



## Can Noncommunicable Diseases Be Prevented? Lessons from Studies of Populations and Individuals

Majid Ezzati and Elio Riboli  
*Science* **337**, 1482 (2012);  
 DOI: 10.1126/science.1227001

*This copy is for your personal, non-commercial use only.*

If you wish to distribute this article to others, you can order high-quality copies for your colleagues, clients, or customers by [clicking here](#).

Permission to republish or repurpose articles or portions of articles can be obtained by following the guidelines [here](#).

**The following resources related to this article are available online at [www.sciencemag.org](http://www.sciencemag.org) (this information is current as of September 27, 2012):**

**Updated information and services**, including high-resolution figures, can be found in the online version of this article at:

<http://www.sciencemag.org/content/337/6101/1482.full.html>

A list of selected additional articles on the Science Web sites **related to this article** can be found at:

<http://www.sciencemag.org/content/337/6101/1482.full.html#related>

This article **cites 90 articles**, 22 of which can be accessed free:

<http://www.sciencemag.org/content/337/6101/1482.full.html#ref-list-1>

This article appears in the following **subject collections**:

Medicine, Diseases

<http://www.sciencemag.org/cgi/collection/medicine>

REVIEW

# Can Noncommunicable Diseases Be Prevented? Lessons from Studies of Populations and Individuals

Majid Ezzati\* and Elio Riboli

Noncommunicable diseases (NCDs)—mainly cancers, cardiovascular diseases, diabetes, and chronic respiratory diseases—are responsible for about two-thirds of deaths worldwide, mostly in low- and middle-income countries. There is an urgent need for policies and strategies that prevent NCDs by reducing their major risk factors. Effective approaches for large-scale NCD prevention include comprehensive tobacco and alcohol control through taxes and regulation of sales and advertising; reducing dietary salt, unhealthy fats, and sugars through regulation and well-designed public education; increasing the consumption of fresh fruits and vegetables, healthy fats, and whole grains by lowering prices and improving availability; and implementing a universal, effective, and equitable primary-care system that reduces NCD risk factors, including cardiometabolic risk factors and infections that are precursors to NCDs, through clinical interventions.

Improvements in sanitation, housing, and nutrition, as well as better treatment, have lowered death rates from infectious diseases such as diarrhea, pneumonia, and tuberculosis in most countries. This success has in turn increased the relative importance of noncommunicable diseases (NCDs)—mainly cancers, cardiovascular diseases (CVDs), diabetes, and chronic respiratory diseases—as causes of death (1). NCDs are now responsible for more than 35 million annual deaths in the world; more than 80% of these deaths occur in low- and middle-income countries (2). Medical interventions have improved the survival of patients with heart disease, stroke, breast cancer, and some other NCDs, but others like lung cancer still have high case fatality. Even when treatment is technically feasible, timely diagnosis and treatment require medical personnel, facilities, and medicines that are either lacking or costly, especially in low- and middle-income countries. Therefore, there is an urgent need for policies and strategies that help prevent NCDs. These policies and strategies should be guided by an understanding of how much, and through what specific actions, NCDs may be prevented or postponed to older ages.

Evidence on NCD preventability comes from data and analyses at two scales: individuals and populations. Studying individuals helps identify and establish risk factors that causally affect NCDs, and hence points to specific tools for disease prevention, but provides little information on how effective each of these tools may be in

disease prevention at the population level because the latter depends on the prevalence of risk factors in the population. Comparison of disease rates across populations or over time, especially when done in relation to risk-factor levels in the population, indicates by how much disease may be prevented and what the most important risk factors are at the population level. Here, we use examples of a number of NCDs and their key risk factors to make a case that we have sufficient knowledge from individual and population studies to substantially reduce the global NCD burden through prevention using a relatively small and coherent set of actions related to major risk factors.

## Modifiable Risk Factors and Cancers: Prevention of Diseases with a Few Dominant Risk Factors

Following the seminal work of Doll and Peto (3), researchers have used individual- and population-level data to examine the extent to which cancers can be prevented and identify interventions and strategies for doing so. The case of lung cancer dramatically illustrates how individual and population studies have come together to leverage a modifiable risk factor for effective prevention of a disease with low survival. We now know that about 70% of lung cancer deaths worldwide are due to smoking (Fig. 1) and would be prevented if people did not smoke (4). For men living in industrialized countries, more of whom have smoked and for longer periods, the proportion of lung cancer deaths due to smoking is even greater—over 90%.

The association between tobacco smoking and lung cancer was first noted nearly a century ago (5, 6). Subsequent studies, especially the work Hill, Doll, and Peto in the British Doctors Study (7, 8), gathered more detailed data on smoking behaviors and disease status and showed

that those who smoke from early adult ages are at least 20 times as likely as those who never smoke to die of lung cancer; the increased risk reaches 40-fold for heavy smokers who smoke about two packs of cigarettes per day (9).

Mirroring the high lung cancer risk in individual smokers, lung cancer death rates vary substantially across populations and over time based on smoking histories. In adult men, lung cancer death rates increased for much of the 20th century and peaked at ~170 to 190 per 100,000 (10) in a few Western European countries and the United States and subsequently in Central and Eastern European countries like Hungary (Fig. 2A). These peaks in lung cancer death rates tracked the peak of the smoking epidemic with a lag of about two decades. In women, lung cancer death rates in the majority of countries were less than 10 per 100,000 in the 1950s, virtually the same as men and women in Western countries who have never smoked (11). Women's lung cancer mortality began to increase two to three decades after that of men, reflecting the rise in women's smoking after World War II, first in English-speaking high-income countries and then in continental Europe. Owing to effective tobacco control and the decline in women's smoking, lung cancer death rates in women appear to have peaked in English-speaking countries, for example, at ~60 per 100,000 in the late 1990s in the United States (Fig. 2B). The situation is not all good, however, and lung cancer mortality continues to increase in women in Continental Europe. For example, the lung cancer death rate of Danish women, who have smoked longer and more than women in other European countries, is now higher than that of American women.



**Fig. 1.** Tobacco smoking is the most important risk factor for lung cancer and also has harmful effects on other NCDs.

MRC-HPA, Centre for Environment and Health and Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London W2 1PG, UK.

\*To whom correspondence should be addressed. E-mail: majid.ezzati@imperial.ac.uk

Although smoking is clearly the dominant modifiable risk factor for lung cancer, in certain populations other risk factors play a major role. People exposed to asbestos or to second-hand cigarette smoke are more likely to develop lung cancer than those who work and live in cleaner environments. In some parts of China, where coal is commonly used for cooking and heating in poorly ventilated homes, lung cancer mortality of people who have never smoked is about 4 to 5 times as high as that of those in Western countries who have never smoked (12). These examples illustrate the important point that the most effective disease prevention strategies are those that take into account the prevalent risk factors in the target population and by how much reducing any combination of these risks may lower disease levels. Patterns of lung cancer and its risk factors across the world and over time nonetheless demonstrate that stopping smoking, and a few environmental interventions in specific places, can reduce lung cancer to very low levels in every population.

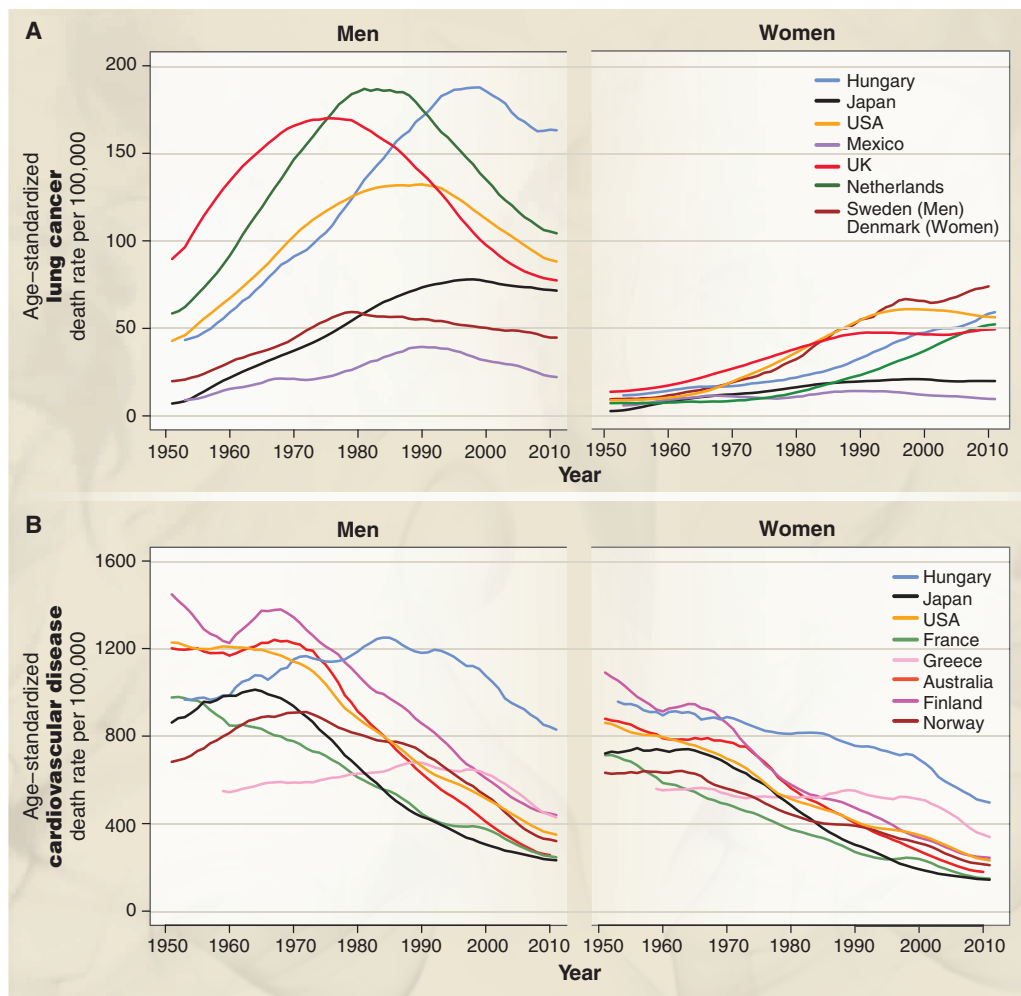
Dominant risk factors have also been identified for a few other cancer types, many in the form of an infection. In each case, these risk factors influence the geographical patterns and trends of these cancers and can be translated into effective prevention strategies and programs. For example, the discovery that *Helicobacter pylori* (*H. pylori*), a bacterium present in the gastrointestinal tract, is a risk factor for lesions that are precursors to stomach cancer (13) has generated new possibilities for its prevention. About 75% of the 870,000 annual noncardia gastric cancers in the world are attributable to *H. pylori* infection (14). Although *H. pylori* was not mentioned in epidemiological reviews of stomach cancer a few decades ago (15, 16), screening tests for the bacterium and treatment with antibiotics are now effective interventions for preventing stomach cancer (17). Epidemiological studies have also established salt consumption, smoking, and diets that are low in fruits and vegetables as risk factors for stomach cancer (16). In the United States, where *H. pylori* prevalence is lower than most other world regions (18, 19), these lifestyle and dietary factors together account for about 60% of stomach cancer deaths (20) (noting that different risk factors may be jointly responsible for some cases).

Although we can now leverage our knowledge about *H. pylori*, salt, smoking, and fresh

fruits and vegetables for preventing stomach cancer, the trends in stomach cancer also provide an example of how prevention may in fact precede and even help with risk factor identification. Adult death rates from stomach cancer are now close to 5 per 100,000 in Canada, the United States, and a few other western countries but reach 20 and 50 among Japanese women and men, respectively; half a century ago, they were as high as 150 to 200 among men in Japan, Chile, and Finland. The impressive declines in stomach cancer began before the epidemiological studies that identified these risk factors. Reductions in salt intake appear to have played an important early role in stomach cancer decline at least in Japan and Finland (15, 16, 21, 22). Stomach cancer prevention was also facilitated through improvements in hygiene, the living environment, and the uptake of refrigerators, which reduced the need to use salt for preserving food, improved the storage of fruits and vegetables, and may have also

reduced infection rates (15, 23)—creating an unintended success in prevention.

In an even more extreme example than stomach cancer, virtually all cervical cancers are due to infection with human papillomavirus (HPV) (14). Although sexual behavior and hygiene have traditionally been major determinants of geographical patterns and trends in cervical cancer, these cancers are preventable through early detection and treatment of precancerous lesions and, more recently, vaccination. However, access to regular cervical cancer screening, and especially vaccines, is lacking in low-income countries and in disadvantaged social groups (24), where the burden of cervical cancer is the highest. As a result, there is a 10-fold difference in cervical cancer incidence between countries in sub-Saharan Africa, where incidence is highest, and those in the Eastern Mediterranean and Western Europe, where it is lowest (25). Preventing cervical cancer in countries and communities with limited resources requires



**Fig. 2.** Trends in death rates from (A) lung cancer and (B) cardiovascular diseases in adults 30 years of age and older in selected countries with vital registration and medical certification of the underlying cause of death. Death rates are age-standardized to the WHO standard population for those aged 30 years and older and smoothed using a 5-year moving average. Source: WHO database of vital statistics, adjusted for completeness of death registration and for validity and comparability of cause-of-death assignment.



strengthening the primary care system, improving access to preventive care, and using the available interventions in such a way that they reach people who have fewer health system contacts (26).

In contrast to the above cancers that can be largely prevented through interventions and actions related to one or few dominant risk factors in most populations, other cancers have more diverse risk factors. For example, the risk factors for liver cancer and liver cirrhosis include infection with hepatitis B and C viruses (HBV and HCV); exposure to aflatoxin due to specific food-handling practices and storage conditions; alcohol use, especially binge drinking; and (for liver cancer but not liver cirrhosis) smoking. Each of these risk factors increases the risk of disease by a smaller amount compared with those discussed earlier for lung, stomach, and cervical cancers. As a result, the trends and geographical patterns of liver cancer and cirrhosis depend on the overall risk-factor profiles, and their population-based prevention should target locally relevant risk factors. HBV prevalence is highest in sub-Saharan Africa and in East Asia, where it is responsible for a large proportion of liver cancers; HCV's role is most important in sub-Saharan Africa, the Middle East, Central and East Asia, and Eastern and Southern Europe (14, 27, 28). Among the most effective means of preventing new HBV and HCV infections are reducing unnecessary medical injections, providing sterile syringes, and a safe blood supply in health care settings (29). Alcohol's role is largest in Eastern Europe (Box 1), especially among men, but it has a relatively small role in the Middle East and South Asia (30); that of tobacco is highest in Western countries, where people, especially men, have smoked for a long period.

**Modifiable Risk Factors and Cardiovascular Diseases: Prevention of Diseases with Diverse Risk Factors**

Even more than liver cancer, CVDs have a large number of risk factors, each increasing disease risk by a relatively small amount. For example, smokers are two to three times as likely as those who have never smoked to die of CVDs, compared with 20 times for lung cancer. The diversity and the combinations of CVD risk factors across individuals and populations create more subtle variations in disease risks and rates than for the cancer risk factors described earlier. This in turn makes it more difficult to identify their independent roles in disease causation and prevention. Yet the evidence from studies of individuals and populations is by now equally compelling that reducing a moderate number of risk factors will have large benefits in CVD prevention. Further, given that the burdens of major CVDs like ischemic heart disease (IHD) and stroke are many times those of most cancers and other NCDs, reducing a prevalent risk factor like high blood pressure can prevent a very large number of disease cases or deaths, even if the

reduction in risk for each individual person is modest. The seminal work of Rose laid out the foundations of population-based prevention on the premise that “a large number of people at a small risk may give rise to more cases of disease than a small number who are at a high risk” (31).

The first line of evidence that CVDs can be prevented at the population level comes from their variations across countries and their long-term trends, which are as impressive as those of cancers. In the 1950s, age-standardized CVD death rates among adult men in Finland, Australia, and the United States were ~1200 per 100,000, compared with less than 600 in Greece and 700 in Norway (Fig. 2B)—a range that is much larger than that of lung cancer in

Fig. 2A. The range was narrower but still relatively large for women (Fig. 2B). Over the subsequent six decades, CVD mortality declined in most high-income countries—steadily and by about two-thirds in some of the countries that had started with the highest mortality. The decline began later, and was slower (including, perhaps, periods of increase), in some of the countries that had low starting mortality like Greece and Norway, and was further delayed in Central and Eastern European countries like Hungary. As a result, except in Central and Eastern Europe, the range of cardiovascular death rates in countries with long-term data is now narrower than it had been a few decades ago. These trends have also changed the ranking of countries

**Box 1. Hazardous alcohol use and cardiovascular diseases in Eastern Europe: A catastrophe in disease prevention.**

Alcohol use is a risk factor for multiple NCDs, injuries, and even infectious diseases like tuberculosis. When consumed moderately and regularly, it has protective effects on CVDs and diabetes (96). On the other hand, irregular heavy (or binge) drinking reverses the protection against CVD and increases the risk of liver disease (97, 98). Hazardous alcohol use has created one of the most catastrophic public health phenomena of recent decades in Russia and some other former Soviet Republics. In these countries, hazardous alcohol use, including medicinal and industrial ethanol, is the leading cause of disease burden among all major risk factors, especially for men (99). Although a part of this burden is due to deaths from injuries in young adults, the majority is due to effects on NCDs, especially cardiovascular diseases (100), leading to the highest NCD death rates in the world (33). The rise in alcohol-related NCD mortality in Russia was so large that it led to a rise in total mortality (101), a situation that is rare outside of epidemics. Although the scale of the problem is unique in Eastern Europe, deprived and marginalized social groups in most places are affected by harmful alcohol use.

This failure of disease prevention has deep social and policy roots. Gorbachev-era policies had helped lower alcohol consumption, leading to lower mortality. Disintegration of the former Soviet Union was followed by a collapse of the social support and welfare systems and a rise in unemployment, deprivation, and stress. Alcohol control policies were also abandoned. Possibly the single most effective tool for NCD prevention in these countries and social groups is control of harmful alcohol consumption through social programs, taxes, and regulation.



in terms of their cardiovascular mortality. Finnish and Norwegian women now have nearly identical mortality, with the difference among men reduced to ~100 per 100,000 (compared with more than 800 in the 1950s). The decline in Australia, which started off with one of the highest mortality levels, has outpaced the United States and most other countries since the 1980s; as a result, Australia now has, together with France and Japan, some of the lowest levels of cardiovascular mortality ever recorded. There are less data on CVD trends in low- and middle-income countries. The available data nonetheless indicate that relatively soon after the decline in infectious diseases, CVD mortality also declines even in low- and middle-income countries (32–34).

What do these differences in CVD mortality level and trends, especially the success of countries like Australia and Finland, tell us about prevention? Faster emergency response times; use of medicines such as antiplatelet agents, angiotensin-converting enzyme inhibitors, beta blockers, and statins after heart attack or stroke; and medical advances such as angioplasty, defibrillation, and thrombolysis have improved the survival of people with a cardiovascular event (35). However, the contribution of postevent treatment to lowering the burden of cardiovascular diseases is less than 40 to 50% (36, 37); rather, the mortality decline is largely a result of lower disease occurrence, itself due to actions related to prevention.

In parallel to these improvements, our knowledge about cardiovascular risk factors has also advanced in studies of individuals and populations (38), providing the foundation for actions and interventions that can continue the past successes and replicate them in other populations. After clinical and early epidemiological research (39), studies with detailed measurement of risk factors and long follow-up, like the Framingham Heart Study, established elevated blood pressure and cholesterol, smoking, and excess body weight as some of the most important risk factors for CVD (40–42). These were followed by larger observational studies in Western and Asian populations that provided more details on the effects of these risk factors on CVDs (43–47); for blood pressure and cholesterol, there is also experimental evidence from randomized trials (48, 49). These studies showed that the benefits of lowering blood pressure, cholesterol, and body weight continue to very low levels—as low as 110 mmHg for systolic blood pressure (SBP), 3.8 mmol/L for serum total cholesterol (TC), and 21 kg/m<sup>2</sup> for body mass index (BMI) (20, 48). [For comparison, in 1950, systolic blood pressures as high as 175 mmHg were considered normal (50)]. Some researchers have even argued for abandoning the concept of hypertension and focusing on all feasible actions to lower blood pressure (51).

Reducing these risk factors in whole populations has contributed to past successes in CVD reduction in a number of countries (37). For ex-

ample, high-quality surveillance data show that the impressive declines in Finland are due to reductions in blood pressure, cholesterol, and smoking, despite the rising BMI levels (52). In 1980, Finnish adults had one of the highest blood pressure and cholesterol levels in the world: Mean SBP of adult Finnish men and women was 143 and 138 mmHg (53), respectively; their serum TC was above 6.1 mmol/L (54–56). Since then, SBP in Finland has declined by about 10 mmHg and TC by about 1 mmol/L (55, 56).

Yet there is more to be gained by further reducing these risk factors at the population level, especially in low- and middle-income countries. Blood pressure has declined in high-income countries but has increased in some other regions over the past few decades. As a result, blood pressure levels are currently highest in countries in Central and Eastern Europe and in parts of sub-Saharan Africa (55). Cholesterol is still highest in Western countries but has been increasing in East Asia (56). High blood pressure and cholesterol are each responsible for an estimated one-half of the global IHD burden, high BMI for about 20%, and tobacco smoking for 13% (57)—noting that the combined effect of these risk factors is much smaller than the sum of their individual effects because many people are exposed to multiple risks and because some of the effects of BMI on cardiovascular diseases are mediated through blood pressure and cholesterol. Similarly, high blood pressure is responsible for nearly two-thirds of stroke burden worldwide, with the other three risk factors each individually responsible for 12 to 18%. When overlaps are taken into account, these four risks together account for 70 to 80% of the burden of IHD and stroke (57). Importantly, the benefits of reducing these key CVD risks not only are very large but also can occur relatively fast and be fully realized within about 5 years, compared with about three decades for achieving the full benefits of smoking cessation on lung cancer and chronic obstructive pulmonary disease (58, 59). This means that actions to reduce key CVD risks can have immediate benefits for disease prevention and also contribute to reduced demand and cost of specialist treatment.

### Is It Feasible to Reduce Major Risk Factors and Prevent NCD?

Identifying risk factors is important but not sufficient for prevention. What is needed is evidence that risk factors can be reduced in whole populations and implementing policies and programs that can do so (60). Examples of such population-based reductions were provided above for some cancer risk factors.

The most basic evidence that it is feasible to prevent and reverse the rise of risk factors like blood pressure, cholesterol, and smoking comes from the differences in their levels and trends across populations, as stated earlier. More importantly, evidence has also accumulated that a

few feasible actions can achieve risk-factor reduction. Tobacco control interventions and policies have helped bring smoking prevalence below 20% in countries such as Australia and Canada (2). The most effective actions for lowering blood pressure and cholesterol, with evidence from individual- and population-based studies (22, 61–63), include lowering salt intake, replacing saturated fats with polyunsaturated fats, and clinical management of blood pressure and cholesterol with antihypertensives and statins through the primary-care system. Diets high in fruits and vegetables (64) and increased physical activity (65) also improve metabolic risk-factor profiles but need more systematic assessments of what combination of policies and actions can increase their uptake in the population, of the sort done in the Finnish cardiovascular risk-reduction experience (66).

In contrast with smoking, blood pressure, and cholesterol, reducing or even curbing the rise in overweight and obesity has proven particularly difficult. BMI has on average risen by as much as 2 to 2.5 kg/m<sup>2</sup> per decade and is now 30 kg/m<sup>2</sup> or higher in the Pacific islands and in some countries in the Middle East (67). Not only does high BMI increase the risk of cardiovascular diseases and some cancers, it is also the most important modifiable risk factor for glycemia and diabetes mellitus. Therefore, the worldwide rise in BMI has been accompanied by increasing diabetes mellitus in most countries (68), with more than one in four or five adults in some countries in the Pacific and in the Middle East now having diabetes (68). In tightly controlled studies of dietary change, moderate weight loss for up to 2 years has been observed, but evidence is lacking on the effectiveness of long-term and large-scale programs (69). Weight loss also appears to be more difficult than avoiding weight gain, perhaps due to specific physiological responses (70). A few controlled studies have successfully slowed down or even reversed a rise in blood glucose, and hence prevented diabetes, among people with impaired glucose tolerance that precedes diabetes, through improved diet and lifestyle and medicines (71, 72). However, the evidence on large-scale prevention and management at the population level is very limited (73). Put simply, we need to find ways that curb and then reverse the massive rise in weight gain if we are to prevent a pandemic of diabetes and to continue and replicate the CVD decline.

### The Way Forward in NCD Prevention

The 2011 United Nations High-Level Meeting created a window of opportunity for NCDs to receive global policy attention. Yet public health and health care systems in countries at all stages of economic development face the need to prioritize among numerous policies and programs related to prevention and treatment, to find financial and human resources to implement them, and to demonstrate that they improve people's health. Strengthening and supporting NCD pre-

**Table 1.** Effective approaches for large-scale NCD prevention.

Prevention mechanism	Action or policy	Evidence of successful implementation at scale	Prevention benefits
Eliminate or substantially reduce tobacco smoking	Comprehensive tobacco control, including taxes to increase prices; restricting availability and accessibility through regulation of sales; warnings; restricting advertising/marketing; public smoking bans (79)	Multiple high-income countries and some low- and middle-income countries	Multiple cancers; cardiovascular diseases; diabetes; chronic respiratory diseases; some other NCDs; respiratory infections and tuberculosis
Eliminate or substantially reduce harmful alcohol use	Comprehensive alcohol control, including taxes to increase prices; restricting availability and accessibility through regulation of production and sales; restricting advertising/marketing; enforcing drinking and driving laws (80, 81)	Some high-income countries and a few middle-income countries (82)	Multiple cancers; cardiovascular diseases*; liver cirrhosis and other gastrointestinal diseases; intentional and unintentional injuries; some infectious diseases
Reduce dietary salt intake to low levels	Taxes; regulation; well-designed public education; perhaps negotiated voluntary actions by food manufacturers (79, 83)	Finland, the United Kingdom, Japan, and a few other high-income countries (22, 62, 83); evidence lacking in low- and middle-income countries	Stomach cancer; blood pressure with benefits for cardiovascular disease and kidney disease
Eliminate manufactured trans fats	Ban partially hydrogenated oils	A few high-income countries (whole country or individual communities) (84, 85)	Cardiovascular diseases
Increase fresh fruits and vegetables in diet	Improving financial and physical access through price mechanisms (e.g., subsidies), agricultural policies, and possibly requiring availability in grocery stores; well-designed public education	Finland (66); some high-income countries but possibly due to broader changes in availability versus specific policies	Cardiovascular diseases; some cancers
Replace saturated fats with poly-unsaturated fats; replace processed carbohydrates with whole grains	Taxes/subsidies; regulation; labeling; perhaps negotiated voluntary actions by food manufacturers; well-designed public education	Finland, New Zealand, and a few other high-income countries for fat replacement (66, 86, 87)	Cardiovascular diseases; diabetes mellitus
Reduce overweight and obesity and increase physical activity	Design, implement, and evaluate actions and strategies for weight management/loss and for increasing physical activity at the population level (88, 89)	None	Cardiovascular diseases; diabetes mellitus; some cancers
Provide clean fuels for cooking and heating	Develop and deliver clean fuels for cooking and heating (90, 91)	Multiple middle-income countries, but possibly due to economic development versus specific policies	Chronic and infectious respiratory diseases; lung cancer; cataracts; possibly cardiovascular diseases
Eliminate or substantially reduce infections that are risk factors for, or predispose to, cancers and cardiovascular diseases	Vaccination for infections related to cancers, including HPV and HBV <sup>†</sup> ; treatment for the above plus HCV, <i>H. pylori</i> , schistosomiasis, and for bacterial infections like Chagas and Lyme disease and group A streptococcal tonsillitis and pharyngitis <sup>‡</sup>	Universal childhood HBV vaccination in some countries (92); relatively high coverage of cervical cancer screening in many middle- and high-income countries (24); successful schistosomiasis control in some developing countries (93); fewer examples, mainly in high-income countries, for other interventions	Cervical, liver, stomach, and bladder cancers; liver cirrhosis; atherosclerosis cardiomyopathies; rheumatic, valvular, and other heart disease; heart failure
Screen for and treat risk factors for NCDs in primary care	Implement an equitable and high-quality primary-care system (94); ensure availability of essential, and typically low-cost, medicines for NCD prevention and early-stage treatment	High-income countries with universal insurance; also implemented in low- and middle-income countries with focus on maternal and child health but has been extended to NCD management in a few countries (73)	Screening, early detection, and treatment of multiple NCDs and their risk factors
Ensure that all prevention strategies are designed to reach disadvantaged and marginalized communities and social groups.			

\*Effects of specific cardiovascular diseases depend on the patterns of alcohol consumption (regular moderate versus irregular heavy drinking). †Vaccines are not currently available for HCV and *H. pylori*. ‡Influenza vaccination among people with coronary heart disease and heart failure is also a secondary prevention that reduces their risk of dying (95).



vention requires a broader notion of preventability than detecting causes that increase disease risk in individuals—one that incorporates the potential for large change in whole populations. Our knowledge from studying NCDs in individuals and populations shows that there are ways to achieve the large-scale disease prevention potential, e.g., in whole countries and communities (Table 1). The policies and actions to change NCD risk factors of the kinds specified here need political support and policy and administrative institutions that can initiate, periodically evaluate, and as needed redirect them. However, once implemented, unlike treatment (which often deals with a single disease), most of these actions can prevent the occurrence of multiple NCDs and can therefore have very large benefits for the health of populations.

### References and Notes

- Death rates from cardiovascular and respiratory diseases, and even some cancers, also decline or shift to older ages as countries develop (32, 74), but this happens later and more slowly than the decline in deaths from infections, hence increasing the relative importance of NCDs.
- World Health Organization, *Global Status Report on Noncommunicable Diseases 2010* (World Health Organization, Geneva, 2011).
- R. Doll, R. Peto, *J. Natl. Cancer Inst.* **66**, 1191 (1981).
- M. Ezzati, S. J. Henley, A. D. Lopez, M. J. Thun, *Int. J. Cancer* **116**, 963 (2005).
- F. H. Müller, *Z. Krebsforsch.* **49**, 57 (1939).
- L. Adler, *Primary Malignant Growth of the Lungs and Bronchi* (Longmans-Green, London, 1912).
- R. Doll, A. B. Hill, *BMJ* **1**, 1451 (1954).
- R. Doll, R. Peto, J. Boreham, I. Sutherland, *BMJ* **328**, 1519 (2004).
- C. A. Pope 3rd et al., *Environ. Health Perspect.* **119**, 1616 (2011).
- Death rates throughout are standardized to the World Health Organization (WHO) standard population for those aged 30 years and older so that comparisons account for differences in age structures of populations over time and across countries.
- M. J. Thun et al., *PLoS Med.* **5**, e185 (2008).
- B. Q. Liu et al., *BMJ* **317**, 1411 (1998).
- B. J. Marshall, J. R. Warren, *Lancet* **323**, 1311 (1984).
- C. de Martel et al., *Lancet Oncol.* **13**, 607 (2012).
- T. Hirayama, *Jpn. J. Clin. Oncol.* **14**, 159 (1984).
- C. P. Howson, T. Hiyama, E. L. Wynder, *Epidemiol. Rev.* **8**, 1 (1986).
- B. C. Wong et al., China Gastric Cancer Study Group, *JAMA* **291**, 187 (2004).
- Y. H. Grad, M. Lipsitch, A. E. Aiello, *Am. J. Epidemiol.* **175**, 54 (2012).
- D. M. Parkin, *Int. J. Cancer* **118**, 3030 (2006).
- G. Danaei et al., *PLoS Med.* **6**, e1000058 (2009).
- J. Tuomilehto, J. Geboers, J. V. Joossens, J. T. Salonen, A. Tanskanen, *Stroke* **15**, 823 (1984).
- T. Laatikainen et al., *Eur. J. Clin. Nutr.* **60**, 965 (2006).
- K. Haruma et al., *J. Clin. Gastroenterol.* **25**, 583 (1997).
- B. McKinnon, S. Harper, S. Moore, *Int. J. Public Health* **56**, 139 (2011).
- M. H. Forouzanfar et al., *Lancet* **378**, 1461 (2011).
- M. Schiffman, P. E. Castle, *N. Engl. J. Med.* **353**, 2101 (2005).
- J. J. Ott, G. A. Stevens, J. Groeger, S. T. Wiersma, *Vaccine* **30**, 2212 (2012).
- C. W. Shepard, L. Finelli, M. J. Alter, *Lancet Infect. Dis.* **5**, 558 (2005).
- Y. J. Huttin, A. M. Hauri, G. L. Armstrong, *BMJ* **327**, 1075 (2003).
- G. Danaei, S. Vander Hoorn, A. D. Lopez, C. J. Murray, M. Ezzati, Comparative Risk Assessment Collaborating Group (Cancers), *Lancet* **366**, 1784 (2005).
- G. Rose, *Int. J. Epidemiol.* **14**, 32 (1985).
- S. Stringhini et al., *Stroke* **43**, 2283 (2012).
- A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, C. J. Murray, *Lancet* **367**, 1747 (2006).
- An implication of declining mortality is that people live to older ages. Because CVD mortality tends to rise with age, this leads to an increase in the absolute number of CVD deaths. However, when death rates are standardized for population age structure, declining trends are seen.
- E. G. Nabel, E. Braunwald, *N. Engl. J. Med.* **366**, 54 (2012).
- H. N. Gouda, J. Critchley, J. Powles, S. Capewell, *BMC Public Health* **12**, 88 (2012).
- E. S. Ford, S. Capewell, *Annu. Rev. Public Health* **32**, 5 (2011).
- J. Stamler, J. D. Neaton, D. B. Garside, M. L. Daviglius, in *Coronary Heart Disease Epidemiology: From Etiology to Public Health*, M. Marmot, P. Elliott, Eds. (Oxford Univ. Press, Oxford, 2005), pp. 32–70.
- J. Stamler, in *Coronary Heart Disease Epidemiology: From Etiology to Public Health*, M. Marmot, P. Elliott, Eds. (Oxford Univ. Press, Oxford, 2005), pp. 18–31.
- W. B. Kannel, T. R. Dawber, A. Kagan, N. Revotskie, J. Stokes 3rd, *Ann. Intern. Med.* **55**, 33 (1961).
- J. T. Doyle, T. R. Dawber, W. B. Kannel, A. S. Heslin, H. A. Kahn, *N. Engl. J. Med.* **26**, 796 (1962).
- T. R. Dawber, W. B. Kannel, N. Revotskie, A. Kagan, *Proc. R. Soc. Med.* **55**, 265 (1962).
- S. Lewington, R. Clarke, N. Qizilbash, R. Peto, R. Collins, Prospective Studies Collaboration, *Lancet* **360**, 1903 (2002).
- C. M. Lawes et al., Asia Pacific Cohort Studies Collaboration, *J. Hypertens.* **21**, 707 (2003).
- X. Zhang et al., Asia Pacific Cohort Studies Collaboration, *Int. J. Epidemiol.* **32**, 563 (2003).
- S. Lewington et al., Prospective Studies Collaboration, *Lancet* **370**, 1829 (2007).
- G. Whitlock et al., Prospective Studies Collaboration, *Lancet* **373**, 1083 (2009).
- M. R. Law, J. K. Morris, N. J. Wald, *BMJ* **338**, b1665 (2009).
- C. Baigent et al., Cholesterol Treatment Trialists' (CTT) Collaboration, *Lancet* **376**, 1670 (2010).
- A. M. Master, L. I. Dublin, H. H. Marks, *J. Am. Med. Assoc.* **143**, 1464 (1950).
- S. MacMahon, B. Neal, A. Rodgers, *Lancet* **365**, 1108 (2005).
- E. Vartiainen et al., *Int. J. Epidemiol.* **39**, 504 (2010).
- Risk-factor levels throughout are standardized to the WHO standard population for those aged 25 years and older so that comparisons account for differences in age structures of populations over time and across countries.
- For comparison, in the same year mean SBP was below 112 mmHg (women) and 120 mmHg (men) in Cambodia and Papua New Guinea—the lowest levels in a national population. Similarly, men in some African countries have serum TC below 4.0 mmol/L, with little change over time. Even lower blood pressure and cholesterol levels have been measured in communities with low intakes of salt and/or saturated fats and relatively high physical activity, with mean SBP as low as 95 mmHg in the Yanomami in Brazil (75) and mean serum cholesterol below 3.5 mmol/L in parts of China in the 1970s (76).
- G. Danaei et al., Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Blood Pressure), *Lancet* **377**, 568 (2011).
- F. Farzadfar et al., Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Cholesterol), *Lancet* **377**, 578 (2011).
- M. Ezzati et al., Comparative Risk Assessment Collaborating Group, *Lancet* **362**, 271 (2003).
- M. R. Law, N. J. Wald, S. G. Thompson, *BMJ* **308**, 367 (1994).
- S. Oza, M. J. Thun, S. J. Henley, A. D. Lopez, M. Ezzati, *Prev. Med.* **52**, 428 (2011).
- Risk factors may also change through broader technological, social, and economic change and more informal diffusion of knowledge and technology. The role of refrigeration in reducing risk factors for stomach cancer, described earlier, is one example of such secular change. In some countries, the amount of alcohol consumed and its consumption patterns changed through social forces in parallel to, or even before, those due to active intervention (77, 78).
- P. Puska, E. Vartiainen, J. Tuomilehto, V. Salomaa, A. Nissinen, *Bull. World Health Organ.* **76**, 419 (1998).
- N. Ikeda, E. Gakidou, T. Hasegawa, C. J. Murray, *Bull. World Health Organ.* **86**, 978 (2008).
- P. Elliott et al., Intersalt Cooperative Research Group, *BMJ* **312**, 1249 (1996).
- F. M. Sacks, H. Campos, *N. Engl. J. Med.* **362**, 2102 (2010).
- S. Mora, N. Cook, J. E. Buring, P. M. Ridker, I. M. Lee, *Circulation* **116**, 2110 (2007).
- P. Puska, T. Ståhl, *Annu. Rev. Public Health* **31**, 315, 3, 328 (2010).
- M. M. Finucane et al., Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Body Mass Index), *Lancet* **377**, 557 (2011).
- G. Danaei et al., Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Blood Glucose), *Lancet* **378**, 31 (2011).
- J. D. Douketis, C. Macie, L. Thabane, D. F. Williamson, *Int. J. Obes.* **29**, 1153 (2005).
- P. Sumithran et al., *N. Engl. J. Med.* **365**, 1597 (2011).
- L. Perreault et al., Diabetes Prevention Program Research Group, *Lancet* **379**, 2243 (2012).
- A. Ramachandran et al., Indian Diabetes Prevention Programme (IDPP), *Diabetologia* **49**, 289 (2006).
- F. Farzadfar et al., *Lancet* **379**, 47 (2012).
- K. Uemura, Z. Pisa, *World Health Stat. Q.* **41**, 155 (1988).
- Intersalt Cooperative Research Group, *BMJ* **297**, 319 (1988).
- Z. Chen et al., *BMJ* **303**, 276 (1991).
- A. Allamani, F. Prina, *Contemp. Drug Probl.* **34**, 187 (2007).
- F. Cipriani, F. Prina, *Contemp. Drug Probl.* **34**, 361 (2007).
- P. Asaria, D. Chisholm, C. Mathers, M. Ezzati, R. Beaglehole, *Lancet* **370**, 2044 (2007).
- S. Casswell, T. Thamarangsi, *Lancet* **373**, 2247 (2009).
- T. Babor, *Alcohol: No Ordinary Commodity: Research and Public Policy* (Oxford Univ. Press, Oxford, 2010).
- D. A. Brand, M. Saisana, L. A. Rynn, F. Pennoni, A. B. Lowenfels, *PLoS Med.* **4**, e151 (2007).
- F. J. He, G. A. MacGregor, *J. Hum. Hypertens.* **23**, 363 (2009).
- T. Leth, H. G. Jensen, A. A. Mikkelsen, A. Bysted, *Atheroscler. Suppl.* **7**, 53 (2006).
- S. Y. Angell et al., *Ann. Intern. Med.* **151**, 129 (2009).
- R. Jackson, R. Beaglehole, *Int. J. Epidemiol.* **16**, 377 (1987).
- P. Pietinen, E. Vartiainen, R. Seppänen, A. Aro, P. Puska, *Prev. Med.* **25**, 243 (1996).
- S. L. Gortmaker et al., *Lancet* **378**, 838 (2011).
- G. W. Heath et al.; Lancet Physical Activity Series Working Group, *Lancet* **380**, 272 (2012).
- R. Bailis, M. Ezzati, D. M. Kammen, *Science* **308**, 98 (2005).
- H. H. Lin, M. Murray, T. Cohen, C. Colijn, M. Ezzati, *Lancet* **372**, 1473 (2008).
- Centers for Disease Control and Prevention (CDC), *MMWR Morb. Mortal. Wkly. Rep.* **52**, 868 (2003).
- L. Chitsulo, D. Engels, A. Montresor, L. Savioli, *Acta Trop.* **77**, 41 (2000).
- R. Beaglehole et al., *Lancet* **372**, 940 (2008).
- M. M. Davis et al.; American Heart Association; American College of Cardiology, *Circulation* **114**, 1549 (2006).
- M. Roerecke, J. Rehm, *Addiction* **107**, 1246 (2012).
- M. Roerecke, J. Rehm, *Am. J. Epidemiol.* **171**, 633 (2010).
- J. Rehm et al., *Addiction* **105**, 817 (2010).
- M. Ezzati, A. D. Lopez, A. Rodgers, S. Vander Hoorn, C. J. Murray, Comparative Risk Assessment Collaborating Group, *Lancet* **360**, 1347 (2002).
- D. Zaridze et al., *Lancet* **373**, 2201 (2009).
- D. A. Leon et al., *Lancet* **350**, 383 (1997).

**Acknowledgments:** We thank G. Danaei, J. Powles, and J. Samet for valuable comments on an earlier draft and P. Asaria, G. Danaei, C. de Martel, P. Elliott, N. Ikeda, J. Kim, G. Mensah, A. Moran, D. Mozaffarian, J. Powles, P. Puska, J. Rehm, L. Riley, G. Roth, F. Sacks, J. Samet, J. Tuomilehto, and J. Yeh for suggestions for materials and readings related to specific topics. We thank C. Di Cesare, Y. Lu, and G. Stevens for materials and assistance with figures. M. Ezzati's research is partially supported by a Strategic Award from the UK Medical Research Council and by the National Institute for Health Research Comprehensive Biomedical Research Centre at Imperial College London and Imperial College Healthcare NHS Trust.

10.1126/science.1227001