A billion lives?

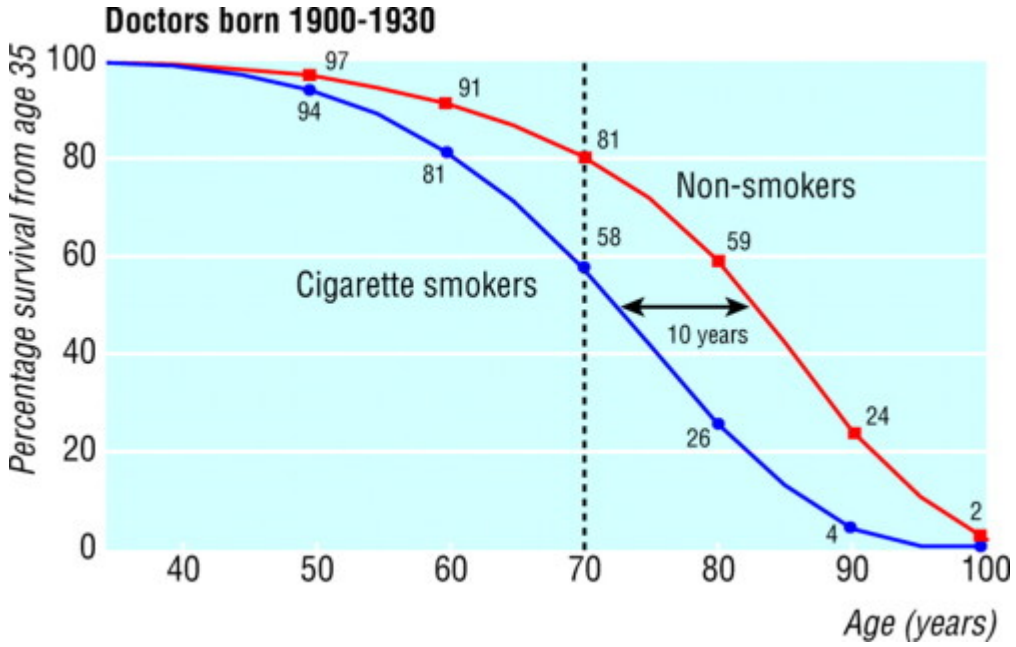
A promising new documentary film is on the way to our screens: *A billion lives* –*"a true story of government failure, big business and the vaping revolution"*. See trailer above.

It gets its name from the often-quoted figure that one billion lives may be lost to diseases caused by smoking in the 21st Century. The eminent epidemiologist Sir Richard Peto summarised the outlook in a comment to the Independent newspaper: *Smoking will 'kill up to a billion people worldwide this century'* (8 Nov 2012)

> *Sir Richard Peto of Oxford University, a co-author of the Million Women study who worked closely with Sir Richard Doll, is also the scientist who first calculated how many people this century will die from tobacco-induced cancers. "We have about 30 million new smokers a year in the world. On present patterns, most of them are not going to stop, and if they don't stop, and if half of them die from it, then that means more than 10 million a year will die – that's 100 million a decade in the second half of the century," said Professor Peto.*
>
> *"So this century we're going to see something like a billion deaths from smoking if we carry on as we are.*

But where do these numbers come from?

So, it starts with the idea that smoking is a cause of serious disease and that people die from it – and they would die later without it. So, in a given year, they have a higher probability of dying (or being already dead). The diagram below, from the famous study of British doctors, is one way of showing that – the probability of living to a given age after age 35. There are some differences between men and women and in different countries.

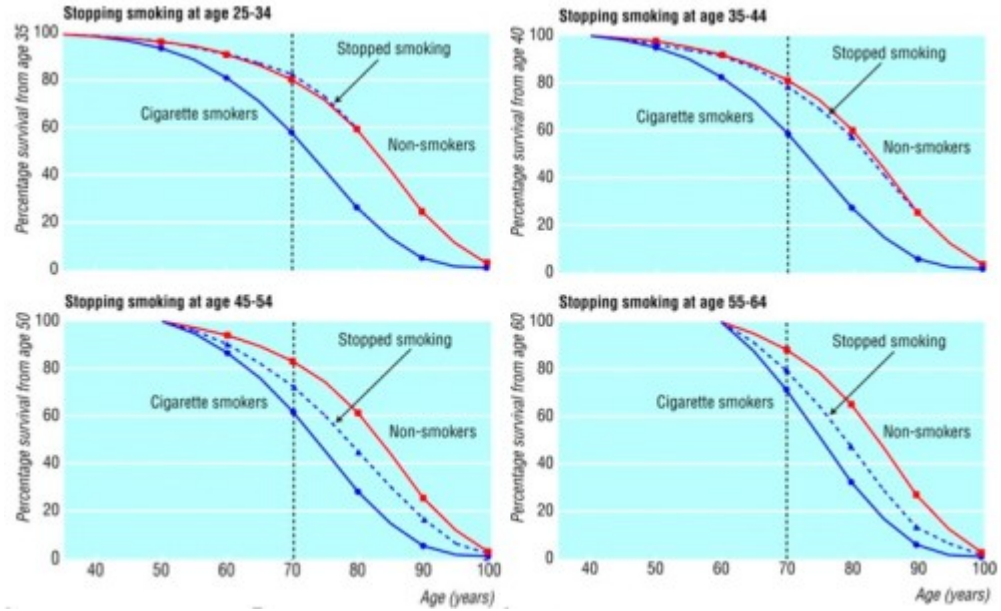


Doll R, Peto R, Boreham J, *et al.* Mortality in relation to smoking: 50 years' observations on male British doctors. *BMJ* 2004;328:1519 [link]

So, this particular study showed that 81% of men who never smoked make it to 70 but only 58% of continuing smokers. Or put another way, the median smoker loses about 10 years of life between 73 and 83, and about 20% lose 10 years between 60 and 70.

Note that some of this increased probability of earlier death may arise from other things that smokers do more or less of. For example, if they take less exercise or do more drinking that might also contribute to shifting that blue curve to the left, for example by dying of liver disease. So these curves are plots of premature death representing the average lifestyle of those studied – doctors in this case. However, most of the difference is down to smoking itself.

Stopping smoking reduces risk. The good news from this study was that "*cessation at age 50 halved the hazard, and cessation at age 30 avoided almost all of it.*" You can see graphically how stopping smoking at different ages changes the probability of early death here.



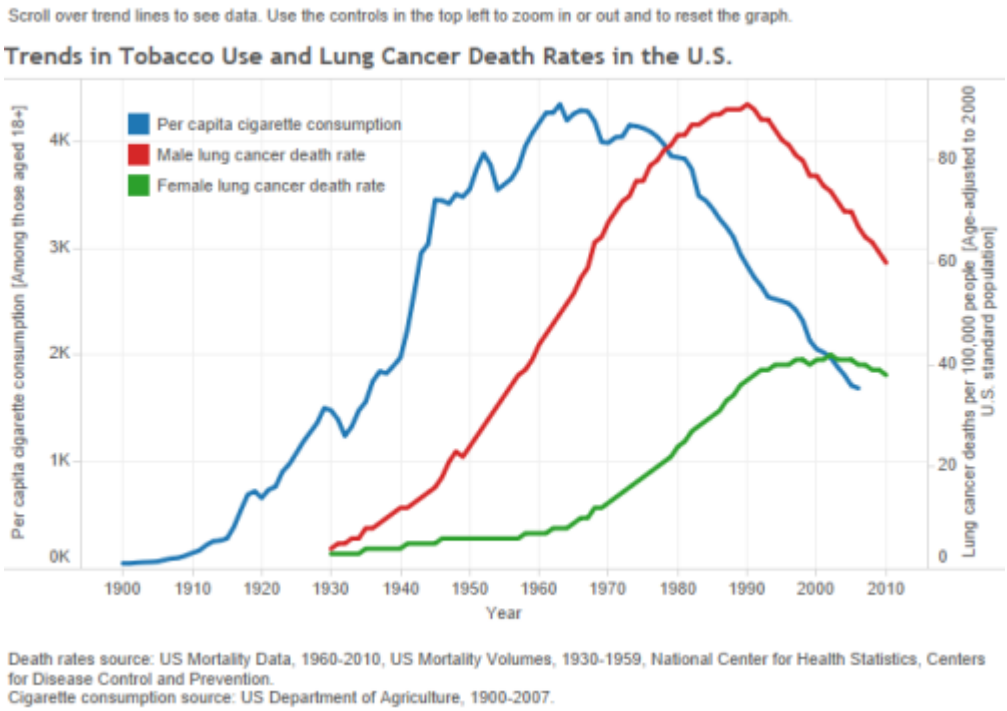
They obviously do not mean by this: *"smoke your head off until 30, then quit and you'll be fine"* – many people who smoke until into their 30s may not find it easy to quit, and may not want to try. But I think with vaping available as an option to eliminate nearly all the risk of recreational nicotine use, a major focus of tobacco policy should be on encouraging, or merely not obstructing, middle-aged adults who cannot or choose not to quit using nicotine to switch from smoking to vaping as rapidly as possible. This means that millions, perhaps *hundreds of millions*, of premature deaths might be avoided if smokers switch or nicotine users never smoke in the first place.

How these numbers are not calculated. A real problem with counting premature deaths is that smoking may reduce the length of nearly every smoker's life, even by a few days or minutes, compared to living exactly the same life and never having smoked. Do they all get counted in the premature death toll? No. Actually, that is not how these calculations are done.

How these numbers are calculated. The approach taken is to look at the main diseases that cause death in smokers (cancer, cardiovascular and respiratory) and then work out how many of the deaths caused by those diseases can be attributed to smoking. The clearest case is lung cancer, where the risk for smokers is about 20 times higher than for non-smokers. So you can look at how many deaths there are from lung cancer, how many smokers there are and then work out how many of the deaths are due to the excess risk created by smoking and how many would have happened anyway. With a few additional complexities for ex-smokers, differences for men and women etc out comes the number of lung cancer deaths

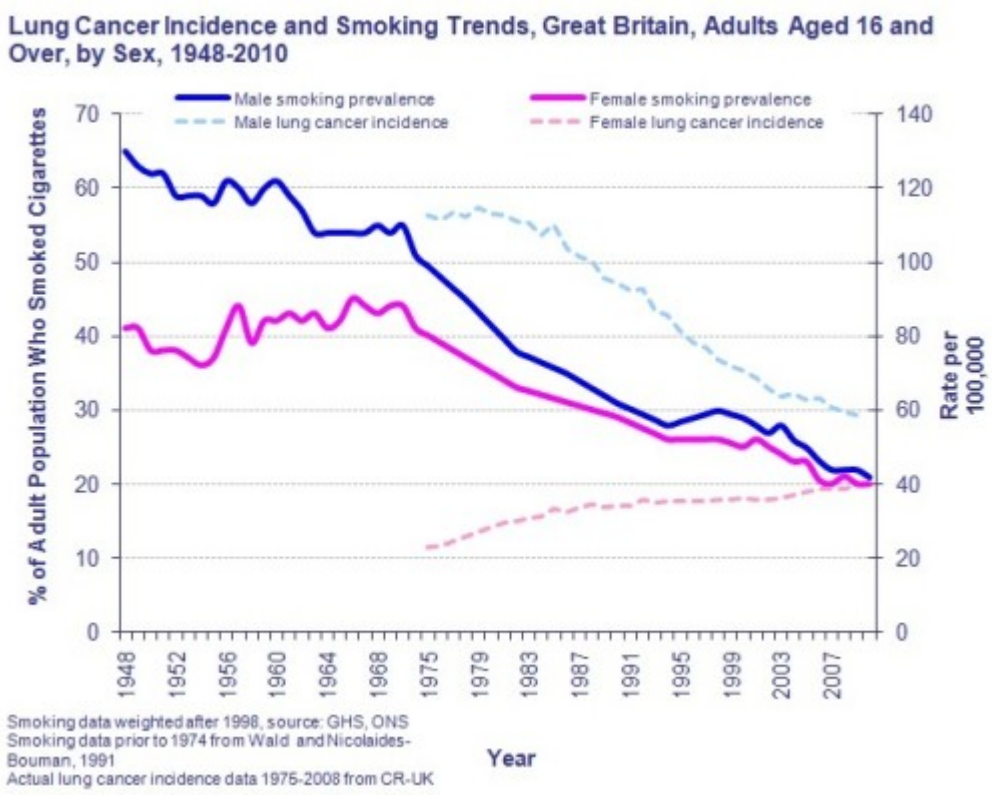
attributed to smoking. Then with even more numerical dexterity, numbers can be calculated for other diseases.

When making projections of future smoking-related deaths, several other things are needed. For example, some way of characterising assumptions about smoking – and how that translates to disease outcomes – often with a lag between the behaviour and the disease.

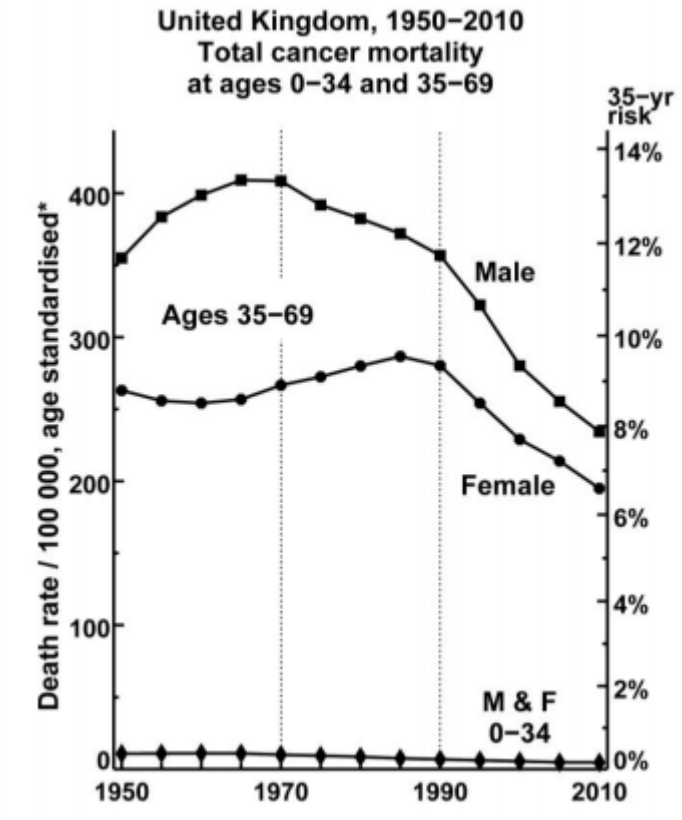


So, some future disease arising from past smoking is already in the system: it may take 50 years for the full consequences of arise in smoking to work through to disease outcomes.

A typical pattern in developed countries from the 1940s is that fewer women ever smoked, and female smoking prevalence peaked later and then converged with male prevalence. This is very different in developing countries, where female smoking has been much lower. But will it stay that way?



We can work through the technique above. So start with the observed cancer deaths. For example, these UK figures:



If we know smokers are more likely to get lung cancer than non-smokers, we can

look at the total lung cancer deaths in a population and decide how many of these are additional to what there would be without smoking. The share of this cancer that is attributed to smoking is known as the "Population Attributable Fraction".

Key concept: the "Population-Attributable Fraction (PAF) [WHO definition]:

> *Population attributable fraction (PAF)… is the proportional reduction in population disease or mortality that would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario (eg. no tobacco use)*

The U.S. Surgeon General 2014 report explains how it works here, and various different methods are reviewed here. If you want the equations, they are at these links.

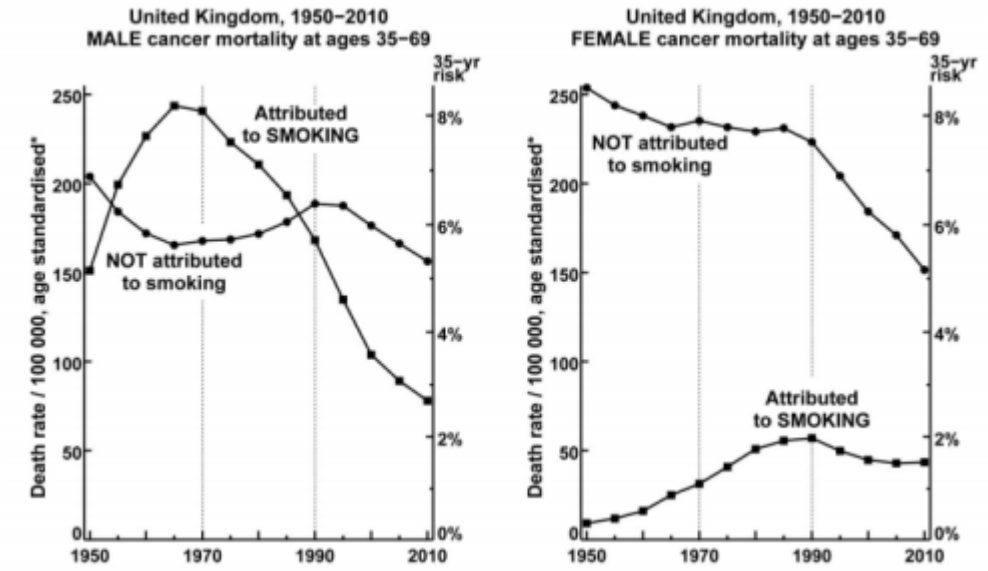
The method involves using the estimate of relative risk of premature death from a disease that has been found large cohort studies. Cohort studies follow a group of people, track what they do (e.g. smoking) and check what fate befalls them. Relative risk is the ratio of the probability of smoker dying of a disease to the probability that a non-smoker will die from it. A high relative risk can mean it is highly likely in smokers or very unlikely in non-smokers (e.g. lung cancer). A low relative risk means there may be many other causes in smokers and non-smokers (e.g. cardiovascular disease caused by diet or physical inactivity). These relative risk estimates are used to attribute the observed deaths from, say, lung cancer, to those caused by smoking and those that would have occurred anyway – giving the PAF.

The biggest of the cohort studies is the American Cancer Society Cancer Prevention Study II (CPS-II) – and from this study much of the estimation of risk and premature death for smoking is derived. It is not just used for cancer but other diseases too, and not just for the U.S. This is how the relative risks turn out for the CPS-II cohort – see table

	Males		Females	
Disease category (ICD–10 code)	**Current smoker**	**Former smoker**	**Current smoker**	**Former smoker**
Malignant neoplasms				
Lip, oral cavity, pharynx (C00–C14)	10.89	3.40	5.08	2.29
Esophagus (C15)	6.76	4.46	7.75	2.79
Stomach (C16)	1.96	1.47	1.36	1.32
Pancreas (C25)	2.31	1.15	2.25	1.55
Larynx (C32)	14.60	6.34	13.02	5.16
Trachea, lung, bronchus (C33–C34)	23.26	8.70	12.69	4.53
Cervix uteri (C53)	n/a	n/a	1.59	1.14
Kidney and renal pelvis (C64–C65)	2.72	1.73	1.29	1.05
Urinary bladder (C67)	3.27	2.09	2.22	1.89
Acute myeloid leukemia (C92.0)	1.86	1.33	1.13	1.38
Cardiovascular diseases				
Coronary heart disease (I20–I25)				
Persons 35–64 years of age	2.80	1.64	3.08	1.32
Persons ≥65 years of age	1.51	1.21	1.60	1.20
Other heart disease (I00–I09, I26–I28, I29–I51)	1.78	1.22	1.49	1.14
Cerebrovascular disease (I60–I69)				
Persons 35–64 years of age	3.27	1.04	4.00	1.30
Persons ≥65 years of age	1.63	1.04	1.49	1.03
Atherosclerosis (I70)	2.44	1.33	1.83	1.00
Aortic aneurysm (I71)	6.21	3.07	7.07	2.07
Other arterial disease (I72–I78)	2.07	1.01	2.17	1.12
Respiratory diseases				
Influenza, pneumonia (J10–J11, J12–J18)	1.75	1.36	2.17	1.10
Bronchitis, emphysema (J40–J42, J43)	17.10	15.64	12.04	11.77
Chronic airways obstruction (J44)	10.58	6.80	13.08	6.78

Relative risks for adult mortality from smoking-related diseases, adults 35 years of age and older

In the case of the chart above, the application of these techniques to attribute cancer deaths to smoking comes out as follows for the UK, separated for men and women:



If these figures are totalled for different countries, the burden of smoking-related cancer can then be estimated.

For other populations and diseases. There are huge assumptions and approximations built into using the CPS-II cohort to estimate relative risks for different populations – e.g outside the U.S. or in future. In much of the work that uses these data, conservative assumptions are made (like halving the relative risk) to take account potentially lower relative risks in different populations. Some clever techniques are used to fill in blanks in data. For example, because lung cancer is known to be relatively rare in non-smokers, it is possible to infer previous rates of smoking from current lung cancer rates. But note the use of conservative assumptions in doing so…

> *Even in the absence of direct information on smoking histories, therefore, national mortality from tobacco can be estimated approximately just from the disease mortality statistics that are available from all major developed countries for about 1985 (and for 1975 and so, by extrapolation, for 1995). The relation between the absolute excess of lung cancer and the proportional excess of other diseases can only be approximate, and so as not to overestimate the effects of tobacco it has been taken to be only half that suggested by a recent large prospective study of smoking and death among one million Americans. [link]*

Understanding the past and present

The pioneering work on this was done in the 1980s and early 1990s. A substantial resource of mortality projections is maintained at Oxford University: Deaths from smoking. The initial focus of research was on developed countries.

Peto R, Boreham J, Lopez AD, *et al.* Mortality from tobacco in developed countries: indirect estimation from national vital statistics. *Lancet* 1992;339:1268–78. [link][PDF]

> *At present [1992] just under 20% of all deaths in developed countries are attributed to tobacco, but this percentage is still rising, suggesting that on current smoking patterns just over 20% of those now living in developed countries will eventually be killed by tobacco (ie, about a quarter of a billion, out of a current total population of just under one and a quarter billion)*

Peto R, Lopez AD, Boreham J, *et al.* Mortality from smoking in developed countries 1950−2000. 2nd Edition. [link] – showing about 2 million smoking-related deaths in developed countries in 2000 – but also the age stratification, with smoking accounting for 30% of male deaths before 70. (Annotation added to show ~2m).

Deaths, by cause, attributed to SMOKING / total deaths (thousands) in the year 2000

Cause	Male (by age) 0–34	35–69	70+	All	Female (by age) 0–34	35–69	70+	All
Lung Cancer	−/0.8	199/217	176/196	375/413	−/0.5	48/70	67/92	115/162
All Cancer	−/21	310/709 (44%)	262/756 (35%)	571/1485	−/19	60/487 (12%)	88/686 (13%)	147/1192
Vascular	−/28	303/995	177/1600	479/2623	−/13	47/503	121/2624	168/3140
Respiratory	−/25	82/154	146/377	229/556	−/18	23/67	92/373	115/459
All Other	−/351	111/847	50/589	160/1787	−/140	26/347	48/935	74/1423
All Causes	−/425	806/2705 (30%)	634/3322 (19%)	1440/6452	−/190	155/1404 (11%)	349/4619 (8%)	504/6213

We start to see studies that look globally.

Ezzati M, Lopez AD. Estimates of global mortality attributable to smoking in 2000. *Lancet* 2003;362:847–52 [link] –

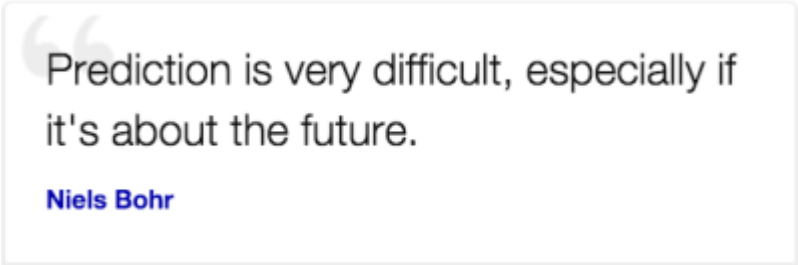
> *We estimated that in 2000, 4·83 (uncertainty range 3·94–5·93) million*

> *premature deaths in the world were attributable to smoking; 2·41 (1·80–3·15) million in developing countries and 2·43 (2·13–2·78) million in industrialised countries. 3·84 million of these deaths were in men.*

Ezzati M, Henley SJ, Thun MJ, *et al.* Role of smoking in global and regional cardiovascular mortality. *Circulation* 2005;112:489–97.[link] – take a global view and focus on cardiovascular mortality.

> *Conclusions— More than 1 in every 10 cardiovascular deaths in the world in the year 2000 were attributable to smoking, demonstrating that it is an important preventable cause of cardiovascular mortality.*

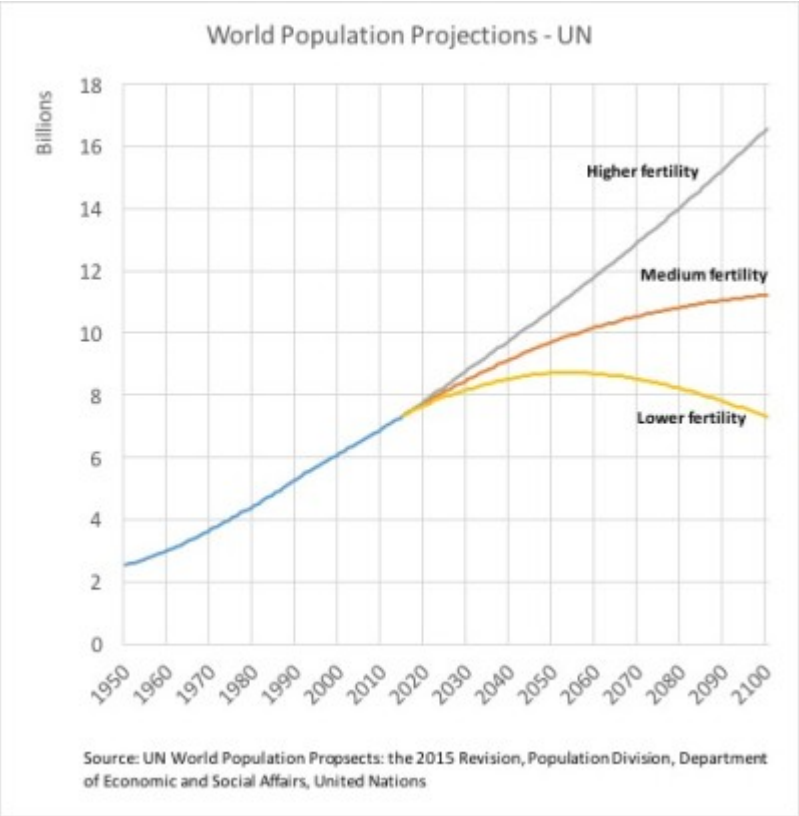
Predictions about the future



There are numerous obvious difficulties projecting forward. Projections require assumptions about future uptake, smoking cessation rates, population size, and treatment for smoking-related diseases that may reduce mortality. There are also some weird effects to consider: as a country grows richer, the risks of dying from other diseases, accidents or violence may decrease, making it more likely a smoker will live long enough to die from a disease caused by smoking. This effect was visible in the doctors' study mentioned above.

Furthermore, behaviours will all depend in part on policy assumptions – like taxation, marketing restrictions, effective quitting aids etc – and availability of alternatives.

So I would take all future projections as 'order of magnitude' approximation that is entirely contingent on assumptions. Here is one example of uncertainty, the population:



We also have to make assumptions about what will happen to smoking prevalence in future. For example, if Chinese smoking followed the pattern in Europe or U.S., we would expect to see female smoking *rising* to meet male smoking as it comes down. Mercifully, this is not happening. [link].

> *Chinese men now smoke more than a third of the world's cigarettes, following a large increase in urban then rural usage. Conversely, Chinese women now smoke far less than in previous generations.*

The one billion deaths figure

The rough 'consensus' emerging from these studies is smoking-attributed-mortality was about 5 million/year in 2000, and will rise to about 10 million/year by 2030, with a total death toll of about 450 million accumulating by 2050. If this carries on after that date at about 10 million per year or slightly rising, the one billion figure is reached by 2100. That's a scenario or projection, not a forecast, because it depends on trends continuing and lots of assumptions about the future.

Nevertheless, this what a few of the studies have concluded.

Doll R, Peto R, Boreham J, *et al.* Mortality in relation to smoking: 50 years'

observations on male British doctors. *BMJ* 2004;328:1519 [link]

> *The general statement that in many very different populations the future risk of death from persistent cigarette smoking will still be about one half is therefore a reasonable one, and the results thus far in a widening range of studies in other developed and developing country populations such as China and India seem consistent with it (as long as the prolonged delay between cause and full effect is properly appreciated). If so, then on current worldwide smoking patterns (whereby about 30% of young adults become smokers) there will be about one billion tobacco deaths in this century, unless there is widespread cessation.*

Jha P, Peto R. Global effects of smoking, of quitting, and of taxing tobacco. *N Engl J Med* 2014;370:60–8 [link] also view the [supplementary appendix]

> *On the basis of current smoking patterns, with a global average of about 50% of young men and 10% of young women becoming smokers and relatively few stopping, annual tobacco-attributable deaths will rise from about 5 million in 2010 to more than 10 million a few decades hence.*

Jha P, Chaloupka FJ, Moore J, *et al*. Tobacco Addiction, Chapter 46 in Disease Control Priorities in Developing Countries. 2nd edition, 2006. [Link]

> *Cigarette smoking and other forms of tobacco use impose a large and growing global public health burden. Worldwide, tobacco use is estimated to kill about 5 million people annually, accounting for 1 in every 5 male deaths and 1 in 20 female deaths of those over age 30. On current smoking patterns, annual tobacco deaths will rise to 10 million by 2030. The 21st century is likely to see 1 billion tobacco deaths, most of them in low-income countries. In contrast, the 20th century saw 100 million tobacco deaths, most of them in Western countries and the former socialist economies.*

Jha P. Avoidable global cancer deaths and total deaths from smoking. *Nat Rev Cancer* 2009;9:655–64.[link]

> *On the basis of current consumption patterns, approximately 450 million adults will be killed by smoking between 2000 and 2050. At least half of these adults*

> *will die between 30 and 69 years of age, losing decades of productive life. Cancer and the total deaths due to smoking have fallen sharply in men in high-income countries but will rise globally unless current smokers, most of whom live in low- and middle-income countries, stop smoking before or during middle age.*

And most recently, an in-depth analysis of smoking in China, looking at current mortality and the trend.

Chen Z, Peto R, Zhou M, et al. Contrasting male and female trends in tobacco-attributed mortality in China: evidence from successive nationwide prospective cohort studies. Lancet 2015;386:1447–56. [link]. Here you can see where large numbers in developing countries emerge. China now has about one-third of the world's smokers and as this century progresses more of them will be dying from smoking.

> *Smoking will cause about 20% of all adult male deaths in China during the 2010s. The tobacco-attributed proportion is increasing in men, but low, and decreasing, in women. Although overall adult mortality rates are falling, as the adult population of China grows and the proportion of male deaths due to smoking increases, the annual number of deaths in China that are caused by tobacco will rise from about 1 million in 2010 to 2 million in 2030 and 3 million in 2050, unless there is widespread cessation.*

Conclusion

- Smoking over several decades does substantially raise the risk of cancer, cardiovascular and respiratory disease, and of dying prematurely as a result. It is possible to put numbers on these deaths.
- The global burden of disease is now rising rapidly as the effect of rising smoking and growing population in developing countries is working through to have its impact on population health.
- It is a daunting task to estimate the historic or current global death toll attributable to smoking, and it requires many approximations, assumptions, and workarounds where data is poor or non-existent. However, statisticians do try to make cautious assumptions.
- Projecting future death tolls depends on further unknown or unknowable

quantities and, therefore, on further assumptions and approximations.

- Most figures quoted for future deaths are *scenarios or projections* rather than *forecasts* and most assume current trends continue.
- With all the caveats above, it is not unreasonable to say that, on current trends, about one billion lives will be ended prematurely by diseases caused by smoking in the 21st Century.
- This one billion deaths figure, if it came to pass, would be a dire failure for public health. Its purpose is to identify policies that work and are acceptable in terms of cost-effectiveness, intrusiveness, equity etc to alter these trends and to reduce the harm done.
- If several hundred million people take up vaping instead of smoking, or switch from smoking to vaping mid-life, and if vapour (or equivalent) products start to obsolete cigarettes for many or most users, there is the potential to avoid hundreds of millions of unnecessary premature deaths. This should be a public health ambition and not something to fight against.
- This strategy is promising because it goes with the grain of consumer preferences and does not require public spending, coercion or punitive and regressive measures – or the massive unintended consequences of prohibitions or excessive regulation.
- This strategy does require public health and tobacco control practitioners to do the following: to stop misleading smokers about the risks of vaping; to stop pretending there are adverse population consequences – there is simply no sign or likelihood of adverse effects; and to stop campaigning for policies that protect the cigarette trade and implicitly promote smoking.
- I hope and expect the film *A billion lives* will explore some of these issues.

Further reading

Carl V. Phillips has done a very nice series of briefings on where these numbers come from – and what they do, and do not, mean:

- X people die from smoking" – what does that even mean?
- So how would you estimate how many deaths are caused by smoking?
- How they estimate deaths from smoking etc.

Postscript

Curiously, in July 2015 the World Health Organisation removed the one billion figure from its factsheet on tobacco. It was there in the May version.