The population approach to prevention has been described as one of the ‘absolute truths’ of preventive medicine. However, when the relationship between risk factor exposure levels and associated risk is J-shaped the population approach can increase risk in a small number of individuals. There is evidence that the relationship between a variety of exposures and all-cause morbidity and mortality is J-shaped. However, such relationships are often overlooked by epidemiological investigations which focus on cause-specific morbidity and mortality. Although the overall beneficial effect of population interventions may outweigh any negative effect seen, the effect on the individuals concerned should not be overlooked—especially when they can be easily identifiable before the intervention. Procedures, akin to gaining informed consent in clinical situations, may be required to ensure that individuals who are at high risk of being negatively affected by population interventions understand the risks involved and have the opportunity to opt out.

Keywords: Population approach, prevention measures, Geoffrey Rose, J-curves

In 1985 Geoffrey Rose proposed that targeting preventive interventions at individuals identified as at high risk of disease would have a minimal effect on population health. Instead, he argued that reducing risk by a small amount in all members of the population, irrespective of baseline risk, would maximize the benefit of preventive interventions to public health. Rose’s reasoning is persuasive and the so-called population approach has been described as one of the ‘absolute truths’ of preventive medicine.

However, Rose’s argument appears to rest on the assumption that rather simplistic, monotonic relationships exist between specific risk factor exposure levels and associated risk of morbidity and mortality. When more realistic relationships between exposure and risk—specifically J-shaped relationships—are considered, the population approach has the potential to harm a small group of individuals by increasing, rather than decreasing, their risk levels.

In this paper we explore the effect of the population approach to prevention when J-shaped relationships between exposure levels and risk exist, present evidence to confirm that such J-shaped relationships exist, suggest some reasons why these J-shaped curves have been overlooked in the past and, finally discuss the implications of this phenomenon for public health policy and practice.

Throughout we use term ‘exposure’ to refer to levels of hypothetical, specific disease risk factors and ‘risk’ to refer to the all-cause risk of morbidity and mortality associated with any particular exposure level. The basic argument that the population approach to prevention, in the presence of a J-shaped relationship between exposure and risk, will lead to an increase in risk in some individuals is simple yet, we believe, widely overlooked in the literature.

The population approach in the context of J-shaped relationships increases risk for some

The arithmetic underlying the population approach assumes that the relationship between exposure and risk is continuously monotonic such that higher (or, in some cases e.g. social support, lower) exposure levels are always associated with more risk of morbidity or mortality and vice versa. Assuming that preventive interventions have exactly the effect intended, in terms of exposure reduction, when the relationship between exposure and risk is continuously positive, population-based
preventive interventions will be beneficial for all individuals in the population—no individual will be put at higher risk after, compared with before, the intervention (Figure 1).

When more complex J-shaped relationships between exposure and risk are considered, the population approach will result in some individuals, originally at the bottom of the J-curve, being pushed to lower exposure levels with associated higher risk levels (Figure 2). In population terms, only a small number of people are likely to be negatively affected and the small increase in risk will generally be substantially outweighed by the decrease in risk seen in the population as a whole (although this is not the case in figure 2). However, the effect on the individuals concerned should not, necessarily, be ignored.

Evidence of J-shaped relationships between exposure and risk

Three examples of J-shaped relationships between exposure and risk are discussed here but many others are likely to exist.

Alcohol consumption

Excess alcohol consumption is well recognized to be a public health problem with between 5000 and 40 000 deaths in the UK annually attributable to drinking.\textsuperscript{6} The possible beneficial effects of moderate alcohol consumption are also beginning to be widely recognized and a J-shaped relationship between alcohol consumption and all-cause mortality has been confirmed by a number of meta-analyses.\textsuperscript{7} The upstroke of this J-curve is thought to be due to the cardioprotective effects of moderate alcohol consumption. In particular, alcohol increases high density lipoprotein levels, inhibits platelet aggregation, and promotes fibrinolysis.\textsuperscript{8} Above an intake of around 10 g of alcohol per day, however, other detrimental effects of alcohol predominate and increased consumption is associated with decreased health.\textsuperscript{7}

Blood pressure

The complications of hypertension have been well described and include stroke, ischaemic heart disease, peripheral vascular disease, and renal failure.\textsuperscript{9} Chronic hypotension has been
dizziness. Fainting leads to further risks including fracture, fatigue, mild depression and anxiety, sweating, fainting and associated with such chronic, idiopathic hypotension include fatigue, mild depression and anxiety, sweating, fainting and dizziness. Fainting leads to further risks including fracture and head injury. Furthermore, it has been suggested that pharmacologically induced hypotension below a diastolic blood pressure of about 85 mmHg increases, rather than decreases, the risk of myocardial infarction in those with cardiac ischaemia.

Body mass index
Obesity has been associated with numerous complications including osteoarthritis, hypertension, ischaemic heart disease, stroke, glucose intolerance, and hyperlipidaemia. Conversely, there are substantial health risks associated with very low body weight. These are seen particularly in those suffering from eating disorders and include amenorrhea, osteoporosis, anaemia, arrhythmias, and depression. In addition, an increased risk of death from all causes over a mean of 18 years has recently been reported in a cohort of apparently healthy individuals with a body mass index (BMI) of <18 kg/m² compared with those with a BMI of 20–22 kg/m².

J-shaped curves have been largely overlooked to date
We believe that the key reason why J-shaped relationships between exposure and risk have been largely overlooked to date is the tendency amongst epidemiologists to investigate the relationship between risk factor exposure and cause-specific morbidity and mortality. This approach has been helpful in identifying disease risk factors and the simplicity it lends to what is otherwise a complex network of cause and effect may be the only way to investigate the causes of particular diseases. However, the one cause–one effect approach to epidemiology encourages us to believe that these simple relationships operate in life. As can be seen from the examples discussed above, the causes of morbidity and mortality association with the elevated risk in the downstroke of the J-curve are generally different from those associations with elevated risk in the upstroke of the J-curve. J-shaped relationships are, therefore, only likely to be identified when the relationship between exposure levels and all-cause, rather than cause-specific, morbidity and mortality are considered.

Further complexities of population approaches to prevention
There are also less-predictable ‘knock-on’ effects of preventive interventions that must be considered. For example, the heavy drinker who begins to drink less as a result of an intervention promoting healthy drinking may also stop going to the pub, stop meeting friends and engaging in their main source of social interaction, become depressed and suffer a number of health consequences not easily associated with apparently healthy levels of drinking. The smoker who successfully quits may find that without nicotine, their appetite increases substantially, their weight goes up and they become susceptible to the wide range of obesity-associated health problems. When a high-risk, targeted approach is used, individuals generally receive individualized follow-up and these unpredictable effects may be partially avoided. However, when population preventive approaches are used, all individuals are asked to respond and individualized support and recognition of possible knock-on effects is usually not provided.

Furthermore, there is little evidence that the wholesale shift in the distribution of a risk factor intended by population approaches is achievable. In particular, there is evidence that those individuals with the healthiest risk factor profiles, and highest socio-economic status, at baseline are the most likely to respond to health promotion messages. This phenomenon may potentiate the risks to some individuals associated with population approaches in the presence of J-curves by pushing those with the healthiest risk factor profiles by baseline into unhealthy exposure levels, whilst failing to have a significant impact on those with the unhealthiest risk factors profiles.

The implications of J-shaped relationships for public health
The population approach to prevention proposes that interventions should be applied to entire populations to achieve a wholesale shift in the distribution of disease risk factors. Our analysis suggest that such one-size-fits-all interventions risk harming a small group of the population.

All public health interventions have the potential to cause harm as well as good. Because of this, the utilitarian principle of striving for the greatest good for the greatest number is often invoked in discussion of the ethics of public health interventions. Indeed, the potential harm of any intervention is often thought to be unavoidable and unimportant. Rose himself noted the possible harm of population approaches to obesity but dismissed them on the basis that ‘there is small prospect of reversing the trend towards ever more obesity’ (ref. 1 p. 79). However, the individuals who are likely to be harmed by population approaches which have the desired effect, in terms of exposure reduction, in the presence of J-shaped relationships are clearly identifiable before the intervention and—as noted—may be the very individuals most likely to respond to any intervention.

A number of authors have argued that public health interventions should be subject to ethical constraints similar to, but not necessarily the same as, clinical medicine. Whilst the population approach in the presence of a J-shaped curves meets the principle of beneficence, that of doing good, it does not meet the requirements of the principle of non-maleficence—the ‘first do no harm’ of the Hippocratic Oath. In clinical medicine it is now accepted that the risks and benefits of any intervention should be clearly explained to the patient before it goes ahead. In circumstances where preventive interventions have the potential to do harm, it has been suggested that informed consent is similarly sought, and given—particularly in the case of identifiable groups of individuals who are at high risk of being harmed by the intervention.
Conclusion

Despite the widespread support that the population strategy of preventive medicine has received, it is not necessarily beneficial to all individuals in a population, particularly when there are J-shaped relationships between exposure and risk. Clear understanding of both the relationship between any specific exposure and associated all-cause risk of morbidity and mortality, and the pattern of response to interventions according to baseline exposure levels is required before population-based interventions should be implemented. The ethical issues surrounding population interventions—especially when clearly identifiable groups of individuals can be predicted to be harmed, rather than helped, by an intervention—should be discussed more widely and clear guidelines agreed concerning how these individuals should be protected from population interventions.

Acknowledgements

Many thanks to two anonymous reviewers whose comments helped us to revise this paper. JA is supported by the Faculty of Public Health Medicine/BUPA joint research fellowship (2001–2004).

KEY MESSAGES

- When the association between risk factor exposure levels and associated risk of morbidity or mortality is J-shaped, a successful population approach to prevention will result in increased disease risk in a small number of individuals.
- There is increasing evidence that the association between risk factor exposure levels and all-cause morbidity and mortality is J-shaped in a number of cases.
- If population approaches to prevention are to be used, the harm that may occur to some people may have to be communicated to those most likely to be effected.

References