CHAPTER FIVE

Some Strategies to Reduce Risk

This chapter puts forward the best available evidence on the cost and effectiveness of selected interventions to reduce some of the major risk factors discussed in Chapter Four. It looks at the extent to which these interventions are likely to improve population health, both singly and in combination. It illustrates how decision-makers can begin the policy debate about priorities with information about which interventions would yield the greatest possible improvements in population health for the available resources. The chapter examines a range of strategies to reduce different types of risk, and the possible impact of those strategies on costs and effectiveness. Many risk reduction strategies involve a component of behaviour change, and some types of behaviour change might require active government intervention to succeed. Different ways of attaining the same goal are discussed, for example, the population-wide versus the individual-based approach and prevention versus treatment. With regard to policy implications, the chapter concludes that very substantial health gains can be made for relatively modest expenditures on interventions. However, the maximum possible gains for the resources that are available will be attained only through careful consideration of the costs and effects of interventions.

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Some Strategies to

Reduce Risk

From health risks to policy

*E*arlier chapters have quantified the burden of disease attributable to major risk factors, and shown the size of the potentially avoidable burden if the population distribution of risk is reduced across the board. This knowledge is important but it is only the first step required to decide how best to improve population health with the available resources. The second step involves assessing what types of intervention are available to decrease exposure to risks or to minimize the impact of exposure on health; to what extent they are likely to improve population health singly and in combination; and what resources are required to implement them. Chapter 4 quantified the importance of selected risk factors in different settings. This chapter evaluates selected interventions to reduce the impact on population health of some of those risk factors.[1]

Different types of evidence on intervention costs and effectiveness have been considered in the analysis detailed in this chapter. Some interventions have been widely implemented in many settings, and relatively good information on their costs and effects exists. The interventions for which it is easier to obtain this type of evidence are often those that focus on individuals rather than on populations as a whole, and the overall impact on population health of such interventions can be relatively small. Some types of population-based interventions with the potential to make very substantial improvements in population health have not been implemented very frequently or have not been evaluated very often. The evidence on the costs and effectiveness of these interventions is less certain, but it is important to consider them because they have the potential to make very substantial differences in health outcomes.

Cost-effectiveness analysis can be undertaken in many ways and there have been several attempts to standardize methods to make results comparable *(1–3)*. WHO has developed a standardized set of methods and tools that can be used to analyze the costs and population health impact of current and possible new interventions at the same time *(3)*. As part of WHO's CHOICE project, these tools and methods have been used to analyze a range of interventions that tackle some of the leading risks identified in Chapter 4.[2] The CHOICE project is intended to provide regularly updated databases on the costs and effects of a full range of promotive, preventive, curative and rehabilitative health interventions.

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[1] This chapter represents a report on the first stage of a long-term work plan to evaluate the burden of all the major risks to health and the costs and effectiveness of all major interventions.

[2] CHOICE stands for CHoosing Interventions that are Cost-Effective – see www.who.int/evidence

To answer key policy questions on tackling risks to health, it is necessary to compare the costs and effectiveness of interventions to the situation that would exist if they were not done. This "counterfactual" scenario – what would happen in the absence of the interventions against a particular risk factor – is different from the counterfactual used in Chapter 4 to estimate the avoidable burden of disease. There the question was what would the burden have been if the distribution of risks could be lowered by 25%, 50% or even 100%. That

Table 5.1 Leading 10 selected risk factors as percentage causes of disease burden measured in DALYs[a]

Developing countries	
High mortality countries	
Underweight	**14.9%**
Unsafe sex	**10.2%**
Unsafe water, sanitation and hygiene	**5.5%**
Indoor smoke from solid fuels	3.7%
Zinc deficiency	**3.2%**
Iron deficiency	**3.1%**
Vitamin A deficiency	**3.0%**
Blood pressure	**2.5%**
Tobacco	**2.0%**
Cholesterol	**1.9%**
Low mortality countries	
Alcohol	6.2%
Blood pressure	**5.0%**
Tobacco	**4.0%**
Underweight	**3.1%**
Overweight	2.7%
Cholesterol	**2.1%**
Indoor smoke from solid fuels	1.9%
Low fruit and vegetable intake	**1.9%**
Iron deficiency	**1.8%**
Unsafe water, sanitation and hygiene	**1.7%**

Developed countries	
Tobacco	**12.2%**
Blood pressure	**10.9%**
Alcohol	9.2%
Cholesterol	**7.6%**
Overweight	7.4%
Low fruit and vegetable intake	**3.9%**
Physical inactivity	3.3%
Illicit drugs	1.8%
Unsafe sex	**0.8%**
Iron deficiency	**0.7%**

[a] Risk factors discussed in this chapter are in bold type.

is useful in showing the relative importance of different risk factors, but some of these risks can be reduced relatively easily, at low cost, and others cannot. Because health resources are always scarce in relation to need, choices must be made about how to allocate them between the substantial number of options available to reduce risks. The best way of doing this is to estimate, for each intervention, the gains in population health and the associated costs compared to the situation that would exist if the intervention were not undertaken.[3]

This chapter reports the best available evidence on the cost and effectiveness of selected interventions to reduce some of the major risk factors discussed in Chapter 4. The list of interventions is not exhaustive and the chapter does not include all the risk factors of Chapter 4. The ones for which interventions are considered here are highlighted in bold type in Table 5.1. A more comprehensive picture of interventions concerning diseases as well as additional risk factors (e.g. alcohol) will be presented in *The World Health Report 2003.*

The analysis is used to identify some interventions that are very cost-effective and some that are not cost-effective in different settings. It illustrates how decision-makers can begin the policy debate about priorities for allocating health resources with information about which interventions have the potential to yield substantial improvements in population health for the available resources.

This evidence will be only one input to the final decision about the best combination of interventions. Improving population health is the defining goal of health systems, but there are other social goals to which health systems contribute. Policy-makers will wish to consider the impact of different combinations of interventions on health inequalities and poverty and on the responsiveness of their systems, for example *(4).* Communities in different settings might differ in their ability and willingness to participate in specific risk-reduction activities, and particular activities might be more difficult to incorporate into existing health system infrastructure in some settings than in others. The information from this chapter is, therefore, one input – a key one, but not the only one – to the policy debate.

The analysis does not apply simply to interventions funded by government. WHO argues that governments should be good stewards of their health systems *(5).* If the population uses interventions that are ineffective, dangerous, or are simply not good value for money,

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[3] The term "intervention" is used in this chapter in a very broad sense. It includes any health action – any promotive, preventive, curative or rehabilitative activity where the primary intent is to improve health. Interventions in the chapter range from the introduction of a tax on tobacco products to treating hypertension to prevent a heart attack.

governments should find ways to encourage people to use resources more appropriately even if the finance is not provided by government. The evidence presented in this chapter will facilitate this process.

WHAT STRATEGIES CAN REDUCE RISKS TO HEALTH?

WHO defines the health system to include all actions whose primary intent is to improve health *(5)* and some activities that improve health fall outside this definition. Examples include reductions in poverty, and improvements in housing and education, which may well reduce exposures to some types of risks but are not primarily designed to improve health. This chapter is concerned mainly with interventions that have the primary intent of improving health.

Some interventions, however, are difficult to categorize strictly using this definition. One set that has traditionally fallen within the remit of public health covers improvements to water and sanitation. Many water and sanitation programmes fall outside the health portfolio, and clearly such improvements do have considerable amenity value outside health. However, clean water and improved sanitation are considered in this chapter because their attributable burden of disease is so significant. It must be noted, however, that although they improve health, many of their benefits are not readily incorporated into a cost-effectiveness framework and should be considered when comparing them with other types of health interventions.

A number of strategies have been used to reduce health risks that are seen as modifiable. They can be categorized broadly as interventions that seek to reduce risks in the population as a whole, and those which target individuals within the population. The former include intervention by governments through legislation, tax or financial incentives; engineering solutions such as the introduction of safety belts in motor vehicles or the provision of piped water; and health promotion campaigns targeting the general public. The latter include strategies to change health behaviours of individuals, often through personal interaction with a health provider; and strategies to change the behaviours of health providers, particularly in the way they interact with their clients.

Genetic screening is a valuable tool for some diseases associated with the risk factors described in this report, but individual genes are not susceptible to manipulation at present. Genetic screening is not considered further in this chapter.

RISK REDUCTION AND BEHAVIOUR

Many risk reduction strategies involve a component of behaviour change. Even engineering solutions, such as the provision of piped drinking-water, will not result in health improvements unless people are willing to use the new source. Social scientists argue that behavioural change first requires understanding *(6, 7)*.[4] A number of individual preferences or characteristics influence how people translate understanding into health behaviours, including how averse to health risks individuals are and how they value possible future health decrements compared with other competing choices in their lives such as wealth and lifestyle. These preferences are influenced by information and the influence of advertising and marketing.

"Perceived risk" is the subjective assessment of personal disease risk, based on an individual's interpretation of epidemiological and other types of data. There may be a difference

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[4] In the case of addiction, individuals can struggle to change their behaviours despite recognition of the harmful effects to themselves and others *(8)*.

between risk perception as an individual and cultural concepts of risk acceptability by society. For example, although driving without a seat belt may be deemed so unacceptable by a society that legislation is enacted to enforce it, individuals within that society may perceive the risk to themselves as trivial and choose not to use a seat belt.

When it comes to risks to health, individuals and societies sometimes prefer to enjoy the benefits of an activity now without thinking about possible future health costs. High consumption of certain types of food, for instance, is perceived by some people to give current pleasure despite the risk of harmful health effects – to which they give less weight because they will occur in the future.

There is considerable variation in the rate at which people value and assess adverse events that might happen in the future. Some research has indicated that smokers "discount the future" more highly than non-smokers – for example, a given probability of developing lung cancer in 20 years is given less weight by smokers than by non-smokers *(9)*. People who discount the future more highly value a given future health risk less highly than people who discount the future less highly, even if they have the same information. The question of how technically to incorporate this into the analysis is discussed later but the effectiveness of behavioural modification interventions is clearly influenced by variations in how people perceive the future.

A set of additional factors also influences the way people respond to risk-reduction interventions. Even when people have heard and understood the message that insecticide-treated nets prevent mosquito bites, and wish to use them to avoid both the nuisance value of mosquitoes and the risk of malaria, a number of factors may prevent them from doing so *(10)*. These include the availability and affordability of nets in their locale and their sleeping arrangements (in a house, or on the street). These in turn will be affected by many factors including personal, community and health system characteristics.

One determinant is culture and the social support networks available, sometimes called social capital. Health system and provider characteristics, such as the way the health system is financed (for example, through social health insurance or user charges) or organized (for example, through managed care or a publicly funded system), also influence behaviours and, through them, the costs and effectiveness of interventions.

INDIVIDUAL-BASED VERSUS POPULATION APPROACHES TO RISK REDUCTION

Two broad approaches to reducing risk were defined earlier. The first is to focus the intervention on the people likely to benefit, or benefit most, from it. The second is to seek to reduce risks in the entire population regardless of each individual's level of risk and potential benefits. In some cases, both approaches could be used at the same time. Focusing on high-risk individuals can reduce costs at the population level because an intervention is provided to fewer people, but on the other hand it might also increase the costs of identifying the group of people most likely to benefit.

Focusing on people who are more likely to benefit has a significant impact on the health of a nation only when there are large numbers of them. For example, lowering cholesterol with drugs is effective in reducing overall mortality in a group of people at high risk of death from heart disease; targeting interventions to reduce cholesterol to the needs of these people focuses the interventions on a group of people likely to benefit.

However, only a small percentage of the population is at high risk of death from heart disease at any given time, and only some of them can be identified purely on the basis of their cholesterol levels. Recent evidence suggests that the group most likely to benefit from
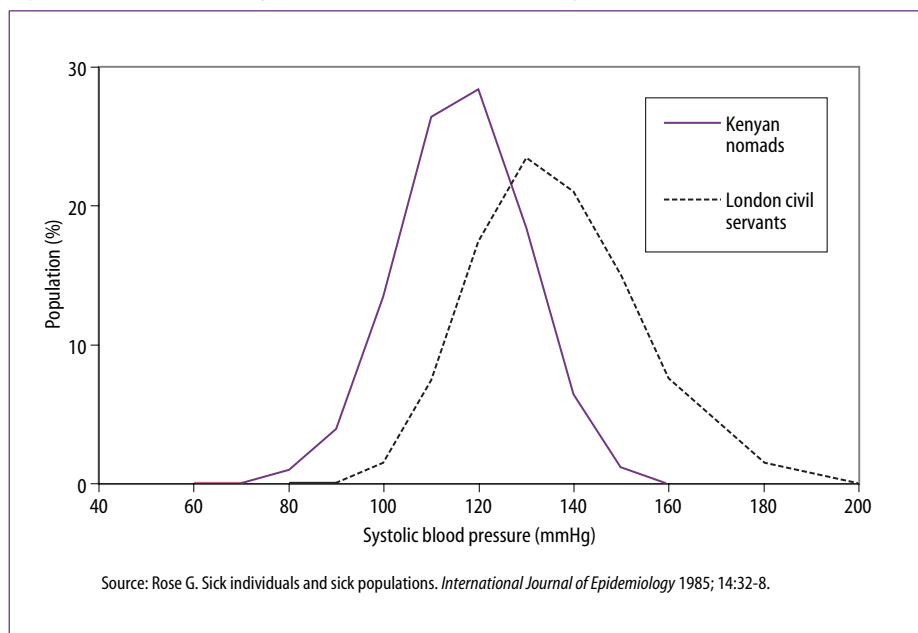
cholesterol reduction consists of individuals with combinations of risk factors, such as being male, with ischaemic changes, who smoke, are obese, are not physically active and have high blood pressure and high cholesterol *(11)*. Designing interventions for people with a combination of those risk factors might well prove to be more effective than treating people only on the basis of their levels of cholesterol *(12)*. This form of targeted approach will subsequently be called the "absolute risk approach".

The high-risk approach can be viewed as targeting the right-hand tail of the risk factor curves in Figure 5.1 *(13)*. The alternative is to try to shift the entire population distribution of risk factors to the left – like shifting the distribution of blood pressure for London civil servants in the direction of that of Kenyan nomads. This has the potential to improve population health to a much greater extent than a high-risk approach, while at the same time reducing the costs of identifying high-risk people. On the other hand, the costs of providing an intervention to the entire population would, in this case, be higher than providing it only to people in the right-hand tail. Which approach is the most cost-effective in any setting will depend on the prevalence of high-risk people in the population and the costs of identifying them compared with the costs of the available blood pressure reduction strategies.

THE ROLE OF GOVERNMENT AND LEGISLATION

Some areas of behavioural change are likely to be adopted relatively easily once information becomes available, assuming that the technology is affordable. Other types of behavioural change will benefit from active government intervention, particularly those where people have high rates of time discount or low rates of risk aversion. Government action is required if the full potential to improve population health through the reduction of alcohol and tobacco consumption is to be achieved, partly because of the addictive nature of these substances. Such action could be through changes in the law or financial incentives and disincentives. Road safety is another area where a significant number of people might not

Figure 5.1 Distributions of systolic blood pressure in middle-aged men in two populations

Source: Rose G. Sick individuals and sick populations. *International Journal of Epidemiology* 1985; 14:32-8.

choose to drive safely, or use seat belts or motorcycle helmets, but government action can encourage them to do so, thereby preventing injuries to themselves and to other people.

Increasing prices through taxation certainly reduces smoking *(14)* even if smuggling increases subsequently *(15)*. A particular focus of this chapter is to explore if this type of government action is cost-effective. In some countries there has been debate about whether governments should play this type of role, and information on the costs and impact on population health are important inputs to this debate.

DIFFERENT WAYS OF ATTAINING THE SAME GOAL

Different sets of interventions can be used to achieve the same goal and some interventions will reduce the burden associated with multiple risk factors and diseases. Interventions to reduce blood pressure, cigarette smoking and cholesterol all reduce cardiovascular disease, and each has been used separately and together with others at different times and in different settings. The effect of doing two at the same time might be more than would be expected by adding the benefits of doing the two interventions singly, or might be less. Much ischaemic heart disease mortality that has traditionally been attributed to particular risk factors is, in fact, caused by those factors in combination with other risk factors *(16)*. Partly as a result of these interactions, risk reduction strategies are generally based on a combination of interventions rather than just one.

The decision about which combination should be undertaken for the available resources is complex. It is necessary to determine the health gains, and the costs, of doing each possible intervention by itself and in combination with the other ways of reducing the burden for a given risk factor or disease. The analysis undertaken for this chapter followed that process by evaluating what would be achieved by each intervention alone and in combination with other interventions.

TECHNICAL CONSIDERATIONS FOR COST-EFFECTIVENESS ANALYSIS

The estimates, which provide the basis of the results reported in this chapter, were undertaken on a regional basis as part of the WHO CHOICE project. The six WHO regions were divided into mortality strata as described in earlier chapters, resulting in 14 epidemiological subregions. The total costs and total effects of each intervention were estimated separately for the 14 subregions. Eventually it is hoped that there will be sufficient data to make estimates at a country level, and even at the subnational level for large countries, but this is not currently possible.

Subregional analysis offers a valuable basis from which country analysts can work to calibrate the results to their settings. It is much more policy-relevant than a global analysis because the epidemiology, cost structures, and starting points (such as the availability of trained health staff and the history of health interventions) varies less within each subregion than across the world as a whole. The results are used here to identify interventions that are very cost-effective, cost-effective, and not cost-effective in each subregion.

Costs are reported in terms of international dollars rather than in US dollars, to account better for differences in cost structures between settings. Unit costs for most regions are higher using international dollars (I$) based on purchasing power parity exchange rates than they would be if official exchange rates had been used.[5] Effectiveness is measured in terms of disability-adjusted life years (DALYs) gained by the intervention. A brief descrip-

tion of the methods is found in Box 5.1, while full details of the methods and the calculations can be found on the WHO web site.[6]

It is not much value to provide decision-makers with information on the costs and effectiveness of interventions that are undertaken badly. Accordingly, the results reported here show what would be achieved if the interventions were undertaken in a relatively efficient manner. For example, we assume capacity utilization of 80% in most settings – for example, staff and capital equipment are fully occupied for 80% of the normal working day – except when estimating the effect of expanding coverage to very high levels. To reach 95% of the population it might be necessary to provide facilities in isolated areas where population numbers are insufficient to support such high rates of capacity utilization. The results, therefore, provide guidance on selected interventions that should be given high priority in the policy debate about resource allocation, but only if they are undertaken in an efficient manner.

Sets of interventions that interact in terms of effectiveness or costs are considered together, as stated earlier. For example, interventions to reduce risks associated with hypertension and high cholesterol interact. The analysis is based on estimates of the effects on population health of reducing blood pressure alone, reducing cholesterol levels alone, and doing both together.

In addition, many of the interventions are evaluated at different levels of coverage. For most, three levels were used (50%, 80% and 95%) and the impact on costs and effects of expanding coverage was incorporated.

The standard practice in this type of analysis is to discount both the health effects and the costs of the different programmes under consideration. There is no controversy about

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Box 5.1 Methods for cost-effectiveness analysis

The cost-effectiveness analysis on which this report is based considered what would have happened if a set of interventions had not been implemented and compared the result with what happens on their implementation. Through a four-state population model, the number of healthy life years lived over a period of a hundred years by a population in the absence of that set of interventions is estimated by inputting parameters of incidence, remission, cause-specific and background mortality, and health state valuations reflecting the natural history of the disease. The parameters reflecting the natural history of the disease were mostly estimated by back-adjusting current rates using coverage and known effectiveness of interventions. The same four-state population model can then be rerun, reflecting changes in the parameters due to in-

terventions or combinations of interventions. For example, based on data from earlier chapters, vitamin A deficiency increases the risk of dying from diarrhoea. The impact of vitamin A supplementation is then mediated in the model by a decrease in case fatality rate for diarrhoea. Effectiveness data came from systematic reviews where available. The difference in the healthy life years gained by the population with and without the intervention is the impact of the intervention and is entered as the denominator of the cost-effectiveness ratio.

Costs covered in this analysis include expenses associated with running the intervention, such as administration, training and contact with the media. They also include costs incurred at the individual level such as counselling. Considerable effort was exerted to try to standardize the methodology used in collecting and classifying costs. The

quantities of inputs required to run each intervention were estimated by experts in 17 regions of the world and validated against the literature. Some individual-level costs were obtained by multiplying unit costs of inputs by the expected utilization of those inputs by the people covered by the programme. Unit costs for outpatient visits and laboratory tests were obtained from a review of literature and supplemented by primary data from several countries. The total costs for implementing a programme for 10 years constitutes the denominator of the cost-effectiveness ratio.

Stochastic uncertainty analysis was carried out for key parameters in both the numerator and denominator.

Sources: *(3, 17–19).*

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[5] This is important to keep in mind when benchmarking the estimates in this chapter against those reported elsewhere, usually in US dollars. International dollars are derived by dividing local currency units by an estimate of their purchasing power parity (PPP) compared to a US$. PPPs are the rates of currency conversion that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries.

[6] www.who.int/evidence

the appropriate discount rate to use for costs: the opportunity cost of capital. The discount rate for benefits is often thought to comprise two parts. One is a "pure" time preference for immediate over postponed consumption. The second relates to the fact that, as the prosperity of a society increases, the utility or benefit to it of a defined unit of consumption is less – that is, there is declining marginal utility of a unit of consumption as income rises. Many cost-effectiveness studies have assumed that this applies to health benefits as well and have discounted future health at a rate between 3% and 5% per year. This practice has long been debated, and some people have argued that the discount rate for health benefits should be close to zero and certainly less than the discount rate for costs *(20–22)*.

This question is important for the analysis in the following section as it can change the relative priority of interventions. Not all health care programmes achieve results at the same rate. Public health and health promotion programmes in particular may take many years to produce tangible results, and applying a discount rate to the benefits of such programmes will reduce their apparent attractiveness compared with programmes that produce rapid benefits of a similar magnitude.

Common practice remains to discount costs and benefits at the same rate, so we follow the same practice in our baseline calculations using a rate of 3%. To be consistent with the approach used in Chapter 4 for measuring the burden of disease, age weights are also included in the baseline calculations.

The recent report of the Commission on Macroeconomics and Health suggested that interventions costing less than three times GDP per capita for each DALY averted represent good value for money and that, if a country could not afford to undertake them all from its own resources, the international community should find ways of supporting them *(23)*. This report's classification of interventions is based on this principle, and defines very cost-effective interventions as those which avert each additional DALY at a cost less than GDP per capita, and cost-effective interventions as those where each DALY averted costs between one and three times GDP per capita.

Finally, cost-effectiveness analyses can be found in the published literature for some of the interventions discussed in this chapter, which does not, however, simply report the published results. The methods used for estimating costs and effectiveness varies considerably across the published studies and their results cannot be compared. Moreover, most provide insufficient information on how they estimated costs to be sure that all possible costs were included and valued appropriately. This report, therefore, re-estimated costs and effects using a standard approach for all interventions, although each study that could be found was evaluated to determine if the parameters it used could be incorporated.

CHOOSING INTERVENTIONS TO REDUCE SPECIFIC RISKS

The results reported in this chapter are important inputs to two types of policy questions. The first is how best to reduce the health burden associated with a specific risk factor, where information on the effectiveness and costs of the alternative interventions is one crucial input. The second is how best to reduce the health burden associated with risk factors in general, where information on the effectiveness and costs of interventions aimed as a variety of risk factors is critical. This section covers the first question, by reviewing the cost-effectiveness of selected interventions aimed at some of the main risk factors described

in Chapter 4. The same organizing format followed in that chapter is followed here. The question of how to decide what combination of those risk factors should be given priority for any given level of resource availability is considered on page 139.

Childhood undernutrition

The strategy of primary health care was adopted by the World Health Assembly in 1977 and outlined further in the 1978 Declaration of Alma-Ata on Health for All *(24)*. The Declaration encouraged governments to strive toward attaining Health for All by ensuring, at a minimum, the following activities: education concerning prevailing health problems, their prevention and control; promotion of food supply and good nutrition; safe water and basic sanitation; maternal and child health care which included family planning; immunization against major infectious diseases; prevention and treatment of locally endemic diseases; appropriate treatment of common diseases and injuries; and provision of essential drugs. Primary health care emphasized programmatic areas rather than diseases, and encouraged community and individual self-reliance and participation, an emphasis on prevention, and a multisectoral approach.

Subsequently, the concept of "selective primary health care" was proposed to allow for the scarcity of resources available to achieve health for all. It involved defining strategies focusing on priority health problems (including infant and child mortality), using interventions that were feasible to implement, of low cost, and with proven efficacy *(25, 26)*. UNICEF's GOBI strategy of 1982 emerged from this. At its foundation were four child health interventions which met the above criteria and which were considered to be synergistic – growth monitoring (G), oral rehydration therapy for diarrhoea (O), the promotion of breastfeeding (B) and childhood immunizations (I). Birth spacing/family planning (F), food supplementation (F) and the promotion of female literacy (F) were added subsequently (GOBI-FFF) *(27)*.

There has been subsequent analysis and discussion of the extent to which the specific interventions can be integrated into primary health care, and whether strategies should be modified in view of new knowledge and changing circumstances. However, concern with ensuring that child health strategies are based on feasible and affordable interventions – that are synergistic and of proven effectiveness – has remained. This chapter builds on that tradition by providing information on the costs and effects of selected interventions targeting key risk factors affecting the health of children. The results not only identify a group of interventions that are very cost-effective, but also illustrate how information on the costs and effectiveness of selected interventions can provide useful insights that can be used to re-assess, from time to time, the need to modify current approaches in view of changing knowledge and circumstances.

The focus is on interventions aimed primarily at the risk factors identified in Chapter 4 rather than all possible child health interventions. We have selected some interventions that can be delivered on a population-wide basis and some that focus on individuals, to illustrate how the two approaches interact. Childhood immunizations have not been included because they do not respond to one of the major risk factors of Chapter 4, and because it is already widely accepted that they are cost-effective *(28)*. The fact that interventions are not included here, therefore, should not be taken to imply that they are not cost-effective.

Childhood undernutrition (and breastfeeding)

Interventions

The childhood interventions were not evaluated in the A subregions where childhood undernutrition is not a major cause of burden.

Complementary feeding. One-time intensive counselling is provided to mothers on the appropriate complementary feeding practices and on the importance of continued breast-feeding. In addition, all infants aged 6 months to 1 year, regardless of nutritional status, are provided with ready-to-mix complementary food, which is collected every two months from a health centre by the carer. The intervention is estimated to shift positively the overall distribution of weight-for-age for children less than one year of age by 0.16 standard deviations (adapted from Caulfield & Huffman) *(29)*. It was then assumed that each cohort of children exposed to this intervention would continue to reap the benefits subsequently because of the knowledge and attitudes retained by the carer.

Complementary feeding with growth monitoring and promotion. All carers are given an initial intensive counselling session on appropriate complementary feeding practices and the importance of continued breastfeeding. Carers are provided with growth charts and, during quarterly visits, the weight of the child is plotted and any deviations from expected weight gain is discussed. Solutions are suggested and targets for weight gain are set. In addition, ready-to-mix complementary food is provided to all children from 6 months to 1 year of age who have been identified to have poor weight gain or are underweight.

Results

The impact of the two types of interventions is identical, but the costs of the more focused approach of complementary feeding with growth monitoring and promotion are considerably lower than those for complementary feeding alone. Complementary feeding by itself is not cost-effective, while complementary feeding with growth monitoring is cost-effective in most regions. It is assumed that the benefits of the intervention in terms of carer's knowledge gained and attitudes changed will persist until the child is five years old. Interactions are considered below.

Iron deficiency

Interventions

Iron fortification. Iron, usually combined with folic acid, is added to the appropriate food vehicle made available to the population as a whole. Cereal flours are the most common food vehicle and are the basis of the analysis, but there is also some experience with introducing iron to other vehicles such as noodles, rice, and various sauces *(30)*. The proportion of the population that consumes the food vehicle in sufficient quantities to absorb sufficient iron varies by region, from 65% to 95%, and this chapter explores the costs and effects in the event that fortification reaches 50%, 80% and 95% of the targeted population. Because of likely problems with absorption, fortification is considered only 50% as efficacious as supplementation in the people who are covered, consistent with the assumptions of Chapter 4.

Iron supplementation. Iron is provided to pregnant women during antenatal visits. The assumed dose follows WHO guidelines, with daily supplementation of 60 mg elemental iron, for six months during pregnancy and three months postpartum *(31)*. Three different levels of coverage are included – 50%, 80% and 95% – and it is assumed that only 67% of these women receive an effective dose because of less than perfect adherence *(32)*. For

the women who currently attend antenatal clinics, only the costs of the iron and the additional time of the visit were included. However, expansion of coverage for iron supplementation purposes beyond current coverage of antenatal visits requires attributing the full cost of the necessary visits to the intervention.

Results

Even though many groups in the population are likely to benefit from iron fortification, only the impact on iron deficiency anaemia in pregnant women (with an impact on maternal health and prenatal mortality) has been included in the analysis. This understates the benefit, but these effects probably account for more than 95% of total deaths averted by fortification. Despite this, supplementation and fortification at 50% coverage are estimated to lead to increases in population health of almost 59 million and 29 million DALYs in turn globally when implemented over a 10-year period.

Supplementation yields greater improvements in population health than fortification, in all subregions with high child mortality (all D and E subregions), and at all levels of coverage. In the other subregions, supplementation has a larger impact on population health than fortification for equivalent levels of coverage. On a global basis, supplementation at 80% would gain just over 9 million DALYs per year compared to doing nothing.

On the other hand, fortification is always less costly than supplementation because it does not require a visit to a provider, and the unit cost of supplementation increases sharply with increasing coverage. This means that the cost-effectiveness of fortification is always lower than the cost-effectiveness of supplementation, regardless of the coverage of fortification. It, then, is the preferred option at low levels of resource availability.

However, in some settings iron fortification is hindered by the absence of ideal food vehicles that are eaten in sufficient quantities and it might be difficult to ensure coverage even as high as 50%. It is also hindered by the absence of ideal iron compounds that would be favorably absorbed, are stable and nonreactive, with little colour, and no taste of their own. Where people's diets are not based around cereal flours or another convenient food vehicle, supplementation is still a cost-effective option. Indeed, in areas with a high prevalence of iron-deficiency anaemia, it is still very cost-effective to spend the higher amounts on supplementation to achieve the greater population benefit. It is less cost-effective to take this option in areas where the burden from iron deficiency anaemia is relatively low, although the cost-effectiveness of switching from fortification to supplementation is between one and three times GDP per capita so does not fall into the band of cost-ineffective interventions.

VITAMIN A DEFICIENCY

Interventions

Vitamin A deficiency is negligible in the European region of WHO, while deaths due to pneumonia and diarrhoea are negligible in AMR-A and WPR-A. The following interventions are not evaluated in those areas.

Vitamin A supplementation. Oral vitamin A supplements are provided to all children under five years of age twice a year at a health centre. The dose is 200 000 i.u. for children from their first birthday. For those less than one year of age, the dose is 50 000–100 000 i.u. Effectiveness of the intervention is adjusted by adherence.

Vitamin A fortification. Fortification of a food staple with vitamin A (in this case assumed to be sugar), whether locally produced or imported or whether for industrial or domestic use, is assured through legislation. The amount of vitamin A required is calculated

based on an estimation of the amount of recommended daily allowance anticipated to be taken in from other sources and the average per capita intake of sugar in different settings. A trend analysis of a number of different fortification programmes in central America shows a relative reduction of about 60% in the prevalence of vitamin A deficiency associated with the introduction of fortification *(33)*. Intervention includes provision of guidelines for quality control of sugar fortification in the mills, regular visits to mills by inspectors, and regular sampling and testing of sugar taken from mills, markets and homes for vitamin A content. Samples from homes are taken opportunistically during mass surveys carried out for other purposes.

Results

As with iron, vitamin A fortification is more cost-effective than supplementation in all regions, because of its lower costs. Supplementation will, however, have a substantially large benefit in terms of population health – approximately twice as high as fortification – although at a higher cost. It is also very cost-effective in its own right. Both remain either cost-effective or very cost-effective in all regions included in the analysis when coverage is increased to the maximum possible level.

ZINC DEFICIENCY

Interventions

Zinc supplementation. During one of the first immunization contacts in infancy, the health worker prescribes zinc gluconate or sulfate (10 mg in solution) as part of a routine. Thereafter, the zinc solution is administered by a carer at home daily to every child until the child reaches five years of age. Effectiveness of the intervention is adjusted by expected adherence for medications needing to be taken daily.

Zinc fortification. The intervention has the same characteristics as for Vitamin A fortification except the food vehicle is wheat, not sugar. Note that in the absence of effectiveness data, the assumption has been made that zinc fortification is half as efficacious as zinc supplementation, consistent with that made for iron fortification.

Results

As with iron and vitamin A, zinc supplementation and fortification both prove to be very cost-effective interventions in all subregions. Fortification is more cost-effective than supplementation and is also slightly more cost-effective than vitamin A supplementation in most regions evaluated. Even though zinc fortification is very cost-effective, the overall impact on population health of this intervention is lower than the gains associated with vitamin A fortification in regions where vitamin A deficiency is a problem. It should, of course, be remembered that no large-scale zinc fortification programme has yet been carried out, so the results are based on the effect on health of assumed increases in zinc intake.

OTHER INDIVIDUAL-BASED INTERVENTIONS FOCUSING ON CHILDREN UNDER FIVE YEARS OF AGE

Interventions

Although not strictly risk-reducing strategies, two ways of reducing the risk of death associated with the risk factors outlined above are considered here.

Oral rehydration therapy. Health workers are trained to use an algorithm for the assessment and management of dehydration caused by diarrhoea in children under five years of age. Children brought to a health facility with watery stools are assessed for signs of

dehydration by a trained health worker. If severely dehydrated, the child is rehydrated in the health facility or referred to a higher-level facility if necessary. Children still able to take in fluids are provided with oral rehydration salts reconstituted in boiled then cooled water at a specified concentration. Advice is given on the frequency of the rehydration and also on danger signals for which the carer should watch. Programme implementation of this intervention has been estimated to achieve a relative reduction in case fatality rate of 36% *(34, 35)*.

Case management of pneumonia. Health workers are trained to assess and manage respiratory distress in children. A child brought to a health facility with a cough is assessed by a trained health worker for presence of rapid breathing and other signs of respiratory distress. Depending on which signs are present, the child is referred to a hospital for intravenous treatment with antibiotics, is prescribed a five-day course of antibiotics with instructions for follow-up, or the carer is provided advice on supportive management and on monitoring the respiratory status of the child. A metaanalysis of several large, community-based trials estimated that the intervention produced a relative reduction of 50% in case-fatality rate *(36)*. This effectiveness estimate was subsequently adjusted for adherence.

Results

The relative magnitude of the effect varies with epidemiology. For example, vitamin A supplementation achieves greater health effects than oral rehydration therapy in some areas (AMR-B, SEAR-B and WPR-B) but in the others the reverse is true. Both oral rehydration therapy and case management of pneumonia achieve substantially greater benefits than zinc fortification and supplementation, despite the zinc interventions being more cost-effective. Both forms of treatment are still very cost-effective in their own right in all subregions.

COMBINED INTERVENTIONS TO REDUCE RISKS IN CHILDREN UNDER FIVE YEARS OF AGE

Most of the childhood interventions considered above prove to be very efficient ways of improving population health. Zinc fortification, under the current assumption of effectiveness is, perhaps, the surprise, being more cost-effective than the other options in all regions. To the extent that the same food vehicles could be used to fortify zinc and iron, the cost-effectiveness of the combined intervention would be even more attractive, making it one of the most attractive options available of any type of intervention. However, zinc fortification by itself, despite its cost-effectiveness, would have a smaller impact on population health than the other interventions discussed in this section except for food supplementation. Moreover, it has yet to be used on the scale assumed for these calculations.

As yet there is little evidence from field studies about the impact of multiple interventions designed to improve the health of children under five years of age. An evaluation study to assess the impact of the integrated management of childhood illness strategy is currently under way (Box 5.2), which should provide evidence in the near future. In the meantime, we have modelled the interactions between the different combinations of interventions relating specifically to children described above (for example, not including iron) taking into account synergies in terms of costs and effects.

Except for the regions where Vitamin A deficiency is not a major cause of burden (EUR-B and EUR-C), the combination of zinc with Vitamin A fortification (or supplementation) with treatment of diarrhoea and pneumonia is the most cost-effective combination of preventive and curative actions, well under the cut-off point for very cost-effective interventions.

This does not imply that other types of interventions are not cost-effective or should be excluded from consideration. It simply illustrates that addition of Vitamin A and zinc interventions to the curative care currently provided routinely in most settings would gain substantial improvements in child health at relatively low cost.

BLOOD PRESSURE AND CHOLESTEROL

Comprehensive approaches to the control of cardiovascular diseases take account of a variety of interrelated risk factors including blood pressure, cholesterol, smoking, body mass index, low levels of physical activity, diet and diabetes. They use a mix of population-wide and individual-based interventions, and countries that have developed comprehensive policies have seen cardiovascular disease mortality fall significantly. In Finland, for example, a comprehensive national strategy that combined prevention, community-based health promotion and access to treatment was associated with a 60% decline in mortality rates from cardiovascular diseases over a 25-year period *(37–39)*.

Cardiovascular disease risk factors are associated with substantial health burdens in all countries, including the poorest countries, which makes it more important than ever to base strategies for their control on interventions that are affordable, feasible, effective and acceptable to communities. This section contributes to this process by reporting on the effectiveness and costs of selected interventions focusing on blood pressure and cholesterol. Box 5.3 reports on an intervention aimed at encouraging increased fruit and vegetable intake, while smoking is considered in a subsequent section.

Population-wide and individual-based interventions are evaluated, alone and in combination. All possible interventions or combinations could not be included here, nor is it possible to analyse all of the different ways of designing the interventions that are included. The information nevertheless shows that certain population-wide interventions that have not yet been widely implemented have the potential to be very cost-effective ways of improving population health and result in substantial health benefits. It also suggests that the combination of selected individual-based interventions with these population-wide interventions would also be cost-effective in most settings.

Box 5.2 Integrated Management of Childhood Illness: interventions that interact

Integrated Management of Childhood Illness (IMCI) is a broad strategy that encourages communities and health workers to see the child as a whole, not just as a single problem or disease. IMCI helps countries use their scarce health resources in efficient ways by combining prevention and treatment of the most common childhood illnesses into simple guidelines and messages. Countries adapt these guidelines to meet their needs and use them to train health workers at all levels, improve supervision, make sure essential drugs are available, and mobilize families and communities in support of child health.

Most of the 10.9 million child deaths in 2000 (99% of which occurred in developing countries) could have been prevented with available, inexpensive interventions that are already available to children in richer countries. These inequities could be reduced if IMCI is implemented at high levels of coverage. Over 80 developing countries have adopted IMCI as part of their national policy to improve child health. The challenge now is to scale up the strategy and to strengthen health systems so that they can deliver IMCI and other child and family services efficiently and effectively.

A multicountry evaluation of IMCI effectiveness, cost and impact is currently under way to obtain information about the barriers to IMCI implementation, the effects the strategy has on health services and communities, how much it costs, and how many lives it can save. The evalua-tion is being conducted in collaboration with Ministries of Health and technical assistance partners in Bangladesh, Brazil, Peru, Uganda, and the United Republic of Tanzania. The early results of the evaluation are already being used to improve the delivery of child health services in developing countries; for example, in the United Republic of Tanzania it has been shown that children in districts implementing IMCI are receiving better care than those in similar districts without IMCI.

Further information is available at: URL: http://www.who.int/child-adolescent-health and http://www.who.int/imci-mce

BLOOD PRESSURE

Interventions

Population wide salt reductions. Two approaches were evaluated. The first involves cooperation between government and the food industry to include appropriate labelling about salt content on products and to ensure a stepwise reduction of salt in commonly consumed processed foods. This could be through multi-stakeholder initiatives such as the development of voluntary codes of conduct *(40)*. The estimated eventual effect would be a 15% reduction in sodium intake with corresponding reductions in regional age-specific and sex-specific mean systolic blood pressure levels *(41)*.

The second approach is based on legislative action to ensure a reduction of salt in processed food with appropriate labelling. It also requires collaboration between multiple stakeholders, with the addition of quality control and enforcement. As a result, costs are higher than the voluntary version, but effects on salt intake are also likely to be higher. An eventual 30% reduction in sodium intakes is assumed *(41)*.

Individual-based hypertension treatment and education. This strategy requires drug treatment; costing of treatment has been based on a standard regimen of 50 mg atenolol (beta-blocker) and 25 mg hydrochlorothiazide (diuretic) per day. Four visits to a health provider for medical check-ups and 1.5 outpatient visits for health education are required each year, with annual renal function, lipid profile, and blood sugar (only in A subregions) tests. Two variations of this intervention were evaluated – treatment for people with systolic blood pressures (SBP) of 160 mmHg and above, and for those with 140 mmHg and above. The intervention is expected to result in a one-third reduction of the difference between starting SBP and 115 mmHg. This reflects the observation that the lower the individual's SBP initially, the lower the typical reduction with treatment.

In subsequent sections, combined risk modification strategies that focus on the individual's absolute risk are analyzed. In addition, as with all the other interventions targeting major risks to ischaemic heart disease and stroke, the benefits of reducing blood pressure, cholesterol, and body mass index are modelled jointly, taking into account the interrelationships in these risks.

Results

In all subregions, population strategies to reduce blood pressure are very cost-effective. Legislation is potentially more cost-effective than voluntary agreements with industry – this effect is due to the assumption that legislation with enforcement will lead to a larger reduction in salt intake in the diet than voluntary agreements – but the trade-off between legislation and voluntary agreements is likely to depend on the national context.

Strategies to reduce blood pressure by treating individuals with a SBP greater than 160 mmHg fall into the most cost-effective category. Lowering the threshold to 140 mmHg implies many more individuals benefit from treatment but at a higher cost, and also increases the number of people suffering side-effects from treatment. The strategy would need to be considered carefully because whether it is cost-effective varies with such factors as epidemiology and costs. It is not cost-effective, for example, in AFR-D and AMR-D, and of borderline cost-effectiveness in AFR-E.

Combinations of individual treatment and population based approaches to reduce salt intake are cost-effective at the 160 mmHg SBP threshold in all settings. However, a focus on blood pressure alone is unlikely to be the most appropriate approach to reducing the

risks associated with cardiovascular disease. To explore this, a strategy to act on multiple risk factors through population and individual treatment-based strategies at the same time is evaluated at the end of this section.

CHOLESTEROL

Interventions

Of the possible interventions, two are evaluated here.

Population-wide health education through mass media. Health education through broadcast and print media is expected to lead to a 2% reduction across the board in total cholesterol levels *(42)*.

Individual-based treatment and education. Two variations are evaluated. The first involves treatment for people with total cholesterol levels above the threshold of 6.2 mmol/l (240 mg/dl) and the second above 5.7 mmol/l (220 mg/dl). Treatment requires the daily intake of 30 mg of lovastatin, four annual visits to a health provider for evaluation, and 1.5 annual outpatient visits for health education sessions. Annual laboratory tests for total cholesterol levels are included in the costs in all regions and for hepatic function in low mortality, high-income areas (A subregions).

Results

In all subregions, population strategies to reduce cholesterol are very cost-effective. The total impact in terms of DALYs gained, however, is relatively small although this is based on evidence from studies with a relatively short period of follow-up. The long-term effect over generations is likely to be greater because overall cultural changes in dietary habits can be self-reinforcing.

Given that statins are now available at very low cost and are rather effective, using statins to reduce cholesterol is very cost-effective in all regions. Total population impacts in terms of DALYs averted are relatively large, though generally slightly smaller than the benefits gained from treating hypertension. The incremental cost-effectiveness of lowering the threshold from 6.2 to 5.7 mmol/l (240 to 220 mg/dl) is not in the very cost-effective category in AMR-D and SEAR-D, and is borderline in AFR-E.

COMBINING INTERVENTIONS TO REDUCE THE RISK OF CARDIOVASCULAR EVENTS

Interventions

Many different combinations are possible – for example, WHO recently convened a meeting to consider the integrated management of cardiovascular diseases by focusing on blood pressure, smoking cessation and diabetes *(43)*. This chapter evaluates different combinations of the interventions considered above for reducing blood pressure and cholesterol levels.

Individual-based treatment and education for systolic blood pressure and cholesterol. The combined costs and effects of individual management of treating systolic blood pressure over 140 mmHg and cholesterol over 6.2 mmol/l (240 mg/dl) have been evaluated for each region. In this intervention, some individuals receive treatment only for blood pressure, some only for cholesterol and some for both depending on measured tests.

Population-wide combination of interventions to reduce hypertension and cholesterol. This combination is based on the population-wide interventions described in the previous two sections – mass media for cholesterol and legislation for salt reduction.

Absolute risk approach. An alternative to focusing on cholesterol or blood pressure levels separately is to evaluate each individual's risk of a cardiovascular event in the next ten years. Several countries have already begun to implement this approach in practical clinical settings. All people with an estimated combined risk of a cardiovascular event over the next decade that exceeds a given threshold are treated for multiple risk factors as well as being provided with health education. Four different thresholds were evaluated – 5%, 15%, 25% and 35%.

Individual risks of a cardiovascular event for this analysis were based on age, sex, body mass index, serum total cholesterol, systolic blood pressure levels and smoking status. Lower cost and more practical implementation strategies for regions with less extensive infrastructure could result in risk assessment solely on the basis of age, sex, smoking status and body mass index, which would reduce the costs of implementing the approach.

People above the threshold level of risk are provided daily with 30 mg of lovastatin, 100 mg acetylsalicylic acid (aspirin), 25 mg thiazides, and 50 mg atenolol, regardless of levels of individual risk factors *(44)*. Annually they will make four visits to a provider for evaluation and 1.5 outpatient visits for health education sessions. In addition to the laboratory tests required to assess the initial level of risk, annual laboratory tests for renal function and lipid profiles are required in all regions with the addition of hepatic function and blood sugar tests in A subregions. The consequences of bleeding associated with the use of aspirin have been accounted for in the estimates of DALYs gained.

Combined population interventions and the absolute risk approach. As a final approach to reducing the burden associated with selected cardiovascular disease risk factors, the impact of a population strategy to reduce salt intake, lower cholesterol and reduce body mass index has been evaluated in combination with treatment based on an absolute risk threshold, for all of the cut-off points evaluated above. This combines most of the major known prevention strategies to reduce the burden of cardiovascular disease, except for smoking cessation which is discussed subsequently.

Results

The absolute risk approach for a theshold of 35% is very cost-effective in all subregions and is always more cost-effective than the alternative of treatment based on observed levels of blood pressure and cholesterol alone. As the threshold is lowered, the health benefits increase but so do the costs – in fact, it gets more and more expensive to obtain each additional unit of health benefit. The exact point at which policy-makers might choose to set the threshold will vary by setting and will take into account many factors in addition to cost-effectiveness, but it is always cost-effective (though not always very cost-effective) to reduce the threshold to 25%. In most subregions, moving to a 5% threshold would be cost-effective even taking into account the increase in side-effects. Overall, the potential to reduce the risk of cardiovascular events through this intervention is very impressive. Population-level effects exceeding a 50% reduction in events are possible.

The assumptions for the impact of the population interventions evaluated here are conservative and do not take into account long-term impacts such as permanent changes in dietary patterns. Combining population-based cholesterol reduction strategies with interventions to reduce salt intake at the population level is always very cost-effective. In addition, a strategy based on the combination of population-wide and individual-based interventions is also cost-effective in all settings. The most attractive strategy among all those evaluated appears to be the combination of salt reduction at a population level through legislation or voluntary agreements with health education through the mass media focus-

ing on blood pressure, cholesterol and body mass, plus the implementation of an absolute risk approach to managing cardiovascular disease risks.

Where resources are very scarce, prime attention would be focused on prevention and promotion, combined with the less intense individual treatment options, for example, treating people whose overall risk of a cardiovascular event over 10 years exceeds 35%. Additional resources would allow consideration of whether the theshold for treatment should be lowered.

This section has focused only on blood pressure and cholesterol, and the addition of interventions to encourage increased physical activity, or to increase fruit and vegetable intake, should also be considered in the development of an overall strategy to deal with cardiovascular disease risks. A critical part of this would be a comprehensive approach to tobacco control. Interventions aimed at that end are discussed below because smoking affects not only cardiovascular diseases but also other important causes of burden.

LOW FRUIT AND VEGETABLE INTAKE

Interventions

Increasing the consumption of fruit and vegetables reduces the risks of ischaemic heart disease, stroke, and colorectal, gastric, lung and oesophageal cancers. A report of a population-based interventions designed specifically to encourage people to increase their consumption of fruit and vegetables is described in Box 5.3.

SEXUAL AND REPRODUCTIVE HEALTH

UNSAFE SEX AND HIV/AIDS

Interventions

Over the last two decades, international agencies, governmental organizations and representatives of civil society have collaborated to develop a range of approaches to respond to the AIDS epidemic. The cornerstone remains the combination of various preventive interventions, community action and participation, and appropriate care and treatment *(56)*. There has been continual reassessment of the role of particular types of interventions

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Box 5.3 Cost-effectiveness of a national nutrition campaign

Although high consumption of fresh fruit and vegetables offers protection against many forms of cancer and coronary heart disease, dietary surveys in Australia indicate that many adults and children do not consume the recommended two servings of fruit and five servings of vegetables a day. The Australian and Victorian burden of disease studies reported that in 1996 approximately 10% of all cancers and 2.8% of the total burden of disease were attributable to insufficient intake of fruit and vegetables.

As part of a larger cost-effectiveness study of cancer control interventions, a national campaign to promote the intake of fruit and was analysed vegetables. The "2 Fruit 'n' 5 Veg" campaigns undertaken in Western Australia and Victoria used multiple strategies, including short, intensive mass media advertising and community-based consumer education through health facilities, food retailers and food service providers. Evaluation before and after the campaign showed that men improved their intake of fruits and vegetables by 11% and women by 6%. Full details of the methods are available from the authors on request.

The results of this analysis show that, while there is considerable uncertainty about the impact of a national campaign, it could avert between 6 and 230 deaths and save between 90 and 3700 DALYs. Campaign costs were estimated to be from just under US$ 1 million to US$ 1.8 million. The cost-effectiveness ratio for such a campaign lies between US$ 280 and US$ 9000 per DALY. If cost offsets (health service costs averted for prevented disease) are included – estimated at US$ 8.2 million – the intervention is "dominant", that is, health benefits are obtained at a net cost saving.

The favourable cost-effectiveness ratio of a fruit and vegetable campaign is similar to that estimated for national campaigns against tobacco use and skin cancer.

Sources: *(45–55)*.

in the overall strategy as new technologies and new information have become available and the epidemic has evolved. This process continues. The information presented in this section is designed to assist by providing information on the effectiveness and costs of selected preventive and curative interventions to reduce the health burden associated with unsafe sex. Although the consequences of unsafe sex can reduce population health in a number of ways, including through increased incidence of a range of sexually transmitted infections and unwanted pregnancies, this section focuses on HIV/AIDS as the leading cause of burden related to unsafe sex.

Many of the interventions that have been evaluated in the published literature, (for example, *(57)*, are really combinations of different types of health actions. For example, the effectiveness and cost data used to evaluate an intervention described as **voluntary counselling and testing (VCT)** were taken from a series of studies which described not only different mixtures of activities but also focused on different groups in the community. Some worked with female sex workers, and some also interacted with their clients. Some involved providing VCT to serodiscordant couples, others to pregnant women and yet others to people with other sexually transmitted infections. Many of these interventions also included health education and condom distribution. The estimates of effectiveness and costs for an intervention described as **outreach peer education programmes for commercial sex workers and their clients** were based on studies of activities that included many of the same components described for VCT above, to the extent that it is difficult to identify from the published literature what were the key components that made the intervention work.

Understanding the contribution of the different components would be very useful in deciding on the appropriate overall strategy. This analysis tries to contribute to this understanding by evaluating a set of individual interventions separately, and then considering their impact when undertaken together. The descriptions used below follow as closely as possible the way the interventions were undertaken in the studies from which effectiveness estimates can be derived.

At the same time, it is recognized that it is not possible to separate totally the impact of the different types of health actions which can be taken to reduce the burden associated with unsafe sexual practices. Encouraging sex workers to use condoms will have an effect on transmission only if clients can also be persuaded to use condoms. The interventions interact and the success of one requires the presence of the other. Similarly, the availability of condoms is a prerequisite for this and other preventive interventions. For this reason the report focuses less on the individual interventions in the discussion of the results, and more on the overall strategy which combines interventions.

In this regard, a separate intervention called **social marketing of condoms** is not evaluated, partly because no study was found which evaluated this activity for the prevention of HIV infections in isolation from other activities, and partly because the availability of condoms and people's willingness to use them are prerequisites for a number of other interventions. For that reason, condom distribution and the encouragement to use them have been incorporated into other interventions as appropriate. There may be various strategies for promoting access to and use of condoms, of which social marketing is only one.

A number of other interventions that are commonly undertaken or advocated have not been evaluated either. They include post-exposure prophylaxis, peer outreach for young people, and free-standing facilities for voluntary counselling and testing. In addition, the interventions that have been evaluated could be organized in various ways. The report has chosen one (or in some cases, several) specific options to enable the calculation of costs and

outcomes, but the results could differ for other possible variations. The purpose of this exercise is not, therefore, to define rigidly the best combination of interventions in each setting. It is to provide valuable information on the effectiveness and costs of selected interventions and to show how this type of information can contribute to the continual reassessment of strategies to fight HIV/AIDS.

Interventions are not evaluated for the regions where injecting drug use plays an important role in transmission, limiting the analysis to the areas where unsafe sex is the dominant concern. EUR-B, EUR-C, WPR-B and the EMR subregions are not included in the discussion. The following interventions are evaluated singly and in combination.

Population-wide mass media using the combination of television, radio and print. This includes television and radio episodes as well as inserts in key newspapers during each year of intervention, with the intervention repeated every year. Development and administration costs to run the programme are included. Effectiveness depends on the coverage of the intervention, which is approximated by the proportion of the population reporting weekly access to any of the three types of media, based on national sample surveys from countries in each subregion *(58)*.

Voluntary counselling and testing (VTC) *(59)* in primary care clinics for anyone who wishes to use the services. Training of health workers is included. Testing is assumed to be based on a rapid test, to increase the proportion of individuals who receive their test results compared with standard assays. The proportion of the population using VCT where it has been made available has varied considerably across regions. In the Rakai study in Uganda *(60)*, approximately one-third of the population requested to be tested when VCT facilities were provided, and this proportion was similar in individuals positive and negative for HIV. Overall, this proportion was approximately twice the overall prevalence level in the population. In the United States, on the other hand, the proportion tested was nearly 45 times the prevalence level, with the probability of being tested among people with known HIV risk factors 2.3 times higher than in other people *(61)*.

Based on this, the assumed coverage of the intervention varied according to the average level of prevalence in each region. For A subregions, it was assumed that the total number tested over a five-year period would equal 45 times the average annual prevalence and that HIV-positive individuals would be 2.3 times as likely to be tested as HIV-negative individuals. For all other regions, the number tested over a five-year period equalled twice the average annual prevalence in each region.

School-based AIDS education targeted at youths aged 10–18 years. School-based education offers the opportunity to prime behaviour rather than seek to change it subsequently. The main effects would be to encourage a delayed age of sexual debut, a higher rate of condom use than in previous generations and a lower number of sex partners *(62)*. A scenario was evaluated where HIV education was provided during regular lessons to all enrolled students. Selected teachers are trained at each school and three different levels of geographical coverage were examined: 50%, 80% and 95% *(63)*.

Interventions for sex workers. Two versions were evaluated. The first involves initial training of selected sex workers so that they are then equipped to interact with their peers. Initial training is undertaken by social workers. In addition to outreach by peers, condoms are made available *(64)*. The second variation builds referral of sex workers for testing and possible treatment of sexually transmitted infections on top of the peer education and condom distribution *(65)*. Effectiveness estimates for the first version utilized results from Ngugi et al. *(64)* and Morisky et al. *(66)* among others; for the second, expanded version Njagi et al. *(67)* and Steen et al. *(68)* served as sources.

Peer outreach for men who have sex with men. Similar to the intervention for sex workers, this involves initial training of selected men to equip them to interact with their peers. This is only evaluated for A subregions, where men who have sex with men are an important cause of transmission and there is reasonable information on behaviours. Initial training is undertaken by social workers. In addition to outreach by peers, condoms are made available. Effectiveness estimates are based on Kahn et al. *(69)*, Mota et al. *(70)* and Haque et al. *(71)*.

Treatment of sexually transmitted infections (STI). The intervention evaluated here is provided in primary care facilities, available to anyone who requests it. Treatment involves not just the visits to a provider and drugs, but some counselling, advice on protection and condom distribution if requested. The mode of diagnosing these infections differs in developing and industrialized countries. Few tests are undertaken in C, D, and E subregions, and symptoms and signs are treated syndromically. In other regions, tests are usually conducted to identify the form of infection. This intervention was evaluated at two or three coverage levels depending on the region: current coverage levels, coverage at the level observed for antenatal care if antenatal care coverage exceeds current STI treatment coverage, and at 95% coverage. It is assumed that the current access to treatment is higher than the actual number treated (i.e., that not all patients with access will seek treatment), and that the same ratio of treatment-seeking to overall access would apply in the expanded coverage scenarios.

Maternal to Child Transmission (MTCT). Women seeking antenatal care are provided with information on the benefit and risks of using nevirapine for the prophylaxis of infection in their infant and are offered pre-test counselling. Women consenting for HIV-1 testing are also offered individual post-test counselling. HIV-positive women who accept prophylaxis are provided with a single dose of nevirapine for use at the onset of labour. If delivery is in a health care facility, a dose of nevirapine is given to the child, based on its weight. Where delivery does not take place in a health facility, the mother is requested to return to the antenatal clinic within 72 hours of delivery to be given a dose of nevirapine. Costs are based on each stage, and effectiveness takes into account not just the efficacy of the intervention but variations in likely acceptance and adherence across settings.[7] In A subregions, the costs include treatment with zidovudine, caesarean section delivery and infant food formulas.

Antiretroviral therapy (ARV) has also been evaluated. Although it is not an intervention designed to reduce the risks associated with unsafe sex behaviours, its role in poor countries is the source of much debate and discussion. Accurate estimates of potential coverage cannot be known at this early stage of scaling-up antiretroviral use, so it was assumed that health systems should be able to reach eventually the same proportion of the population with ARVs as they currently reach with antenatal care services.

Four different ARV interventions for people identified to have clinical AIDS are defined along two dimensions: (a) standard treatment vs standard treatment with more intensive monitoring of medication; (b) use of first-line drugs alone vs first- and second-line drugs where the latter are clinically necessary. The combinations range from standard treatment without second-line drugs to treatment with intensive monitoring and the option of second-line drugs. Standard treatment without second-line drugs may be undesirable for many reasons, but at the other extreme, the intensive monitoring option evaluated here incorporates more frequent monitoring than might be necessary or possible in some settings. The exact strategy chosen is likely to lie somewhere between the two extremes.

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[7] Based on the information provided by the HIV/AIDS Department of WHO.

These examples explore how the intensity of monitoring would influence adherence, health effects and costs; and how the choice of drugs would influence both outcomes and costs. The outcomes of treatment are modelled in terms of survivorship curves in cohorts of treated patients which depend on the particular strategy that is used. The possibility that the use of second-line drugs could delay the onset of drug resistance has not been incorporated, so the results might understate the true benefits of their use.

For the standard ARV option, monthly visits to a health provider were included in the costing. The intensive monitoring option assumed weekly contact. Levels of adherence will increase with the intensity of monitoring, and standard treatment is assumed to be half as effective as treatment with intensive monitoring as a consequence of lower adherence.

Where both first-line and second-line drugs are available, it is assumed that 30% of patients will require the second-line drugs and will incur additional costs of monitoring. Patients treated in these settings will face survivorship probabilities similar to those in patients treated in industrialized countries, conditional on adherence. Where only first-line drugs are available, we assume that the 30% of patients who would require, but would not receive, second-line drugs would face the same mortality rates as untreated people *(72–74)*.

Following Stover et al. *(57)*, we do not include the impact of ARVs on new infections because little empirical evidence is available on the impact of treatment and care on incidence.

Intervention combinations. The costs and effects at the population level of combining all of the above interventions in different ways were also estimated. This must be the basis of any realistic strategy for reducing the risks of unsafe sex. The impact on population health of using the interventions was evaluated using the GOALS model *(75)*.

Results

These interventions improve population health (i.e. result in gains in DALYs) by reducing the incidence of HIV, which subsequently reduces mortality and morbidity. The exception is treatment with ARVs which reduces morbidity and mortality directly in those who are treated successfully. All the preventive interventions individually have a substantial impact on population health in the high mortality subregions. This is despite the fact that the assumptions of effectiveness used here are conservative. For example, the fact that condoms prevent STIs and unwanted pregnancies has not been included in the estimate of benefit (although the former is used to assess the impact of condoms on HIV transmission).

Care needs to be taken when considering which specific intervention aimed at reducing the risks associated with unsafe sex practices would achieve the greater impact in different settings. This is partly because many of the interventions cannot be effective unless other interventions exist, as discussed earlier. In addition, some of the effectiveness figures have had to be derived from studies undertaken in one region and applied to very different settings. This can be defended less easily for interventions requiring behavioural changes such as these, where effectiveness might change according to many factors such as social attitudes towards HIV. However, the treatment of STIs has a higher impact on population health than the other preventive interventions in all except the A subregions where peer outreach for men who have sex with men also has a very substantial impact. Interventions to prevent MTCT and VCT have the lowest impacts on population health overall.

This does not necessarily mean they are cost-ineffective. There is very little difference between the preventive interventions in terms of their cost-effectiveness ratios in most settings, with peer outreach to commercial sex workers, the treatment of STIs, and mass

media being very cost-effective in all settings. The cost-effectiveness of interventions for men who have sex with men is of a similar order of magnitude in the regions where they were evaluated. School-based health education was only slightly less cost-effective. MTCT and the version of VCT considered here were less cost-effective than the other preventive interventions, but remained in the most cost-effective category in areas of high HIV prevalence when considered by themselves. Not surprisingly, VCT was less cost-effective in areas of low HIV prevalence.

When the interactions between the preventive interventions are taken into account, the combination of peer outreach to commercial sex workers, treatment of STIs, mass media, school-based health education and interventions to prevent MTCT would be cost-effective in all settings. This supports the current approach of developing preventive strategies based on a culturally acceptable combination of these interventions.

Offering ARVs to people with clinical AIDS gains a substantial health benefit at the population level although the gain is lower than for the preventive interventions. The ways in which ARVs can be made widely available in developing countries are likely to evolve with increasing experience with their use, and it is not suggested that the modes of delivery evaluated here would be the fixed template for action. For example, early indications are that adherence to treatment might be increased by inclusion of family and community members to create a supportive environment and to help monitor ARV uptake (rather than basing this on skilled health care workers alone), but this could not be evaluated for the current exercise.

The information provided here is a useful input for the continued development and assessment of alternative strategies. It shows how standard treatment with ARVs would cost less than treatment schemes with more intensive monitoring, and how the use of second-line drugs increases costs. It also shows that the increase in costs also results in large improvements in population health. The conclusion from this analysis is that at least one of the versions of ARV considered here proved to be cost-effective in all subregions where it was evaluated, and allocating additional resources to the provision of more intensive monitoring would be cost-effective if the expected gains in adherence can be achieved.

There are many reasons why the pure health effects of treatment calculated in this way might understate the social benefits. For example, the availability of treatment might encourage people to present voluntarily for counselling and testing. This is one of the most important factors to overcome denial, stigma and discrimination, which are among the main barriers to effective and scaled-up prevention interventions. It would also allow key workers such as those in the medical and education sectors to report more regularly for work, thereby alleviating severe personnel shortages in those sectors in many countries. In addition, the costs of the drugs currently used for first- and second-line therapy are likely to fall over time. These issues reinforce the results of the cost-effectiveness analysis that antiretrovirals have an important role to play when combined with preventive strategies.

ADDICTIVE SUBSTANCES

SMOKING

Interventions

In most countries some form of government action, including taxes and legislation, has been enacted to control tobacco consumption. Countries that have adopted comprehensive tobacco control programmes involving a mix of interventions including a ban on tobacco advertising, strong warnings on packages, controls on the use of tobacco in indoor

locations, high taxes on tobacco products, and health education and smoking cessation programmes have had considerable success *(76)*. Governments interested in choosing the best mix of interventions for their circumstances will focus on the cultural relevance of interventions, their resulting effects on population health, and costs.

Taxation. Tobacco taxes are generally established and collected by ministries other than the Ministry of Health, and in federal systems (such as the United States) they may be collected at more than one level of government (federal, state, county or city). The most common form of tobacco taxation is excise taxes on cigarettes.

Taxation increases the price to the consumer of tobacco products, leading to a decrease in consumption. At the same time, government tax revenues increase. Sometimes a portion of revenues from tobacco taxes is allocated to the health sector to promote health and discourage smoking behaviors. This in turn can help to make other types of tobacco control efforts both more effective and self-financing. This is particularly important to developing countries where resources to finance new public health initiatives are often very limited.

The effect of price changes on consumption is estimated from information about price elasticities of demand for tobacco products (the percentage change in consumption resulting from a 1% price increase). For every 10% real rise in price due to tobacco taxes, tobacco consumption generally falls by between 2% and 10% *(77)*. Studies suggest that the decrease is relatively larger for young smokers, for smokers with low incomes, and possibly for women. Regional price elasticities were estimated from a regression analysis of the relationship between the price elasticities observed in countries where studies had been undertaken and GDP per capita (in international dollars), with adjustments for differences in the age and sex structure of smokers.

Currently taxes on tobacco products account for approximately 44% of the final retail price of tobacco products, which translates to a 79% mark-up on the pre-tax price. This is a global average based on estimated regional data *(78)*. In the region with the highest rate of taxation, almost 75% of the final retail price consists of taxes (a mark-up on the pre-tax price of approximately 300%). Accordingly, this analysis evaluates three levels of taxation – the current average level (a 79% mark-up), the current maximum (a mark-up of 300%) and double the current maximum (a mark-up of 600% translating to a situation where taxes account for 89% of the final retail price).[8]

Since a majority of countries employ some combination of specific excise tax (based on quantity) and ad valorem taxes (based on value), a 50–50 split between the two forms is assumed; also, that the specific tax is not changed after the first year, so the real value of the price increase declines with inflation over time. In the last scenario (600% mark-up), it is not possible to know the price elasticity of demand because such rates of tax have been implemented in a few countries, so the elasticities observed at the current level of taxation are assumed to apply also at the higher rate.

Clean indoor air laws in public places, through legislation and enforcement. Laws banning smoking in indoor places were initially enacted as measures of fire prevention or as a means of ensuring food hygiene. Over time, legislation has increasingly acknowledged the strong evidence about the harmful effect of passive smoking, more commonly referred to as second-hand tobacco smoke.

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[8] Because of the oligopolistic structure of the tobacco industry in most countries, price changes of tobacco products may at least match or most likely exceed the tax increase. To avoid the overestimation of the effectiveness of interventions, it is assumed that tax incidence is entirely borne by the consumers. It is also assumed that smuggling increases proportionally to the price changes.

Laws that control smoking in public places can protect non-smokers from the danger of passive smoking, but also encourage smokers to quit or reduce tobacco consumption *(79)*. Clean air laws that are strong and comprehensive can lead to a significant reduction in tobacco consumption. In addition, the posting of signs to indicate smoking and non-smoking areas tends to help prevent violations of the law.

Comprehensive bans on advertising of tobacco products through legislation. In countries where tobacco advertising is permitted, tobacco companies make advertising and promotion their single largest item of expenditure – often exceeding the amount spent on the purchase of the raw material, tobacco leaf. Large sums of money are also spent sponsoring sports and cultural events. This form of advertising generally associates tobacco with healthy and pleasurable activities and reaches wide audiences, many of them children and youth.

One of the principal arguments for enacting a ban on tobacco advertising is that it keeps young people free of pressures to commence smoking. Legislation to ban comprehensively tobacco advertising prohibits tobacco advertising in print, broadcasting, other mass media and billboards and at the point-of-purchase *(80)*. It also includes a ban on the tobacco industry's sponsorship of sports and other cultural events. A total ban on tobacco advertising also outlaws the distribution of free tobacco product samples as well as the distribution of items displaying tobacco company logos or trademarks such as T-shirts. This type of comprehensive intervention, evaluated here, can reduce tobacco consumption, while a more limited advertising ban has little or no effect *(81)*. Consequently, Australia, Canada, Finland, New Zealand, South Africa, Sweden and Thailand, to name a few, have enacted legal bans on tobacco advertising and promotion.

Information dissemination through health warning labels, counter-advertising, and various consumer information packages. Even in the most developed countries, the risks of tobacco use and the benefits of quitting are not fully appreciated by all segments of the population. Public health advocates argue that large numbers of individuals are not equipped to make fully informed decisions about their health particularly in relation to addictive substances. Accordingly, efforts are needed on the part of the government, media and the health sector to ensure that constant and continual anti-smoking messages are brought to the attention of the public, particularly young people in the regions where baseline levels of awareness are low.

The dissemination of health information often involves one or more of the following: (1) the provision of health education to the general public on the dangers of smoking and how to quit; (2) health education about the risks of tobacco use in schools; and (3) specific education for high-risk individuals. Information dissemination is also often referred to in the literature as health promotion or counter-advertising. Many different forms of information dissemination exist including: media advocacy, paid media advertising, community-based health promotion, school-based health education, and the issuance of noticeable health warning labels on tobacco products and tobacco advertisements. Experience with innovative graphic health warning labels such as those found in Brazil or Canada is as yet too limited to allow its inclusion, although early reports show that they are effective at discouraging smoking.

Here we evaluate an information dissemination package which has been shown to be effective to reduce tobacco consumption *(82)* and consists of: (1) special health information interventions (including issuance of health warning labels, mass media counter-advertising/anti-smoking campaigns, and public debates about anti-smoking legislation); and (2)

health information shocks that capture various forms of anti-smoking publicity, including health reports published by large institutions (specifically, the 1964 US Surgeon General's Report and Reports from the American Cancer Society) as well as professional health publications that associate smoking with mortality.

Nicotine replacement therapy (NRT) targeted at all current smokers aged 20–60 years. Nicotine dependence is a critical barrier to successful smoking cessation. As a result, policy interventions to control smoking often aim to strengthen a smoker's motivation to quit (for example, increased health education, price policies and smoke-free policies) as well as reduce dependence-type barriers that stand in the way of quitting (for example, through pharmacological and behavioural treatments).

NRT includes pharmacological aids used to help smokers in their quest to stop smoking. NRT includes transdermal patches (commonly referred to as nicotine patches), nicotine chewing gum, nicotine nasal sprays, lozenges, aerosol inhalers and some classes of antidepressants, including biuproprion. Brief advice from a health provider coupled with NRT has been associated with sustained levels of smoking cessation in 6% of all smokers seeking to quit. This is sizably larger than the 1–2% per year who quit without any advice *(76)*.

To achieve successful and large-scale cessation rates, the introduction of NRT into a society is probably not sufficient by itself. When deciding to introduce NRT into a country's tobacco control policy, policy-makers need to ensure that health professionals (including doctors, nurses and pharmacists) have appropriate training so that they are confident and capable of providing advice and treatment to tobacco-dependent patients. Such costs were also included for the evaluation of the NRT intervention.

Results

The benefits of anti-smoking interventions for population health (in terms of DALYs) are estimated through the impact of reduced smoking on the incidence of cardiovascular disease, respiratory disease, and various forms of cancer. The interventions, not surprisingly, have a larger impact on population health in regions with a high prevalence of tobacco use, especially those in the second or third stage of the tobacco epidemic (for example, AMR-B, AMR-D, EUR-B, EUR-C, SEAR-B, SEAR-D and WPR-B).[9] Their cost-effectiveness also varies across regions, not only because of variations in exposure to tobacco but also differences in the efficiency of the tax collection system, the degree of anti-tobacco sentiment, and the amount of smuggling.

If only one intervention can be chosen, taxation is the intervention of choice in all regions. Not only does it have the greatest impact on population health, but it is also the most cost-effective option. Taxation also raises revenue for governments. For D and E subregions where price elasticities are generally high, taxation by itself could reduce tobacco consumption significantly. Higher rates of taxation achieve greater improvements in population health and are more cost-effective than lower rates. On purely health grounds, the higher the rate of taxation, the better.[10]

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[9] The second stage of the tobacco epidemic is characterized by rapidly increasing male smoking prevalence and gradually increasing female prevalence. In the third stage, male smoking prevalence reaches its peak and starts to decrease while female prevalence continues to increase *(76)*. The measure of tobacco exposure used here is the smoking impact ratio (SIR) defined in Chapter 4, and the effectiveness of each intervention was assessed by the changes of SIR as a function of the past tobacco consumption.

[10] It should be remembered that it is not possible to be certain how such levels would affect demand for and supply of tobacco products, although there are a few current examples of taxes involving a mark-up of around 600% on the pre-tax price. It should be also noted that the appropriate size of tax depends on various social factors.

To achieve even greater improvements in population health, the combination of taxation, comprehensive bans on advertising, and information dissemination activities would be affordable and cost-effective in the majority of subregions. Adding restrictions of smoking in public places increases the costs, but also gains even greater improvements in population health and is still very cost- effective in A, B and C subregions.

NRT by itself is not in the most cost-effective band of interventions, but does not fall outside the cut-off point of three times GDP per capita in many regions. When added to the other interventions as part of a comprehensive package, it certainly increases the costs of the package, but improves effectiveness as well. Although the additional cost of adding NRT to anti-smoking activities would be considerable, the additional expense would be justified on purely cost-effectiveness grounds in A, B and C subregions (with the exception of WPR-B).

Environmental risks

Unsafe water, sanitation, and hygiene
Interventions

Millennium development goals. The first intervention relates to the costs and effects of reaching the millennium development goal of halving the number of people with no access to safe water, giving preference to those who already have improved sanitation. To accomplish this, the choice of technology depends on a number of environmental factors and the cost, but the possibilities include public stand posts, bore holes, protected springs or wells, and collected rainwater. This does not mean that the new source of water is totally safe, but that some measures are taken to protect it from contamination.

A variation of this strategy is also considered: to halve the number of people without access to improved water *and* basic sanitation, using the same technologies for improving water described above. Low-cost technologies for provision of basic sanitation do not involve treatment of wastewater, and include septic tanks, simple pit latrines, and ventilated improved pit-latrines.

The cost-effectiveness of improving the current situation was evaluated. The current state of water and sanitation infrastructure in the different regions, determined largely by social and economic development in the past, was taken as the starting point from which interventions should be evaluated, just as the current state of education of the population helped to define the starting point for all interventions. For that reason it is not possible to evaluate interventions routinely at 50%, 80% and 95% coverage – coverage is already above that level in many settings. Accordingly, the costs and effectiveness of moving from the current level to 98% were routinely evaluated.

Disinfection at point of use. This involves using chlorine and safe storage vessels for people without current access to improved drinking sources. It also includes limited hygiene education. As opposed to the other interventions in this section, disinfection at point of use can be considered strictly as a health action – it is designed purely to improve health and is usually undertaken by the health sector.

Improved water supply and sanitation, low technologies. This provides the same type of water supply and basic sanitation improvements as described for the millennium development goals above but at a higher level of coverage.

Improved water supply and sanitation, with disinfection at point of use. This strategy adds disinfection at point of use to the low-technology strategy described above.

Improved water supply and sanitation, high technologies. The costs and effectiveness of using high technologies are also evaluated at the maximum possible level of coverage (98%). This involves provision of piped water to houses, with treatment to remove pathogens, quality monitoring and pollution control as well as sewage connection with partial treatment of wastewater.

Results

The interventions were not evaluated in EUR-A and AMR-A where virtually all people currently have access to safe water and basic sanitation. In the other areas, the main outcome evaluated was the reduction in the incidence and deaths from diarrhoeal disease. If improved water supply and basic sanitation were extended to everyone, 1.8 billion cases of diarrhoea (a 17% reduction of the current number of cases) would be prevented annually. If universal piped and regulated water supply was achieved, 7.6 billion cases of diarrhoea (69.5% reduction) would be prevented annually.

The millennium declaration goals specify access to safe drinking-water ("to halve, by the year 2015, the proportion of people who are unable to reach or to afford safe drinking-water"). This strategy would be the least costly to implement in each region, at a global cost of approximately I\$ 37.5 billion over 10 years. The gain is estimated to be approximately 30 million DALYs worldwide. Achieving universal access (evaluated at 98% coverage) of improved water supply and basic sanitation plus disinfection at point of use would result in an additional 553 million DALYs gained though at an additional cost of I\$ 449 billion. Each unit of additional health gains would cost of more than three times GDP per capita in some subregions.

The intervention which is consistently the most cost-effective across regions and would be classified as very cost-effective in all areas where it was evaluated was the provision of disinfection capacity at point of use. On purely cost-effectiveness grounds it would be the first choice where resources are scarce. Adding basic low technology water and sanitation to this option would also be either very cost-effective or cost-effective in most settings. It is likely that interventions targeting key behaviours such as improving hand washing practices would also provide considerable health benefits and prove to be cost-effective. As yet, moving to the ideal of piped water supply and sewage could not be considered a cost-effective means of improving health in poor areas of the world.

However, the principal driver for improvements to water supplies, apart from disinfection at point of use, is not health but economic development and convenience. These benefits may be tangible (time saved) or intangible (convenience, well-being). For example, Table 5.2 suggests that there would be a substantial benefits in terms of convenience involved in providing the interventions in this group in AFR-D and EMR-D. This might well be reflected in gains in economic output.

The great majority of costs also falls outside the health sector and is shared by diverse groups (gov-

Table 5.2 Time gains from improved access to water and sanitation in subregions AFR-D and EMR-D[a]

Potential outcomes achieved by:	Time gains by subregions (hours per year per capita)	
	AFR-D	EMR-D
halving the population without access to safe water	5.9	2.0
halving the population without access to safe water and by improving sanitation	44.1	19.4
disinfecting at point of use for water	88.2	38.8
improving sanitation (low technologies) + disinfection	88.2	38.8
increasing piped water systems and sewer connections	144.6	96.0

[a] See the List of Member States by WHO Region and mortality stratum for an explanation of subregions.

ernment, private sector, donors, nongovernmental organizations, communities and consumers). While it is possible to capture all the costs in a cost-effectiveness ratio, only health benefits have been included in these calculations. This certainly understates the benefits to society of improving water and sanitation. In addition, the cost-effectiveness ratios estimated for these interventions are based on conservative estimates of the health gains. Some possible longer-term benefits of preventing cases of diarrhoea, such as improved nutritional status, are not captured fully in an analysis focusing on the acute effects. Moreover, there will be benefits in different settings in terms of other health outcomes such as trachoma, schistosomiasis, and infectious hepatitis. The results for water and sanitation need to be interpreted in this light.

The burden of disease associated with unsafe water supply, sanitation and hygiene is concentrated in children in developing countries. Accordingly, emphasis should be placed on interventions likely to yield accelerated and affordable health gains in this group. Disinfection at point of use is an attractive option. The intervention has a large health impact in regions of high child mortality and the costs are relatively low. A policy shift to encourage better household water quality management using this technology (and probably better hygiene, although it was not analysed here), placing greater emphasis on achieving health gains associated with drinking-water access at the household level, would appear to be the most cost-effective water-related health intervention in many developing countries. This would complement the continuing expansion of coverage and upgrading of piped water and sewage services, which is naturally a long-term aim of most developing nations.

OCCUPATIONAL RISK FACTORS

Occupational risks have not been fully evaluated, but some information about intervention to reduce the burden associated with motor vehicle accidents is included in Box 5.4 and Box 5.5 summarizes the effectiveness and costs of various interventions to reduce the incidence of back pain associated with occupational ergonomic stressors. In that case, calculations are presented for three different types of settings, two with low mortality and one with high mortality (AMR-A, EUR-B, and SEAR-D).

Box 5.4 Reducing injuries from motor vehicle accidents

An estimated 1.2 million people died from road traffic injuries in 1998, raising such injuries to the rank of tenth leading cause of death worldwide. By 2020, they are expected to be the second leading cause of death. Interventions to reduce road traffic injuries are increasingly commonplace in industrialized countries, but little evidence is available from developing countries. WHO has recently commissioned a review of published and unpublished data sources and has critically examined the economic impact of interventions to prevent road traffic injuries and their potential applicability to developing countries.

The limited number of economic evaluations of interventions have used cost-benefit analysis where the outcome has been the assumed economic value of extending life and preventing accidents. One study of motorcycle helmet laws in the United States suggested that reduced costs of treating injuries exceeded the costs of introducing and policing the law by US$ 22.7 million. Motor vehicle inspection laws and the mandatory use of headlamps in daytime also reduced the subsequent costs of treating injuries, and the savings could also be substantially higher than the costs of introducing and administering the laws.

The installation of seat belts showed a net reduction in the costs of treatment by US$ 162 per vehicle, while seat belt regulations were found to be very cost-effective – costing just US$ 1406 per life saved. Although several economic evaluations of speed limits have been carried out, mostly in the United States, there is no clear consensus about the relative economic benefits of different speed limits. Speed bumps, deviations and other devices to calm traffic are used in many countries, but there have been very few comprehensive economic evaluations.

Only one of the studies reviewed focused on the developing world. As 90% of the world's population live in low and middle income countries, where the rates of road traffic injuries and fatalities are highest, it is essential for this major research gap in health information to be filled.

Sources: *(83–89).*

Health practices

Unsafe health care injections

Interventions

Decreased reuse of injection equipment without sterilization. This consists of the provision of new, single use injection equipment. This intervention included safe collection and management of sharps waste.

Decreased unnecessary use of injections. This consists of interactive, patient–provider group discussions.

The impact of these interventions singly and combined was assessed in terms of their potential impact on the incidence of HIV, hepatitis B and hepatitis C. Start-up activities
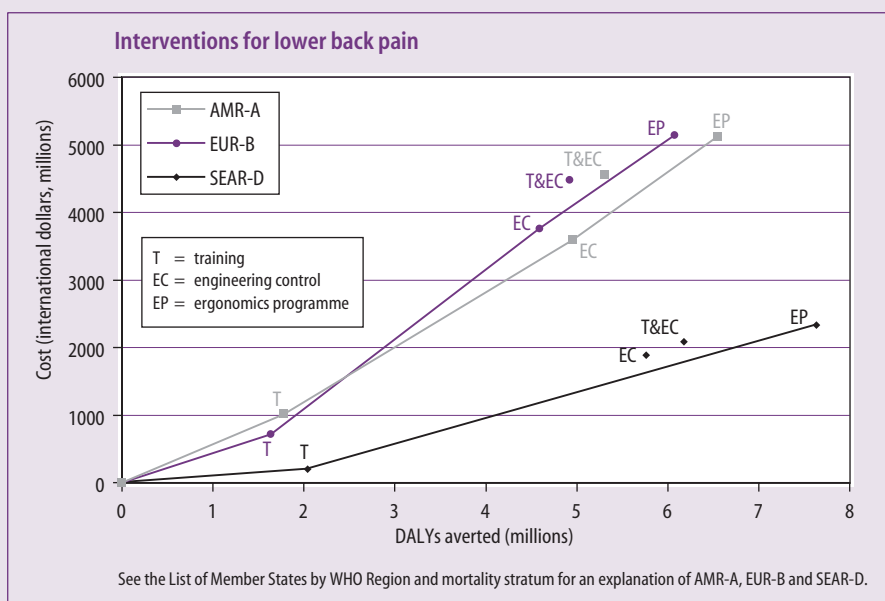

Box 5.5 Cost-effectiveness of interventions to reduce occupational back pain

The problem of back pain related to ergonomic stressors at work is widespread in highly industrialized and developing countries alike. Despite its prevalence and the toll it exacts from workers and their families with the concomitant economic losses, cost-effective interventions are available. Interventions for the prevention of back pain fall into three major categories: training of workers to raise their awareness of risks and improve their handling of hazardous jobs; engineering control, that is, physical measures that control exposure to the hazard, including equipment that assists with lifting, pushing and pulling; and a full ergonomics programme that includes both of these interventions together with further implementation procedures related to workplace organization and design.

Although there is considerable scientific uncertainty about the exact level of effectiveness of interventions on occupational ergonomic stressors, estimates obtained from several observational studies demonstrate that the largest improvement in population health – a 74% reduction in back-pain incidence – would be obtained from the full ergonomics programme. Lower benefits at the population level would be achieved by the other interventions: a 60% reduction by engineering control and training together, a 56% reduction by engineering control alone, and a 20% reduction by training alone.

The total costs of the worker training intervention are significantly lower than those of the full ergonomics programme. In the three subregions for which estimates are available (AMR-A, EUR-B

and SEAR-D), training is the most cost-effective option. It should be the first choice where resources are scarce. The costs of training are largely related to labour, the costs of engineering control are primarily capital expenditure, and the costs of a full ergonomics programme are equally related to both. As wage costs differ widely, the total costs of the interventions vary substantially across the subregions. Nevertheless, analysis suggests that full ergonomics programmes are cost-effective in the three subregions for their health effects alone, without allowing for the possible increase in productivity brought about by the interventions.

Interventions for lower back pain

Legend:
- AMR-A
- EUR-B
- SEAR-D

T = training
EC = engineering control
EP = ergonomics programme

y-axis: Cost (international dollars, millions)
x-axis: DALYs averted (millions)

See the List of Member States by WHO Region and mortality stratum for an explanation of AMR-A, EUR-B and SEAR-D.

include a national planning workshop, the development and production of information, education and communication material, a workshop for the training of the trainers, the training of the procurement officer, and district planning workshops. The post-start-up activities included the supply of injection equipment, annual national follow-up work-shops, interactional group discussions between patients and health care providers, and annual monitoring surveys.

Results

These interventions were not evaluated in the low mortality subregions where the bur-den from unsafe injections is not significant (all A subregions). In the other mortality strata, reducing unnecessary use of injections will have a lower total impact on population health than reducing reuse of injection equipment without sterilization. The effect of doing both at the same time is less than additive, although doing both together does improve population health to a greater extent than doing simply one.

In approximately half the subregions (AMR-B, AMR-D, EUR-B and EUR-C), reducing reuse is also the most cost-effective option and it would be done as the first choice in the presence of severe resource constraints. However, in the other subregions (AFR-D, AFR-E, EMR-D, SEAR-B, SEAR-D and WPR-B), behavioural interventions to reduce overuse are more cost-effective than interventions to reduce reuse that require large quantities of injec-tion equipment. They would be done first if resources were scarce. In the event of additional resources being available, the combined intervention would be undertaken. In all cases, moving from the most cost-effective option to the combination has a cost-effectiveness ratio well below the cut-off point of three times GDP per capita.

COMBINING RISK REDUCTION STRATEGIES

The previous section reviewed the effectiveness, costs and cost-effectiveness of a series of interventions aimed at reducing specific risks to health. That analysis allows decision-makers with an interest in reducing the burden related to a specific cause – for example, cardiovascular disease or child undernutrition – to assess what types of interventions would be cost-effective in that area for the resources that are available. This section takes the broader perspective of a government as the steward of the entire health system. As argued earlier, one of the intrinsic goals of a health system is to improve population health, and information about how best to achieve this for the available resources is of vital importance. This requires not only deciding which combinations of interventions are cost-effective ways of reducing the risks associated with unsafe sex, for example, but also deciding which of the myriad of risks to health that could be targeted should be given priority.

The information considered in the previous section is used again to illustrate how cost-effectiveness analysis can make an important contribution to this debate. Figures 5.2 and 5.3 report the results for interventions considered in the previous section, for two of the 14 subregions, AFR-D and AMR-B.[11] Interventions that are both more costly and less effec-tive than alternative ways of achieving the same goal (for example, reducing the impact of unsafe sex) are not shown on the graphs so that the more cost-effective interventions can be identified more easily. That is why most of the interventions that are shown appear to be cost-effective. (The key to the interventions is found in Table 5.3.) The vertical axis depicts

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[11] Full results for all interventions in all regions are found on the WHO web site: www.who.int/evidence

Figure 5.2. Cost and effects of selected interventions in subregion AFR-D

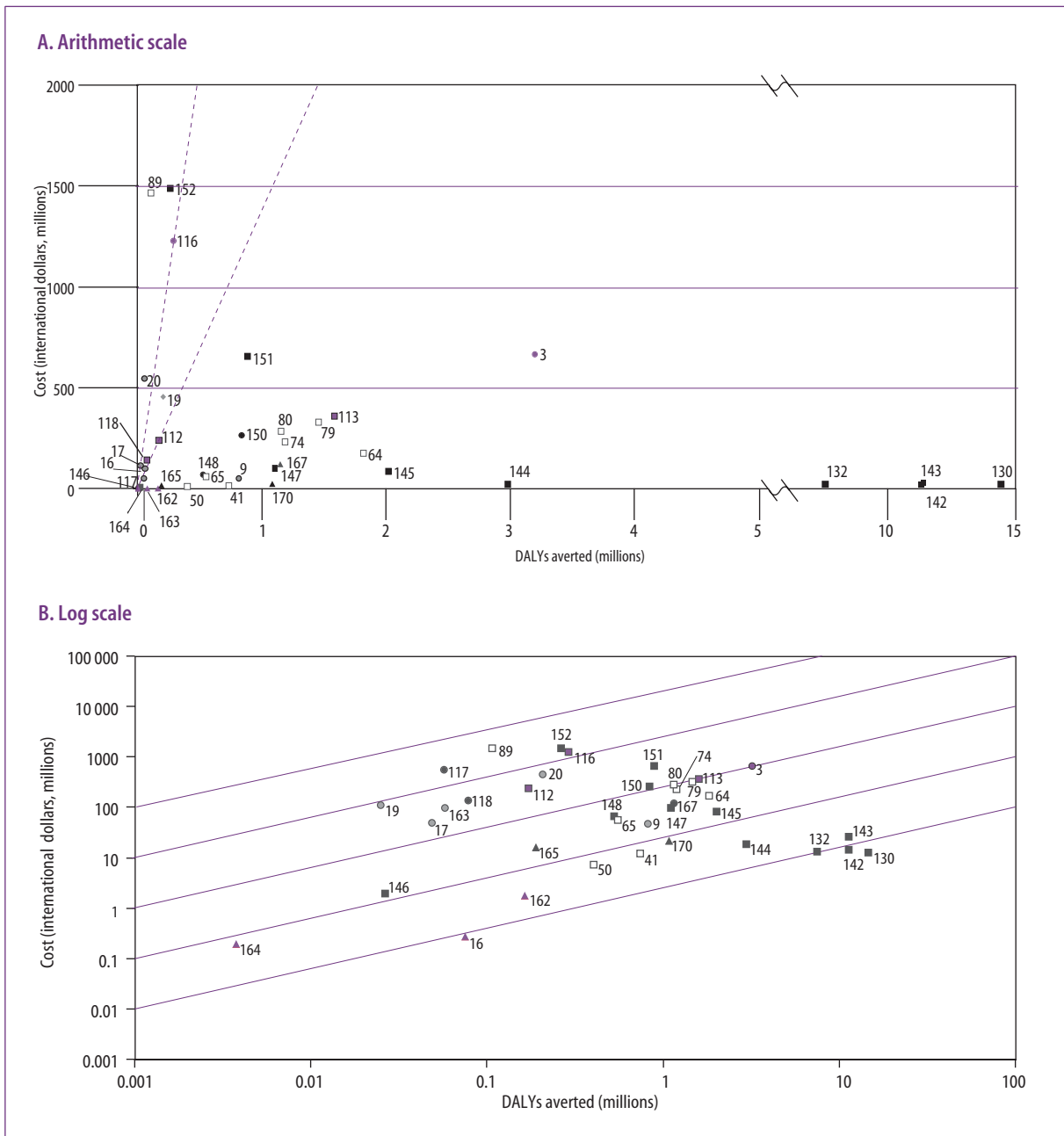**A. Arithmetic scale**

B. Log scale

Figure 5.2. Cost and effects of selected interventions in subregion AFR-D

C. Legend

See the List of Member States by WHO Region and mortality stratum for an explanation of subregion AFR-D.
See Table 5.3 for a complete list of interventions.
For water and sanitation, only interventions considered to be purely health interventions are included.

Number	Legend	Description
		Unsafe water, sanitation and hygiene
3	◕	Disinfection at point of use for population without improved water sources
		Addictive substances: Tobacco
9	◯	Doubling the maximum tax (2TAX)
16	◯	2TAX, Comprehensive ban (BAN) on advertising and Information dissemination (INF) through health warning labels, counter-advertising, and various consumer information packages
17	◯	2 TAX and BAN
19	◯	2TAX, Clean indoor air laws (LAW), BAN and INF
20	◯	2TAX, LAW, BAN, INF and Nicotine replacement therapy (NRT)
		Childhood undernutrition
41	☐	Vitamin A fortification (VAF) of staple food, 95% coverage
50	☐	VAF and Zinc fortification (ZF) of staple food, 95% coverage
64	☐	VAF, ZF and Case management for childhood pneumonia (CM)), 80% coverage
65	☐	VAF, ZF and Case management for childhood pneumonia (CM), 95% coverage
74	☐	Vitamin A supplementation for all children aged 6 months to 5 years (VAS5), Zinc supplementation daily for all children 0–5 years of age (ZS5) and CM, 95% coverage
79	☐	VAS5, ZS5, Oral rehydration therapy for diarrhoea (ORT) and CM, 80% coverage
80	☐	VAS5, ZS5, ORT and CM, 95% coverage
89	☐	VAS5, ZS5 , Improve complementary feeding through nutrition counselling and provision of nutrient-dense food for all underweight children aged 6–12 months identified through growth monitoring and promotion (CFGM), ORT and CM, 95% coverage
		Other nutrition-related risk factors and physical inactivity
112	▨	Treatment with triple therapy (TRI) of hypertension-lowering drug (beta-blocker), statins and aspirin for individuals with absolute risk of cardiovascular event of 25% in 10 years
113	▨	TRI with risk of 35% in 10 years
116	▨	Legislation (LEG) to decrease salt content of processed foods, plus appropriate labelling and enforcement, Health education (HE) through mass media to reduce cholesterol and TRI with risk of 5% in 10 years
117	▨	LEG, HE and TRI with risk of 15% in 10 years
118	▨	LEG, HE and TRI with risk of 25% in 10 years
		Sexual and reproductive health
130	■	Mass media (MED), 100% coverage
132	■	Treatment of sexually transmitted infections (STI), enhanced coverage
142	■	Educating sex workers (EDS) and MED
143	■	EDS, MED and STI enhanced coverage
144	■	EDS, MED and STI, 95% coverage
145	■	EDS, MED, STI and School-based education (SBE) 50% coverage
146	■	EDS+STI, MED, STI 95% coverage and SBE 50% coverage
147	■	EDS+STI, MED, STI 95% coverage and SBE 80% coverage
148	■	EDS+STI, MED, STI 95% coverage and SBE 95% coverage
150	■	EDS+STI, MED, STI 95 % coverage, SBE 95% coverage, Voluntary counselling and testing (VCT) and Preventing mother-to-child transmission (MTCT)
151	■	Antiretroviral therapy: intensive monitoring, first-line drugs only (ARV2), EDS + STI, MED, STI 95% coverage, SBE 95% coverage, VCT and MTCT
152	■	Antiretroviral therapy: intensive monitoring, first- and second-line drugs (ARV4), EDS +STI, MED, STI 95% coverage, SBE 95% coverage, VCT and MTCT
		Unsafe injections
162	▲	Reduction in overuse of injections through interactive patient--provider group discussions (GD)
163	▲	Reduction in unsafe use of injections with single use injection equipment (SUI)
164	▲	GD and SUI
		Iron deficiency
165	▲	Iron supplementation (IS), 50% coverage
167	▲	IS, 95% coverage
170	▲	Iron fortification (IF), 95% coverage

Table 5.3 Cost-effective interventions

Number	Description	Number	Description
	Unsafe water, sanitation and hygiene	40	VAF, 80% coverage
1	Millennium development goal (MDG): to halve the proportion of people with no access to improved water sources	41	VAF, 95% coverage
		42	Zinc fortification (ZF) of staple food, 50% coverage
2	MDG and basic sanitation	43	ZF, 80% coverage
3	Disinfection at point of use for population without improved water sources	44	ZF, 95% coverage
4	MDG, 98% coverage	45	ORT and CM, 50% coverage
5	Improved water supply, disinfection and basic sanitation (low technologies), 98% coverage	46	ORT and CM, 80% coverage
		47	ORT and CM, 95% coverage
6	Piped water supply and sewer connection (high technologies), 98% coverage	48	VAF and ZF, 50% coverage
	Addictive substances: Tobacco	49	VAF and ZF, 80% coverage
7	Global average tax rate (44% of the final retail price with a mark-up of 79%)	50	VAF and ZF, 95% coverage
		51	ZF and CM, 50% coverage
8	Highest regional tax rate (75% of the final retail price with a mark-up of 300%)	52	ZF and CM, 80% coverage
		53	ZF and CM, 95% coverage
9	Doubling the maximum tax (2TAX) (89% of the final retail price with a mark-up of 600%)	54	VAS5 and ZS5, 50% coverage
		55	VAS5 and ZS5, 80% coverage
10	Clean indoor air laws (LAW) in public places, through legislation and enforcement	56	VAS5 and ZS5, 95% coverage
		57	Zinc supplementation daily for all children aged 0--2 years (ZS2) and ZF, 50% coverage
11	Comprehensive ban (BAN) on advertising of tobacco products through legislation and enforcement	58	ZS2 and ZF, 80% coverage
		59	ZS2 and ZF, 95% coverage
12	Information dissemination (INF) through health warning labels, counter-advertising, and various consumer information packages	60	VAF, ZF and ORT, 50% coverage
		61	VAF, ZF and ORT, 80% coverage
13	Nicotine replacement therapy (NRT): 20 mg/day treatment with nicotine gum for three months, plus regular visits to a GP or health centre (1 per month) and a nurse counsellor (1.5 per month)	62	VAF, ZF and ORT, 95% coverage
		63	VAF, ZF and CM, 50% coverage
		64	VAF, ZF and CM, 80% coverage
		65	VAF, ZF and CM, 95% coverage
14	2TAX and INF	66	ZF, ORT and CM, 50% coverage
15	2TAX, LAW and INF	67	ZF, ORT and CM, 80% coverage
16	2TAX, BAN and INF	68	ZF, ORT and CM, 95% coverage
17	2TAX and BAN	69	ZS5, ORT and CM, 50% coverage
18	2TAX, LAW and BAN	70	ZS5, ORT and CM, 80% coverage
19	2TAX, LAW, BAN and INF	71	ZS5, ORT and CM, 95% coverage
20	2TAX, LAW, BAN, INF and NRT	72	VAS5, ZS5 and CM, 50% coverage
	Childhood undernutrition	73	VAS5, ZS5 and CM, 80% coverage
21	Oral rehydration therapy for diarrhoea (ORT), 50% coverage	74	VAS5, ZS5 and CM, 95% coverage
22	ORT, 80% coverage	75	VAS5, ZS5 and ORT, 50% coverage
23	ORT, 95% coverage	76	VAS5, ZS5 and ORT, 80% coverage
24	Case management for childhood pneumonia (CM), 50% coverage	77	VAS5, ZS5 and ORT, 95% coverage
25	CM, 80% coverage	78	VAS5, ZS5, ORT and CM, 50% coverage
26	CM, 95% coverage	79	VAS5, ZS5, ORT and CM, 80% coverage
27	Vitamin A supplementation for all children aged 6 months to 5 years (VAS5), twice a year at the health centre, 50% coverage	80	VAS5, ZS5, ORT and CM, 95% coverage
		81	VAF, ZF, ORT and CM, 50% coverage
28	VAS5, 80% coverage	82	VAF, ZF, ORT and CM, 80% coverage
29	VAS5, 95% coverage	83	VAF, ZF, ORT and CM, 95% coverage
30	Zinc supplementation daily for all children aged 0--5 years (ZS5), 50% coverage	84	VAS2, VAF, ZS2, and ZF, 50% coverage
		85	VAS2, VAF, ZS2, and ZF, 80% coverage
31	ZS5, 80% coverage	86	VAS2, VAF, ZS2, and ZF, 95% coverage
32	ZS5, 95% coverage	87	VAS5, ZS5, CFGM, ORT and CM, 50% coverage
33	Improved complementary feeding (CF) through nutrition counselling and provision of nutrient-dense food for all children aged 6--12 months, 50% coverage	88	VAS5, ZS5, CFGM, ORT and CM, 80% coverage
		89	VAS5, ZS5, CFGM, ORT and CM, 95% coverage
34	CF, 80% coverage	90	VAF, ZF, CFGM, ORT and CM, 50% coverage
35	CF, 95% coverage	91	VAF, ZF, CFGM, ORT and CM, 80% coverage
36	Improved complementary feeding through nutrition counselling and provision of nutrient-dense food for all underweight children aged 6--12 months identified through growth monitoring and promotion (CFGM), 50% coverage		
37	CFGM, 80% coverage		
38	CFGM, 95% coverage		
39	Vitamin A fortification (VAF) of staple food, 50% coverage		

Number	Description	Number	Description
92	VAF, ZF, CFGM, ORT and CM, 95% coverage	135	SBE, 80% coverage
93	VAS2, VAF, ZS2, ZF and CM, 50% coverage	136	SBE, 95% coverage
94	VAS2, VAF, ZS2, ZF and CM, 80% coverage	137	Voluntary counselling and testing (VCT), 95% coverage
95	VAS2, VAF, ZS2, ZF and CM, 95% coverage	138	Preventing mother-to-child transmission (MTCT), antenatal care coverage
96	VAS2, VAF, ZS2, ZF, ORT and CM, 50% coverage	139	Educating men who have sex with men (EDM), 50% coverage
97	VAS2, VAF, ZS2, ZF, ORT and CM, 80% coverage	140	EDM, 80% coverage
98	VAS2, VAF, ZS2, ZF, ORT and CM, 95% coverage	141	EDM, 95% coverage
99	VAS2, VAF, ZS2, ZF, CFGM, ORT and CM, 50% coverage	142	EDS and MED
100	VAS2, VAF, ZS2, ZF, CFGM, ORT and CM, 80% coverage	143	EDS, MED and STI enhanced coverage
101	VAS2, VAF, ZS2, ZF, CFGM, ORT and CM, 95% coverage	144	EDS, MED and STI 95% coverage
		145	EDS, MED, STI 95% coverage and SBE 50% coverage
	Other nutrition-related risk factors and physical inactivity	146	EDS+STI, MED, STI 95% coverage and SBE 50% coverage
102	Voluntary cooperation of food manufacturers with government to decrease salt in processed foods, plus appropriate labelling	147	EDS+STI, MED, STI 95% coverage and SBE 80% coverage
103	Legislation (LEG) to decrease salt content of processed foods, plus appropriate labelling and enforcement	148	EDS+STI, MED, STI 95% coverage and SBE 95% coverage
		149	EDS+STI, MED, STI 95% coverage, SBE 95% coverage and VCT
104	Health education (HE) through mass media to reduce cholesterol	150	EDS+STI, MED, STI 95% coverage, SBE 95% coverage, VCT and MTCT
105	Hypertension-lowering drug treatment (DRG) and education (ED) on lifestyle modification including dietary advice, delivered by physicians to individuals with systolic blood pressure (SBP) >160 mmHg.	151	ARV2 , EDS+STI,MED, STI 95% coverage, SBE 95% coverage, VCT and MTCT
		152	ARV4 , EDS+STI,MED, STI 95% coverage, SBE 95% coverage, VCT and MTCT
		153	EDS and MED
106	DRG and ED with SBP >140 mmHg	154	EDS, MED and STI 95% coverage
107	Cholesterol-lowering drug treatment (statins) and education (ED) on lifestyle modification including dietary advice, delivered by physicians to individuals whose serum cholesterol concentration (CHOL) exceeds 220 mg/dl (5.7 mmol/l)	155	EDS+STI, MED and STI 95% coverage
		156	EDS+STI, MED, STI 95% coverage and SBE 80% coverage
		157	EDS+STI, MED, STI 95% coverage and SBE 95% coverage
		158	ARV1, EDS+STI, MED, STI 95% coverage and SBE 95% coverage
108	Statins and ED with CHOL >240 mg/dl (>6.2 mmol/l)	159	ARV2, EDS+STI, MED, STI 95% coverage and SBE 95% coverage
109	Nicotine replacement therapy (NRT) with medical advice and counselling, provided by physicians and outpatient carers to all smokers in the population	160	ARV2, EDS+STI, MED, STI 95% coverage, SBE 95% coverage and MTCT
		161	ARV4, EDS+STI, MED, STI 95% coverage, SBE 95% coverage and MTCT
110	Treatment with triple therapy (TRI) of hypertension-lowering drug (beta-blocker), statins and aspirin for individuals with absolute risk of cardiovascular event of 5% in 10 years		**Unsafe injections**
		162	Reduction in overuse of injections through interactive patient--provider group discussions (GD)
111	TRI with risk of 15% in 10 years	163	Reduction in unsafe use of injections with single use injection equipment (SUI)
112	TRI with risk of 25% in 10 years	164	GD and SUI
113	TRI with risk of 35% in 10 years		**Iron deficiency**
114	LEG and HE	165	Iron supplementation (IS), 50% coverage
115	DRG and statins and ED, with treatment of all individuals with SBP >140 mmHg and/or CHOL >240 mg/dl (>6.2 mmol/l)	166	IS, 80% coverage
		167	IS, 95% coverage
116	LEG, HE and TRI with risk of 5% in 10 years	168	Iron fortification (IF), 50% coverage
117	LEG, HE and TRI with risk of 15% in 10 years	169	IF, 80% coverage
118	LEG, HE and TRI with risk of 25% in 10 years	170	IF, 95% coverage
119	LEG, HE and TRI with risk of 35% in 10 years		
	Sexual and reproductive health		
120	Antiretroviral therapy: standard monitoring, first-line drugs only (ARV1)		
121	Antiretroviral therapy: intensive monitoring, first-line drugs only (ARV2)		
122	Antiretroviral therapy: standard monitoring, first- and second-line drugs (ARV3)		
123	Antiretroviral therapy: intensive monitoring, first- and second-line drugs (ARV4)		
124	Educating sex workers (EDS), 50% coverage		
125	Educating sex workers, 80% coverage		
126	Educating sex workers (EDS), 95% coverage		
127	EDS and treatment of sexually transmitted infections (EDS+STI), 50% coverage		
128	EDS+STI, 80% coverage		
129	EDS+STI, 95% coverage		
130	Mass media (MED), 100% coverage		
131	Treatment of sexually transmitted infections (STI), current coverage		
132	STI, enhanced coverage		
133	STI, 95% coverage		
134	School-based education (SBE), 50% coverage		

the annualized discounted costs of the intervention. All costs are included regardless of who pays.[12] The horizontal axis shows the yearly DALYs gained from this action.

The two rays drawn from the origin represent the cut-off points used to denote interventions as cost-effective and very cost-effective. All points on the lower ray (closer to the south-east corner) have a cost-effectiveness exactly equal to GDP per capita in the region. Interventions appearing to the right of it are defined as very cost-effective – most of the preventive interventions aimed at reducing unsafe sexual practices and improving child undernutrition fall in this category in both regions. All points on the upper ray (closer to the north-west corner) have a cost-effectiveness equal to three times GDP per capita, the cut point used to distinguish between cost-effective and cost-ineffective interventions. Points to the left of this ray would not be cost-effective in that region.

In AFR-D, preventive interventions to reduce the health effects of unsafe sex and the combined approach of population-wide and individual-based interventions for cardiovascular disease are among those in the most cost-effective category. On the other hand, treatment of people based purely on observed levels of blood pressure and cholesterol would not be cost-effective. In AMR-B, high rates of taxation to reduce smoking would be very cost-effective, but the combination of all the possible smoking-reduction interventions would not be in the most cost-effective category.

The figures show which interventions are in the the most cost-effective category. They also illustrate that it is possible for an intervention to be cost-effective but at the same time have a relatively small impact on population health. In AFR-D, for example, iron supplementation at 50% coverage (intervention 165) is cost-effective by itself. So is the combination of case management for pneumonia, ORT, vitamin A and zinc supplementation (intervention 80). The former would gain 1.28 million DALYs while the latter would gain 11.6 million. Despite the fact that both are very cost-effective, policy-makers need to have information about which one will have the greatest total impact on population health, and the total cost of achieving these health gains.[13]

In both figures, however, interventions cluster close to the origin and it is difficult to identify all of them clearly. Accordingly, the figures are redrawn with the axes on a logarithmic scale, enabling the individual interventions to be identified. In this case, the lines drawn obliquely across the figures represent lines of equal cost-effectiveness. All points on the line at the south-east extreme have a cost-effectiveness ratio (CER) of I$ 1 per DALY gained. Because of the logarithmic scale, each subsequent line moving in a north-easterly direction represents a one order of magnitude increase in the CER, so all points on the next line have a CER of I$ 10, and the subsequent line represents a CER of I$ 100.

These figures illustrate more clearly that the variation in CERs across interventions within each region is substantial. In both subregions, some interventions (for example, preventive interventions aimed at reducing the incidence of HIV, and interventions to improve unsafe injection practices) gain each DALY at a cost of less than I$ 10. On the other hand, adding nicotine replacement therapy to the cost-effective population-wide set of anti-smoking

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[12] The points depict the total costs and total DALYs averted only for the most cost-effective interventions in any set (for example, interventions relating to unsafe sex). In other cases, the points show the additional costs and additional effects of moving from the most cost-effective option to that intervention. This is because decision-makers interested in maximizing population health for a given level of resources would first choose the most cost-effective intervention, then if additional resources were available, choose between alternative ways of using them based on the additional DALYs that would be gained from the additional expenditure.

[13] Iron supplementation at 50% coverage costs I$ 38.2 million, while the combination of interventions would cost I$ 1 billion at the regional level.

activities would cost more than I$ 10 000 per additional DALY gained (intervention 20). A similar range of cost-effectiveness ratios is observed in AMR-B.

The information on costs and effectiveness of a set of interventions targeting different risk factors can help to identify which interventions would be selected for given levels of resource availability in the different regions if the goal were to maximize population health.[14] In AFR-D, for example, a very severe restriction of resources would see most attention paid to preventive interventions to reduce the impact of unsafe sexual behaviours, unsafe injection use and micronutrient supplementation or fortification.

If the substantial increase in resources for health in Africa that is now becoming available allows all interventions costing less than three times GDP per capita to be funded, the optimal mix would include HIV prevention interventions combined with ARV treatment. It would include supplementation or fortification of vitamin A, iron and zinc in combination with treatment for diarrhoea and pneumonia in children. Disinfection at point of use would be combined with provision of improved sanitation facilities, and interventions designed to reduce the overuse of injections and unsafe injection practices would be introduced. Population-wide interventions to reduce the risks of cardiovascular disease would be combined with treatment of individuals with an absolute risk of an event in the next 10 years estimated to be above 25% (possibly even 15%), and high rates of taxation on cigarettes would be introduced and maintained.

These interventions are not exhaustive because not all risk factors were included, nor were all possible interventions analysed. However, they show that an annual expenditure of approximately I$ 6.8 billion would gain over 140 million DALYs in that region alone.

POLICY IMPLICATIONS

Very substantial health gains can be made for relatively modest expenditures on interventions to reduce risks. However, the maximum possible health gains will be attained only if careful consideration is given to the costs and effects of interventions. Risk reduction strategies need to be based on a thorough analysis of the best possible evidence on the health effects and the costs of technically feasible interventions, undertaken by themselves and in various combinations. The analysis of interactions between interventions is a critical but neglected question, which is the reason it has been given prominence in this chapter.

A selected number of interventions targeting some of the major risks to health have been discussed. Some that have not been considered are likely to also be cost-effective in different settings and will be included in *The World Health Report 2003*, but already a number of important messages emerge.

- A strategy to protect the child's environment is cost-effective in all settings. The components shown here to be very cost-effective include some form of micronutrient supplementation (depending on the prevalence of micronutrient deficiencies, either vitamin A, iron, or zinc) disinfection of water at point of use to reduce the incidence of diarrhoeal diseases; and treatment of diarrhoea and pneumonia.
- Preventive interventions to reduce incidence of HIV infections, including measures to encourage safer injection practices, are very cost-effective, although care needs to be taken when extrapolating the effectiveness of behaviour change interventions from one setting to another. The use of some types of antiretroviral therapy in conjunction with preventive activities is cost-effective in most settings. While directly

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[14] As stated earlier, there are other goals of the health system as well and information on costs and effects will be only one of the inputs to the decision-making process.

Figure 5.3 Cost and effects of selected interventions in subregion AMR-B
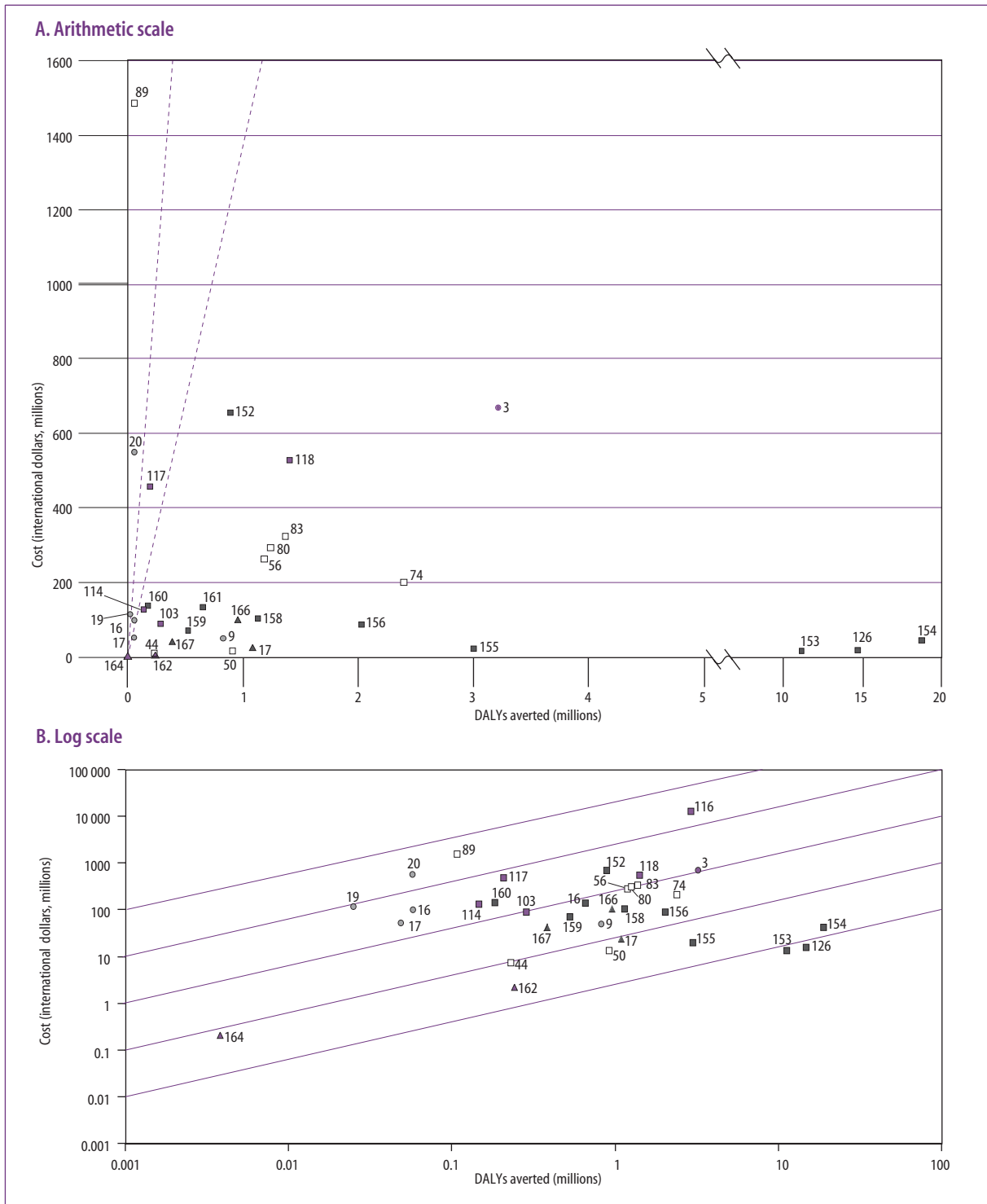
Figure 5.3 Cost and effects of selected interventions in subregion AMR-B

C. Legend

See the List of Member States by WHO Region and mortality stratum for an explanation of subregion AFR-D.
See Table 5.3 for a complete list of interventions.
For water and sanitation, only interventions considered to be purely health interventions are included.

Number	Legend	Description
		Unsafe water, sanitation and hygiene
3	◍	Disinfection at point of use for population without improved water sources
		Addictive substances: Tobacco
9	◯	Doubling the maximum tax (2TAX)
16	◯	2TAX, Comprehensive ban (BAN) on advertising and Information dissemination (INF) through health warning labels, counter-advertising, and various consumer information packages
17	◯	2TAX and BAN
19	◯	2TAX, Clean indoor air laws (LAW), BAN and INF
20	◯	2TAX, LAW, BAN, INF and Nicotine replacement therapy (NRT)
		Childhood undernutrition
44	□	Zinc fortification of food staple (ZF), 95%
50	□	Vitamin A fortification (VAF) of staple food and ZF, 95% coverage
56	□	Vitamin A supplementation for all children aged 6 months to 5 years (VAS5), twice a year at the health centre and Zinc supplementation daily for all children aged 0--5 years (ZS5), 95% coverage
74	□	VAS5, ZS5 and Case management for childhood pneumonia (CM), 95% coverage
80	□	VAS5, ZS5, Oral rehydration therapy for diarrhoea (ORT) and CM, 95% coverage
83	□	VAF, ZF, ORT and CM, 95% coverage
89	□	VAS5, ZS5, Improved complementary feeding through nutrition counselling and provision of nutrient-dense food for all underweight children aged 6–12 months identified through growth monitoring and promotion (CFGM), ORT and CM, 95% coverage
		Other nutrition-related risk factors and physical inactivity
103	◼	Legislation (LEG) to decrease salt content of processed foods, plus appropriate labelling and enforcement
114	◼	LEG and Health education (HE) through mass media to reduce cholesterol
116	◼	Legislation (LEG) to decrease salt content of processed foods, plus appropriate labelling and enforcement, HE and TRI with risk of 5% in 10 years
117	◼	LEG, HE and TRI with risk of 15% in 10 years
118	◼	LEG, HE and TRI with risk of 25% in 10 years
		Sexual and reproductive health
126	■	Educating sex workers (EDS), 95% coverage
152	■	Antiretroviral therapy: intensive monitoring, first- and second-line drugs (ARV4), EDS+ Treatment of sexually transmitted infections (EDS+STI), Mass media (MED) 100% coverage, School-based education (SBE) 95% coverage, STI, 95% coverage, Voluntary counselling and testing (VCT) 95% coverage and Preventing mother-to-child transmission (MTCT)
153	■	EDS and MED
154	■	EDS, MED and STI 95% coverage
155	■	EDS+STI, MED and STI 95% coverage
156	■	EDS+STI, MED, STI 95% coverage and SBE 80% coverage
158	■	Antiretroviral therapy: standard monitoring, first-line drugs only (ARV1), EDS+STI, MED, STI 95% coverage and SBE 95% coverage
159	■	Antiretroviral therapy: intensive monitoring, first-line drugs only (ARV2), EDS+STI, MED, STI 95% coverage and SBE 95% coverage
160	■	ARV2, EDS+STI, MED, STI 95% coverage, SBE 95% coverage and MTCT
161	■	Antiretroviral therapy: intensive monitoring, first- and second-line drugs (ARV4), EDS+STI, MED, STI 95% coverage, SBE 95% coverage and MTCT
		Unsafe injections
162	△	Reduction in overuse of injections through interactive patient--provider group discussions (GD)
164	△	GD and Reduction in unsafe use of injections with single use injection equipment (SUI)
		Iron deficiency
166	▲	Iron supplementation (IS), 80% coverage
167	▲	IS, 95%
170	▲	Iron fortification (IF),95%

observed artiretroviral therapy combined with testing for resistance does not seem to be cost-effective in all settings, there might well be other reasons, that cannot be included in a standard cost-effectiveness framework, for pursuing it.

- Improved water supply based on disinfection at point of use is cost-effective in regions of high child mortality. While acknowledging that regulated piped water supplies will be the long-term aim of most countries, a policy shift towards household water management appears to be the most attractive short-term water-related health intervention in developing countries.
- In all settings at least one type of intervention to reduce the risks associated with cardiovascular disease was cost-effective. Population-wide salt and cholesterol lowering strategies are always very cost-effective singly and combined. Combining them with an individual risk reduction strategy is also cost-effective, particularly with interventions to reduce risk based on assessed levels of absolute risk. The cost-effectiveness of the absolute risk approach would improve further if it is possible to assess accurately individual risks without the need for laboratory tests, and further work towards testing this possibility is recommended. Additional interventions that were not evaluated here, such as those aimed at encouraging people to increase their physical activity levels, should also be considered when comprehensive strategies are being assessed in different settings.
- There is an important role for governments in encouraging risk reduction strategies. For example, taxes on cigarette products are very cost-effective globally and higher tax rates result in larger improvements in population health. In addition, governments would be well advised to consider taking steps to reduce the salt content of processed foods on a population-wide basis, either through legislation or through self-regulation. Both approaches would require consultation with a variety of stakeholders.

This report acknowledges that there are other goals of health policy in addition to improving population health. In choosing appropriate combinations of interventions, governments are also concerned with reducing poverty and other inequalities, and with questions of human rights, community acceptance and political needs. They must also consider how different types of interventions can be incorporated into the health infrastructure available in the country, or how the infrastructure could be expanded or adapted to accommodate the desired strategies. This is particularly important when considering if it is feasible to expand coverage to high levels. However, improving population health is the defining goal of a health system, the reason why it exists. The type of information reviewed in this chapter is one of the critical inputs required to inform the decision-making process about efficient ways to reduce risks to health.

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