplementary Table S18: Relative risk for underlying risk, incidence and mortality: physical inactivity in adults [38-39]

Relative risk of Coronary Heart Disease, Stroke and Diabetes from physical (in)activity levels from WHO GBD Study, relative to those considered physically active

	CHD		Stroke		Diabetes	
Age	**Inactive**	**Insufficient**	**Inactive**	**Insufficient**	**Inactive**	**Insufficient**
15-69	1.71	1.44	1.53	1.1	1.45	1.24
70-79	1.5	1.31	1.38	1.08	1.32	1.18
80+	1.3	1.2	1.24	1.05	1.20	1.11

Physical (in)activity in the WHO GBD study was treated as a categorical variable with three categories: Level 1: Inactive: ‘doing no or very little physical activity at work, at home, for transport, or during discretionary time’. Level 2: Insufficiently active: ‘doing some physical activity but less than 150 minutes of moderate-intensity physical activity or 60 minutes of vigorous-intensity physical activity a week accumulated across work, home, transport or discretionary domains’. Level 3: Sufficiently active (unexposed): ‘at least 150 minutes of moderate-intensity physical activity or 60 minutes of vigorous-intensity physical activity a week accumulated across work, home, transport or discretionary domains’, which approximately corresponds to current recommendations in many countries.

Supplementary Table S19: Relative risk for underlying risk, incidence and mortality: obesity and overweight in adults [40-41]

Relative risk of Coronary Heart Disease, Stroke Hypertension and Diabetes from overweight and obesity levels from WHO GBD Study, relative to those considered physically active

	Overweight		**Obese**	
	under 65	**over 65**	**under 65**	**over 65**
CHD	1.38	1.00	1.90	1.23
Stroke	1.30	1.00	1.55	1.18
Hypertension	1.40	1.40	2.35	2.35
Diabetes	1.80		8.95	

Supplementary Table S20: Relative risk for underlying risk, incidence and mortality: dementia in adults [42]

Age	Risk factor	RR
Early life (<18 yrs)	Less education	1.6
Midlife (45-65 yrs)	Hypertension	1.6
	Obesity	1.6
	Hearing loss	1.9
Late life (age > 65)	Smoking	1.6
	Depression	1.9
	Physical inactivity	1.4
	Social isolation	1.6
	Diabetes	1.5

Supplementary Table S21: Relative risk for underlying risk, incidence and mortality: Hypertension and Hypercholesterolaemia in adults [43]

Relative risk for CHD and stroke

	CHD	Stroke
Hypertension	2.86	5.08
High cholesterol	3.00	1.50

Supplementary Table S22: Relative risk reduction for CHD and stroke [43]

Age group (years)	Relative risk 10mmHg decrease		Relative risk 1mmol/l decrease	
	CHD	Stroke	CHD	Stroke
30-44	0.52	0.42	0.51	0.66
45-59	0.60	0.50	0.50	0.66
60-69	0.75	0.64	0.70	0.77
70-79	0.80	0.72	0.77	0.92
80+	0.94	0.83	0.75	0.84

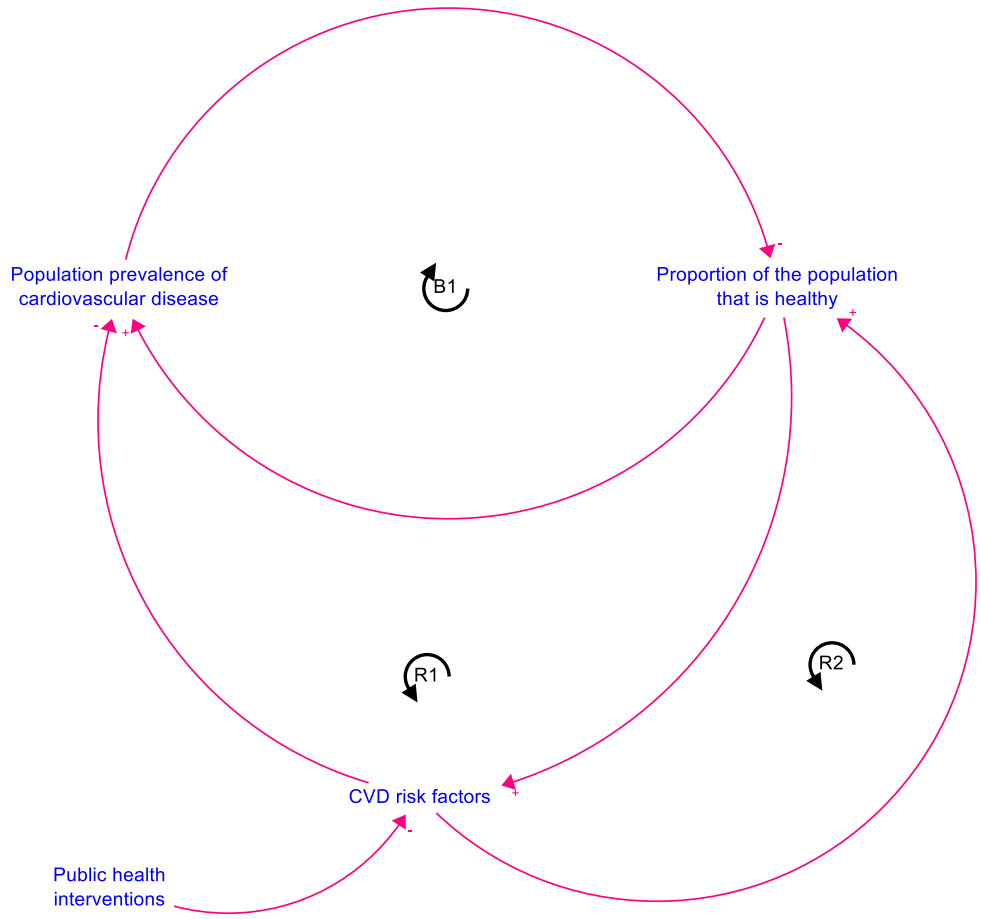
Supplementary Table S23: Relative risk for underlying risk, incidence and mortality: Alcohol consumption in adults

Category	Disease or injury	ICD-10 codes	Source for risk function	Low	Hazardous	Harmful
Wholly attributable to alcohol, chronic (10)	Alcohol-induced pseudo-Cushing's syndrome	E24.4	NA	NA	NA	NA
	Degeneration of nervous system due to alcohol	G31.2	NA	NA	NA	NA
	Alcoholic polyneuropathy	G62.1	NA	NA	NA	NA
	Alcoholic myopathy	G72.1	NA	NA	NA	NA
	Alcoholic cardiomyopathy	I42.6	NA	NA	NA	NA
	Alcoholic gastritis	K29.2	NA	NA	NA	NA
	Alcoholic liver disease	K70.0-K70.4, K70.9	NA	NA	NA	NA
	Acute pancreatitis (alcohol induced)	K85.2	NA	NA	NA	NA
	Chronic pancreatitis (alcohol induced)	K86.0	NA	NA	NA	NA
	Maternal care for (suspected) damage to foetus from alcohol	O35.4	NA	NA	NA	NA
Wholly attributable to alcohol, acute (7)	Mental and behavioural disorders due to use of alcohol	F10	NA	NA	NA	NA
	Excessive Blood Level of Alcohol	R78.0	NA	NA	NA	NA
	Toxic effect of alcohol	T51.0, T51.1, T51.8, T51.9	NA	NA	NA	NA
	Accidental poisoning by exposure to alcohol	X45	NA	NA	NA	NA
	Intentional self-poisoning by and exposure to alcohol	X65	NA	NA	NA	NA
	Poisoning by and exposure to alcohol, undetermined intent	Y15	NA	NA	NA	NA
	Evidence of alcohol involvement determined by blood alcohol level	Y90	NA	NA	NA	NA

Partially attributable to alcohol, chronic	Malignant neoplasm of lip, oral cavity and pharynx	NA	NA	1.65	3.11	6.45
	Malignant neoplasm of oesophagus	NA	NA	1.30	1.93	3.59
	Malignant neoplasm of colon	NA	NA	1.04	1.10	1.21
	Malignant neoplasm of rectum	NA	NA	1.07	1.19	1.42
	Malignant neoplasm of liver and intrahepatic bile ducts	NA	NA	1.15	1.40	1.81
	Malignant neoplasm of larynx	NA	NA	1.33	2.02	3.86
	Malignant neoplasm of] breast	NA	NA	1.14	1.35	NA
	Diabetes mellitus (type II)	NA	NA	0.93	0.85	0.73
	Epilepsy and Status epilepticus	NA	NA	3.26	7.52	6.83
	Hypertensive diseases	NA	NA	1.29	2.04	4.15
	Ischaemic heart disease	NA	NA	0.86	1.04	1.53
	Cardiac arrhythmias	NA	NA	1.75	2.23	2.23
	Haemorrhagic stroke	NA	NA	1.15	1.82	4.70
	Ischaemic stroke	NA	NA	0.88	1.17	4.37
	Oesophageal varices	NA	NA	2.43	7.13	26.53
	Unspecified liver disease	NA	NA	2.43	7.13	26.53
	Cholelithiasis	NA	NA	0.77	0.59	0.50
	Acute and chronic pancreatitis	NA	NA	1.23	1.78	3.19
Partially attributable to alcohol, acute (9)	Transport injuries (including road traffic accidents)	V01-V98, Y85.0		NA	NA	NA
	Fall injuries	W00-W19		NA	NA	NA
	Exposure to mechanical forces (including machinery accidents)	W20-W52		NA	NA	NA
	Drowning	W65-W74		NA	NA	NA
	Other Unintentional Injuries	W75-W99, X30-X33, X50-X58		NA	NA	NA

	Accidental poisoning by exposure to noxious substances	X40-X49 excl. X45		NA	NA	NA
	Intentional self-harm	X60-X84, Y87.0 excl. X65		NA	NA	NA
	Assault	X85-Y09, Y87.1		NA	NA	NA
	Other intentional injuries	Y35		NA	NA	NA

Supplementary Figure S3: Casual Loop Diagram (CLD)



Explanation for causal loop diagram example:

1. If the population prevalence of CVD increases (as a result of ageing), then the proportion of the population that is healthy goes down, which reduces the potential for further increases in CVD – this is B1 a balancing loop.
2. If the proportion of the population that is healthy goes down the prevalence of CVD risk factors goes up, which means that the population prevalence of CVD also goes up and, as above the proportion of the population that is healthy goes down – this is a negative reinforcing loop R1 that could tend toward escalating levels of CVD, tempered by B1, i.e. it will not grow exponentially for ever due to the natural limit of population size.
3. The introduction of public health interventions on CVD risk factors is designed to reduce the prevalence of risk factors, which increases the proportion of the population that is healthy and feeds back in a positive reinforcing loop R2 that will compete with the negative reinforcing look R1, which itself is being dampened by the balancing loop B1.

This complex relationship of competing feedback is at the heart of the model and is replicated for overlapping conditions and public health interventions.

Supplementary Figure S4: Relative deviation [47]

Two performance indicators were used to evaluate model validation against collected surveillance data or externally modelled data. These calculations for these are outlined below.

The relative deviation rate illustrates the deviation between the simulated and actual output.

$$E_r = \left|\frac{V_{sim} - V_{act}}{V_{act}}\right| \times 100\%$$

Where:

- E_r is the relative deviation rate
- V_{sim} is the simulated value
- V_{act} is the actual value

The average relative deviation rate summarises the deviation between the simulated and actual output.

$$E_r = \left|\frac{V_{sim} - V_{act}}{V_{act}}\right|_{ave} \times 100\%$$

Where:

- E_r is the relative deviation rate
- V_{sim} is the simulated value
- V_{act} is the actual value

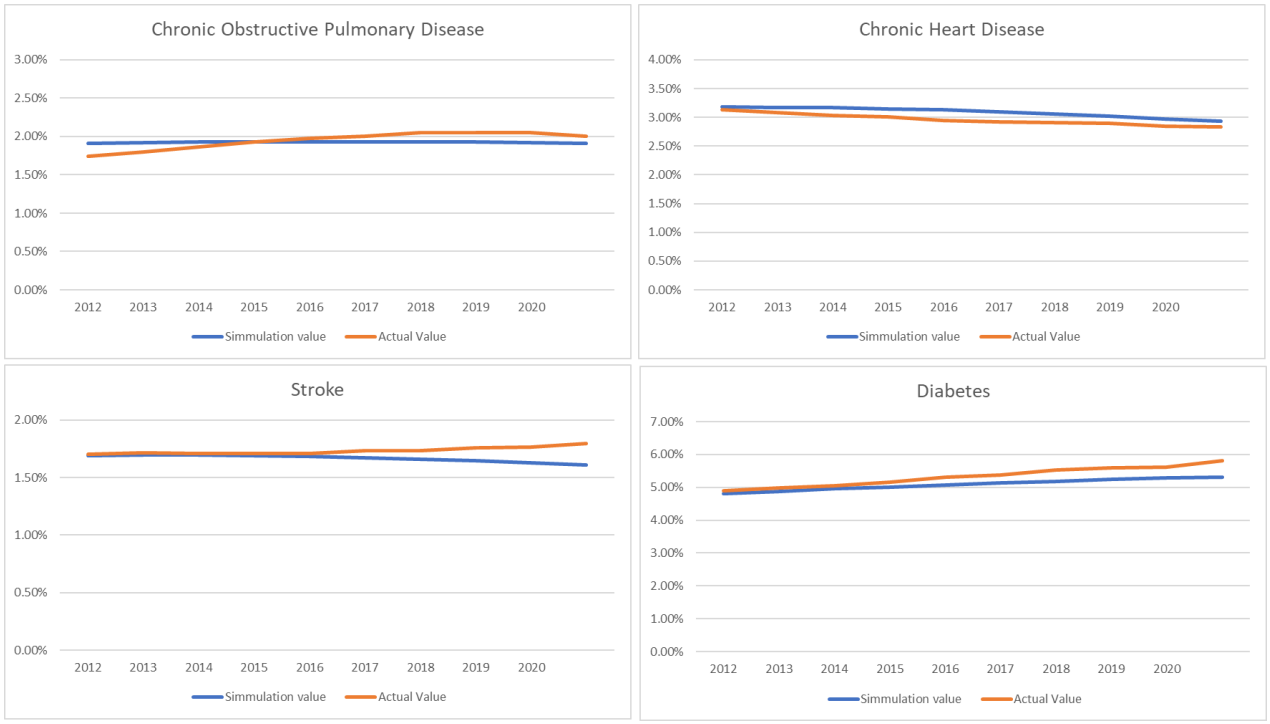
Supplementary Table S24: Single prevalence validation through relative deviation rates[45]

Variable	Value	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CHD	**Simulation value**	3.18%	3.17%	3.17%	3.15%	3.13%	3.10%	3.06%	3.02%	2.98%	2.93%
	Actual Value	3.14%	3.08%	3.03%	3.01%	2.95%	2.93%	2.91%	2.89%	2.85%	2.83%
	Er	1.24%	2.99%	4.55%	4.79%	6.04%	5.82%	5.21%	4.32%	4.44%	3.38%
	Eave					4.28%					
COPD	**Simulation value**	1.91%	1.92%	1.93%	1.93%	1.93%	1.93%	1.93%	1.93%	1.92%	1.91%
	Actual Value	1.75%	1.80%	1.86%	1.93%	1.97%	2.00%	2.05%	2.05%	2.05%	2.01%
	Er	9.57%	6.56%	3.60%	0.01%	2.03%	3.49%	6.01%	6.21%	6.30%	4.62%
	Eave					4.84%					
Diabetes	**Simulation value**	4.80%	4.88%	4.95%	5.01%	5.08%	5.13%	5.18%	5.24%	5.28%	5.30%
	Actual Value	4.89%	4.99%	5.04%	5.16%	5.30%	5.38%	5.52%	5.58%	5.62%	5.81%
	Er	1.76%	2.33%	1.72%	2.94%	4.28%	4.69%	6.16%	6.14%	6.07%	8.83%
	Eave					4.49%					
Stroke	**Simulation value**	1.69%	1.69%	1.70%	1.69%	1.69%	1.67%	1.66%	1.65%	1.63%	1.61%
	Actual Value	1.70%	1.71%	1.71%	1.71%	1.71%	1.73%	1.74%	1.76%	1.77%	1.80%
	Er	0.79%	1.12%	0.67%	1.03%	1.47%	3.45%	4.43%	6.62%	7.82%	10.35%
	Eave					3.77%					

Supplementary Table S25: Population validation through relative deviation rates [48]

Variable	Value	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Population total	**Simulation value**	1465197	1480428	1496972	1513996	1530433	1546948	1562687	1580082	1601037	1622480
	Actual Value	1465381	1479078	1492417	1509263	1523618	1540186	1556241	1571427	1590920	1613357
	Er	0.01%	0.09%	0.31%	0.31%	0.45%	0.44%	0.41%	0.55%	0.64%	0.57%
	Eave					0.38%					
Population 0-17	**Simulation value**	323284.6	326147.5	329101.4	332172.9	335291.9	338355.6	341514.7	345096.7	349277.9	353601.2
	Actual Value	323468.8	324997.4	326758.4	328990.8	331108	333166.2	335761.1	339179.3	343712.5	349441.6
	Er	0.06%	0.35%	0.72%	0.97%	1.26%	1.56%	1.71%	1.74%	1.62%	1.19%
	Eave					1.12%					
Population 18+	**Simulation value**	1141913	1154280	1167871	1181823	1195141	1208593	1221172	1234985	1251759	1268879
	Actual Value	1141913	1154080	1165659	1180272	1192510	1207019	1220480	1232248	1247208	1263916
	Er	0.00%	0.02%	0.19%	0.13%	0.22%	0.13%	0.06%	0.22%	0.36%	0.39%
	Eave					0.17%					

Supplementary Figure S5: Visual single prevalence model validation [45]

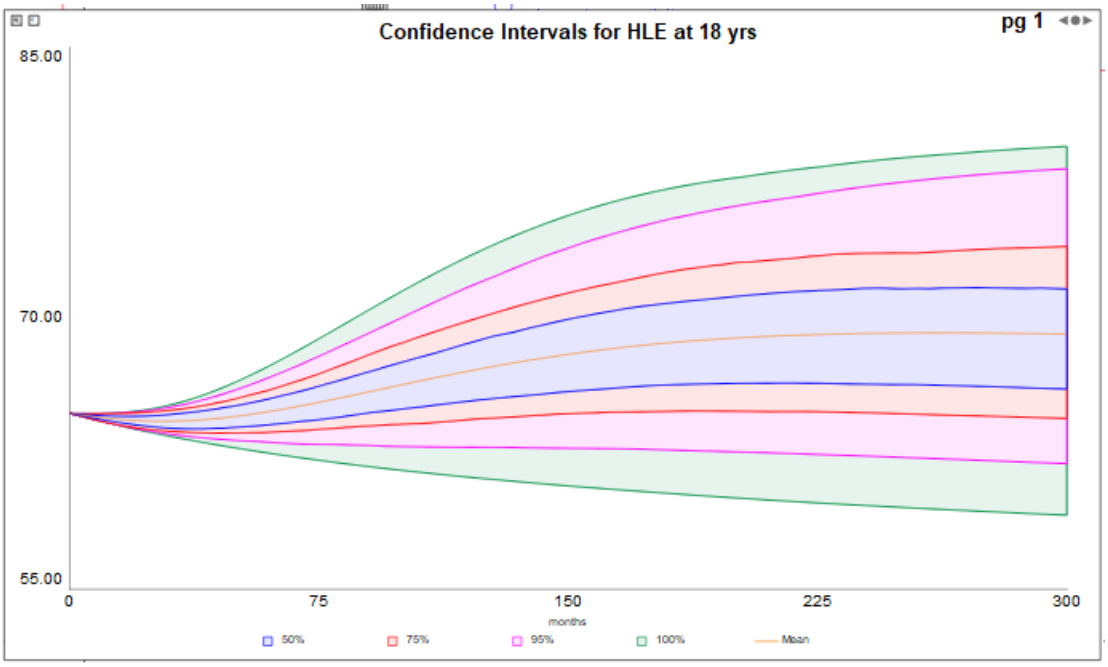


Supplementary Figure S6: Visual population model validation [48]

Supplementary Table S26: Sensitivity analysis testing ranges

Variable	Lower	Mean	Upper
Smoking prevalence	-0.6%	-0.3%	0.0%
Obesity prevalence	0.0%	0.3%	0.5%
Annual Systolic Blood Pressure reduction	-0.4%	-0.2%	0.0%
Annual total cholesterol reduction	-0.04%	0.0%	0.0%

Supplementary Figure S7: Sensitivity analysis variation for Healthy Life Expectancy (HLE) at 18



Supplementary Table S27: Relative risk for underlying risk, incidence: breastfeeding, smoking in pregnancy, child obesity, fuel poverty and ACE in Children and Young People [51-54]

Risk	Cohort / condition	Relative Risk	Age group affected
Breastfeeding	Asthma	0.91	5-19 yrs
	Admission respiratory	0.43	<2 yrs
	Overweight and obese	0.74	Child adol & adults
	Blood pressure	0.5	Child adol & adults
	Diabetes	0.65	Child adol & adults
Smoking during pregnancy	Stillbirth	1.49	At birth
	ADHD	2.39	Child, ad
	Conduct Disorder	2.6	16-18
	Substance misuse	2.4	16-18
	Depression	1.4	16-18
	Overweight	1.5	Child, ad

Fuel Poverty

Children living in cold and damp housing are 1.5-3 times more likely to suffer from Asthma and respiratory diseases [55]. A child who develops asthma in this way is more likely to persist into adulthood and to possibly life [56].

Adverse Childhood Experience (ACE)

ACEs are, as the name implies, experiences that adversely affect children.

The evidence cites issues commonly categorised as ACEs. This is not necessarily an exclusive list. In part based on the CDC ACE questions - refer to the respondent's first 18 years of life.

Five Direct

- Sexual abuse by parent / caregiver.
- Emotional abuse by parent / caregiver.
- Physical abuse by parent / caregiver.
- Emotional neglect by parent / caregiver.
- Physical neglect by parent / caregiver.

Five Indirect

- Parent / Caregiver addicted to alcohol / other drugs.
- Witnessed abuse in the household
- Family member in prison
- Family member with a mental illness.
- Parent / Caregiver disappeared through abandoning family / divorce.

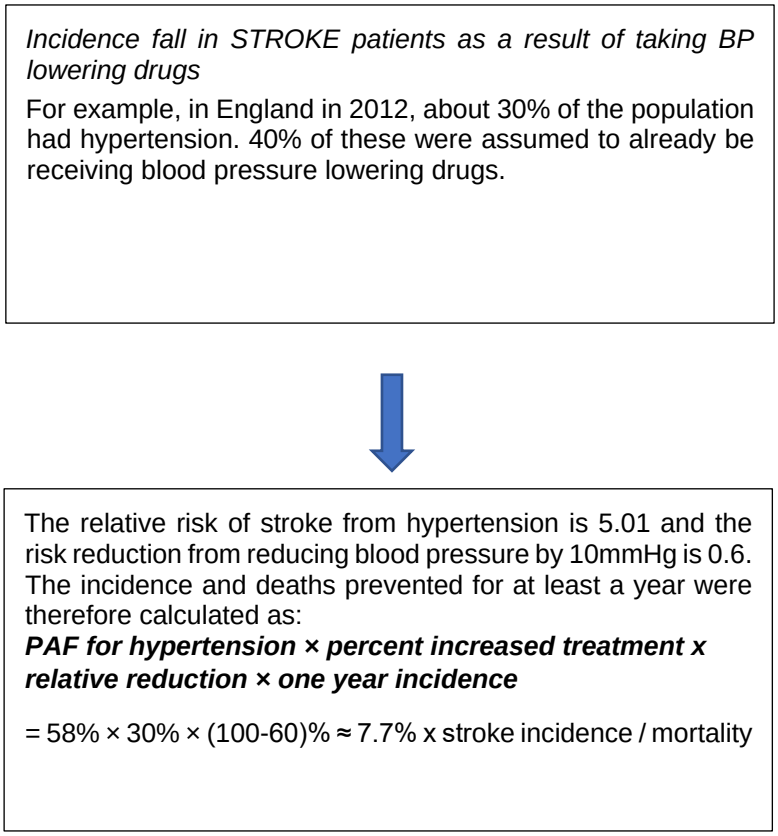
Some surveys also include mother treated violently

In this high-risk population, the rate of childhood mental health problems is 3 times higher than children without these risk factors.

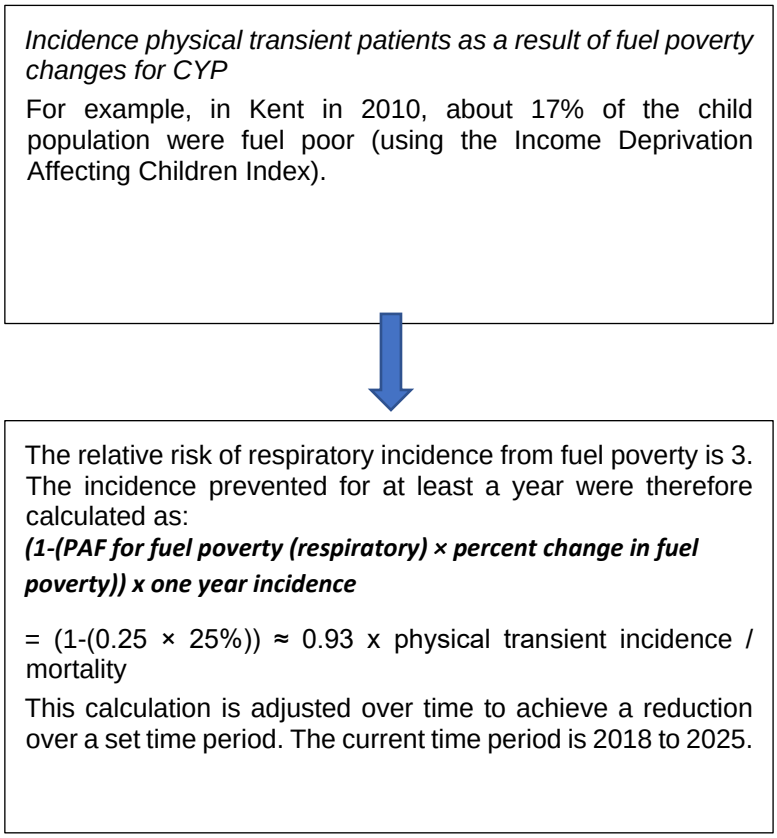
The rate of adults diagnosed with chronic diseases was more than twice as high as that of adults with no ACEs, and more than four times higher for type 2 diabetes. Compared with people with no ACEs, those with four or more were [57]

- 9.5 times more likely to currently be receiving treatment for mental illness
- 6.1times more likely to have ever received treatment for mental illness
- 3.7 times more likely to have ever felt suicidal or self-harmed

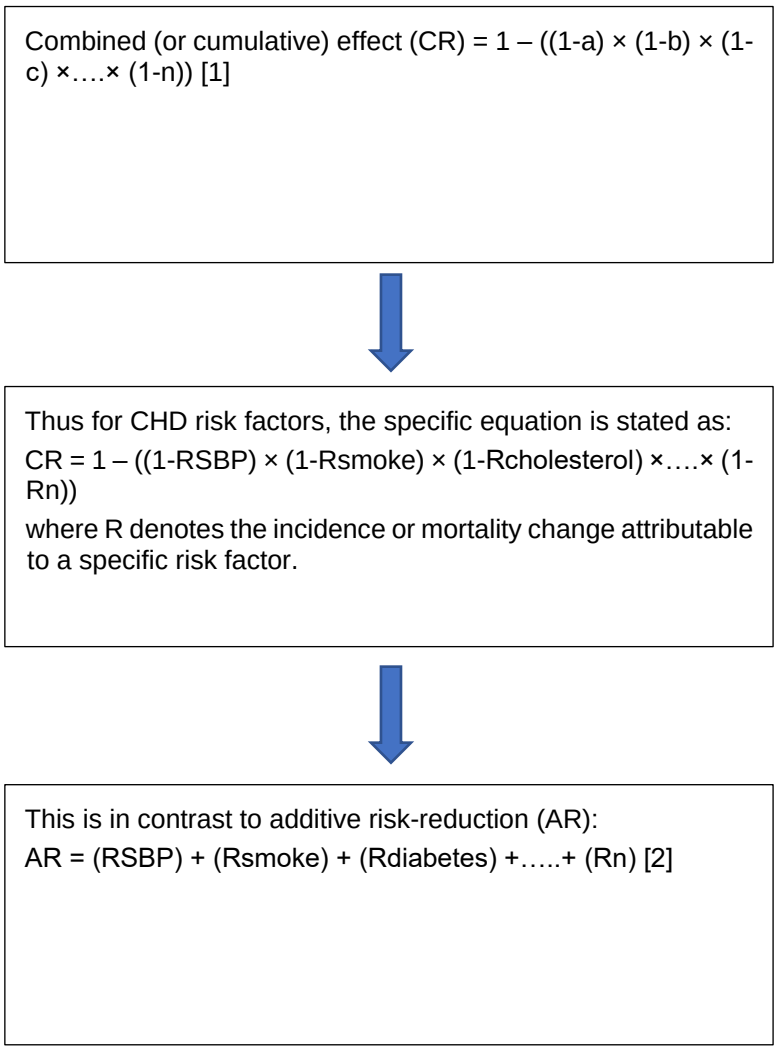
Supplementary Figure S8: Estimation of incidence and mortality changes from a specific treatment



Supplementary Figure S9: Estimation of incidence changes from fuel poverty changes



Supplementary Figure S10: Cumulative risk-reduction



Supplementary Figure S11: Proportional change in cohort incidence and mortality rate over time