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Sick individuals and sick populations

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Aetiology confronts two distinct issues: the determinants of individual cases, and the determinants of incidence rate. If exposure to a necessary agent is homogeneous within a population, then case/control and cohort methods will fail to detect it: they will only identify markers of susceptibility. The corresponding strategies in control are the 'high-risk' approach, which seeks to protect susceptible individuals, and the population approach, which seeks to control the causes of incidence. The two approaches are not usually in competition, but the prior concern should always be to discover and control the causes of incidence.

The Determinants of Individual Cases

In teaching epidemiology to medical students, I have often encouraged them to consider a question which I first heard enunciated by Roy Acheson: 'Why did *this* patient get *this* disease at *this* time?'. It is an excellent starting-point, because students and doctors feel a natural concern for the problems of the individual. Indeed, the central ethos of medicine is seen as an acceptance of responsibility for sick individuals.

It is an integral part of good doctoring to ask not only, 'What is the diagnosis, and what is the treatment?' but also, 'Why did this happen, and could it have been prevented?'. Such thinking shapes the approach to nearly all clinical and laboratory research into the causes and mechanisms of illness. Hypertension research, for example, is almost wholly pre-occupied with the characteristics which distinguish individuals at the hypertensive and normotensive ends of the blood pressure distribution. Research into diabetes looks for genetic, nutritional and metabolic reasons to explain why some people get diabetes and others do not. The constant aim in such work is to answer Acheson's question, 'Why did *this* patient get this disease at this time?'.

The same concern has continued to shape the thinking of all of us who came to epidemiology from a background in clinical practice. The whole basis of the case-control method is to discover how sick and healthy individuals differ. Equally the basis of many cohort studies is the search for 'risk factors', which identify certain individuals as being more susceptible to disease; and from this we proceed to test whether these risk factors are also causes, capable of explaining why some individuals get sick while others remain healthy, and applicable as a guide to prevention.

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To confine attention in this way to within-population comparisons has caused much confusion (particularly in the clinical world) in the definition of normality. Laboratory 'ranges of normal' are based on what is common within the local population. Individuals with 'normal blood pressure' are those who do not stand out from their local contemporaries; and so on. What is common is all right, we presume.

Applied to aetiology, the individual-centred approach leads to the use of relative risk as the basic representation of aetiological force: that is, 'the risk in exposed individuals relative to risk in non-exposed individuals'. Indeed, the concept of relative risk has almost excluded any other approach to quantifying causal importance. It may generally be the best measure of aetiological force, but it is no measure at all of aetiological outcome or of public health importance.

Unfortunately this approach to the search for causes, and the measuring of their potency, has to assume a heterogeneity of exposure within the study population. If everyone smoked 20 cigarettes a day, then clinical, case-control and cohort studies alike would lead us to conclude that lung cancer was a genetic disease; and in one sense that would be true, since if everyone is exposed to the necessary agent, then the distribution of cases is wholly determined by individual susceptibility.

Within Scotland and other mountainous parts of Britain (Figure 1, left section)[1] there is no discernible relation between local cardiovascular death rates and the softness of the public water supply. The reason is apparent if one extends the enquiry to the whole of the UK. In Scotland, everyone's water is soft; and the possibly adverse effect becomes recognizable only when study is extended to other regions which have a much wider range of exposure ($r = -0.67$). Even more clearly, a case-control study of this question within Scotland would have been futile. Everyone is exposed, and other factors operate to determine the varying risk.

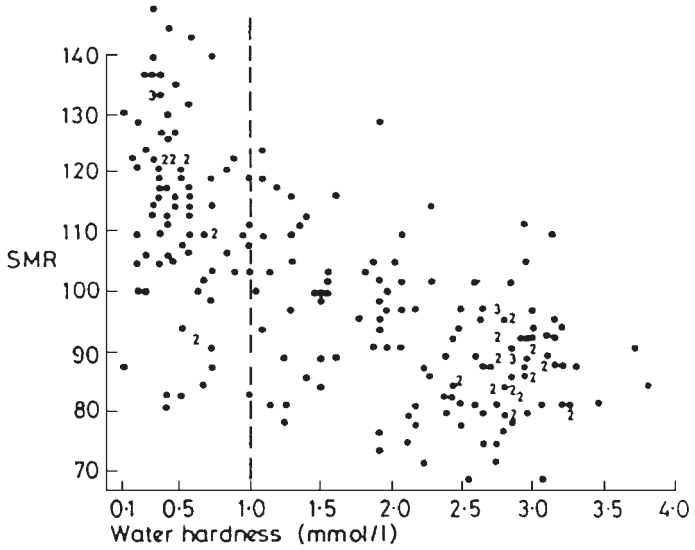

Figure 1 Relation between water quality and cardiovascular mortality in towns of the UK[1]

Epidemiology is often defined in terms of study of the determinants of the distribution of the disease; but we should not forget that the more widespread is a particular cause, the less it explains the distribution of cases. The hardest cause to identify is the one that is universally present, for then it has no influence on the distribution of disease.

The Determinants of Population Incidence Rate

I find it increasingly helpful to distinguish two kinds of aetiological question. The first seeks the causes of cases, and the second seeks the causes of incidence. 'Why do some individuals have hypertension?' is a quite different question from 'Why do some populations have much hypertension, whilst in others it is rare?'. The questions require different kinds of study, and they have different answers.

Figure 2 shows the systolic blood pressure distributions of middle-aged men in two populations—Kenyan nomads[2] and London civil servants.[3] The familiar question, 'Why do some individuals have higher blood pressure than others?' could be equally well asked in either of these settings, since in each the individual blood pressures vary (proportionately) to about the same extent; and the answers might well be much the same in each instance (that is, mainly genetic variation, with a lesser component from environmental and behavioural differences). We might achieve a complete understanding of why individuals vary, and yet quite miss the most important public health question, namely, 'Why is hypertension absent in the Kenyans and common in London?'. The answer to that question has to do with the determinants of the population mean; for what distinguishes the two groups is nothing to do with the characteristics of individuals, it is rather a shift of the whole distribution —a mass influence acting on the population as a whole. To find the determinants of prevalence and incidence rates, we need to study characteristics of populations, not characteristics of individuals.

A more extreme example is provided by the population distributions of serum cholesterol levels[4] in East Finland, where coronary heart disease is very common, and Japan, where the

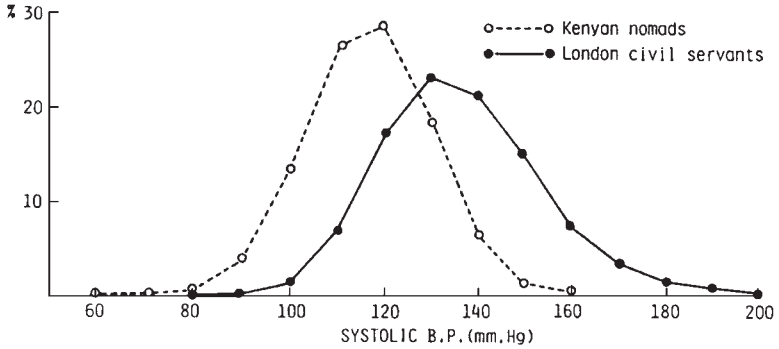

Figure 2 Distributions of systolic blood pressure in middle-aged men in two populations[2,3]

incidence rate is low: the two distributions barely overlap. Each country has men with relative hypercholesterolaemia (although their definitions of the range of 'normal' would no doubt disagree), and one could research into the genetic and other causes of these unusual individuals; but if we want to discover why Finland has such a high incidence of coronary heart disease we need to look for those characteristics of the national diet which have so elevated the whole cholesterol distribution. Within populations it has proved almost impossible to demonstrate any relation between an individual's diet and his serum cholesterol level; and the same applies to the relation of individual diet to blood pressure and to overweight. But at the level of populations it is a different story: it has proved easy to show strong associations between population mean values for saturated fat intake *versus* serum cholesterol level and coronary heart disease incidence, sodium intake *versus* blood pressure, or energy intake *versus* overweight. The determinants of incidence are not necessarily the same as the causes of cases.

How do the Causes of Cases Relate to the Causes of Incidence?

This is largely a matter of whether exposure varies similarly within a population and between populations (or over a period of time within the same population). Softness of water supply may be a determinant of cardiovascular mortality, but it is unlikely to be identifiable as a risk factor for individuals, because exposure tends to be locally uniform. Dietary fat is, I believe, the main determinant of a population's incidence rate for coronary heart disease; but it quite fails to identify high-risk individuals.

In the case of cigarettes and lung cancer it so happened that the study populations contained about equal numbers of smokers and non-smokers, and in such a situation case/control and cohort studies were able to identify what was also the main determinant of population differences and time trends.

There is a broad tendency for genetic factors to dominate individual susceptibility, but to explain rather little of population differences in incidence. Genetic heterogeneity, it seems, is mostly much greater within than between populations. This is the contrary situation to that seen for environmental factors. Thus migrants, whatever the colour of their skin, tend to acquire the disease rates of their country of adoption.

Most non-infectious diseases are still of largely unknown cause. If you take a textbook of medicine and look at the list of contents you will still find, despite all our aetiological research, that most are still of basically unknown aetiology. We know quite a lot about the personal characteristics of individuals who are susceptible to them; but for a remarkably large number of our major non-infectious diseases we still do not know the determinants of the incidence rate.

Over a period of time we find that most diseases are in a state of flux. For example, duodenal ulcer in Britain at the turn of the century was an uncommon condition affecting mainly young women. During the first half of the century the incidence rate rose steadily and it became very common, but now the disease seems to be disappearing; and yet we have no clues to the determinants of these striking changes in incidence rates. One could repeat that story for many conditions.

There is hardly a disease whose incidence rate does not vary widely, either over time or between populations at the same time. This means that these causes of incidence rate, unknown though they are, are not inevitable. It is possible to live without them, and if we knew what they were it might be possible to control them. But to identify the causal agent by the traditional case-control and cohort methods will be unsuccessful if there are not sufficient differences in exposure within the study population at the time of the study. In those circumstances all that these traditional methods do is to find markers of individual susceptibility. The clues must be sought from differences between populations or from changes within populations over time.

Prevention

These two approaches to aetiology—the individual and the population-based—have their counterparts in prevention. In the first, preventive strategy seeks to identify high-risk susceptible individuals and to offer them some individual protection. In contrast, the 'population strategy' seeks to control the determinants of incidence in the population as a whole.

The 'High-Risk' Strategy

This is the traditional and natural medical approach to prevention. If a doctor accepts that he is responsible for an individual who is sick today, then it is a short step to accept responsibility also for the individual who may well be sick tomorrow. Thus screening is used to detect certain individuals who hitherto thought they were well but who must now understand that they are in effect patients. This is the process, for example, in the detection and treatment of symptomless hypertension, the transition from healthy subject to patient being ratified by the giving and receiving of tablets. (Anyone who takes medicines is by definition a patient.)

What the 'high-risk' strategy seeks to achieve is something like a truncation of the risk distribution. This general concept applies to all special preventive action in high-risk individuals—in at-risk pregnancies, in small babies, or in any other particularly susceptible group. It is a strategy with some clear and important advantages (Table 1).

Table 1 Prevention by the 'high-risk strategy': advantages

1. Intervention appropriate to individual
2. Subject motivation
3. Physician motivation
4. Cost-effective use of resources
5. Benefit: risk ratio favourable

Its first advantage is that it leads to intervention which is appropriate to the individual. A smoker who has a cough or who is found to have impaired ventilatory function has a special reason for stopping smoking. The doctor will see it as making sense to advise salt restriction in the hypertensive. In such instances the intervention makes sense because that individual already has a problem which that particular measure may possibly ameliorate. If we consider screening a population to discover those with high serum cholesterol levels and advising them on dietary change, then that intervention is appropriate to those people in particular: they have a diet-related metabolic problem.

The 'high-risk' strategy produces interventions that are appropriate to the particular individuals advised to take them. Consequently it has the advantage of enhanced subject motivation. In our randomized controlled trial of smoking cessation in London civil servants we first screened some 20 000 men and from them selected about 1500 who were smokers with, in addition, markers of specially high risk for cardio-respiratory disease. They were recalled and a random half received anti-smoking counselling. The results, in terms of smoking cessation, were excellent because those men knew they had a special reason to stop. They had been picked out from others in their offices because, although everyone knows that smoking is a bad thing, they had a special reason why it was particularly unwise for them.

There is, of course, another and less reputable reason why screening enhances subject motivation, and that is the mystique of a scientific investigation. A ventilatory function test is a powerful enhancer of motivation to stop smoking: an instrument which the subject does not quite understand, that looks rather impressive, has produced evidence that he is a special person with a special problem. The electrocardiogram is an even more powerful motivator, if you are unscrupulous enough to use it in prevention. A man may feel entirely well, but if those little squiggles on the paper tell the doctor that he has got trouble, then he must accept that he has now become a patient. That is a powerful persuader. (I suspect it is also a powerful cause of lying awake in the night and thinking about it.)

For rather similar reasons the 'high-risk' approach also motivates physicians. Doctors, quite rightly, are uncomfortable about intervening in a situation where their help was not asked for. Before imposing advice on somebody who was getting on all right without them, they like to feel that there is a proper and special justification in that particular case.

The 'high-risk' approach offers a more cost-effective use of limited resources. One of the things we have learned in health education at the individual level is that once-only advice is a waste of time. To get results we may need a considerable investment of counselling time and follow-up. It is costly in use of time and effort and resources, and therefore it is more effective to concentrate limited medical services and time where the need—and therefore also the benefit—is likely to be greatest.

A final advantage of the 'high-risk' approach is that it offers a more favourable ratio of benefits to risks. If intervention must carry some adverse effects or costs, and if the risk and cost are much the same for everybody, then the ratio of the costs to the benefits will be more favourable where the benefits are larger.

Unfortunately the 'high-risk' strategy of prevention also has some serious disadvantages and limitations (Table 2).

The first centres around the difficulties and costs of screening. Supposing that we were to embark, as some had advocated, on a policy of screening for high cholesterol levels and giving dietary advice to those individuals at special risk. The disease process we are trying to prevent (atherosclerosis and its complications) begins early in life, so we should have to initiate screening perhaps at the age of ten. However, the abnormality we seek to detect is not a stable lifetime characteristic, so we must advocate repeated screening at suitable intervals.

Table 2 Prevention by the 'high-risk strategy': disadvantages

1. Difficulties and costs of screening
2. Palliative and temporary—not radical
3. Limited potential for (a) individual (b) population
4. Behaviourally inappropriate

In all screening one meets problems with uptake, and the tendency for the response to be greater amongst those sections of the population who are often least at risk of the disease. Often there is an even greater problem: screening detects certain individuals who will receive special advice, but at the same time it cannot help also discovering much larger numbers of 'borderliners', that is, people whose results mark them as at increased risk but for whom we do not have an appropriate treatment to reduce their risk.

The second disadvantage of the 'high-risk' strategy is that it is palliative and temporary, not radical. It does not seek to alter the underlying causes of the disease but to identify individuals who are particularly susceptible to those causes. Presumably in every generation there will be such susceptibles; and if prevention and control efforts were confined to these high-risk individuals, then that approach would need to be sustained year after year and generation after generation. It does not deal with the root of the problem, but seeks to protect those who are vulnerable to it; and they will always be around.

The potential for this approach is limited—sometimes more than we could have expected—both for the individual and for the population. There are two reasons for this. The first is that our power to predict future disease is usually very weak. Most individuals with risk factors will remain well, at least for some years; contrariwise, unexpected illness may happen to someone who has just received an 'all clear' report from a screening examination. One of the limitations of the relative risk statistic is that it gives no idea of the absolute level of danger. Thus the Framingham Study has impressed us all with its powerful discrimination between high and low risk groups, but when we see (Figure 3)[5] the degree of overlap in serum cholesterol level between future cases and those who remained healthy, it is not surprising that an individual's future is so often misassessed.

Often the best predictor of future major disease is the presence of existing minor disease. A low ventilatory function today is the best predictor of its future rate of decline. A high blood pressure today is the best predictor of its future rate of rise. Early coronary heart disease is better than all the conventional risk factors as a predictor of future fatal disease. However, even if screening includes such tests for early disease, our experience in the Heart Disease Prevention Project (Table 3)[6] still points to a very weak ability to predict the future of any particular individual.

This point came home to me only recently. I have long congratulated myself on my low levels of coronary risk factors, and I joked to my friends that if I were to die suddenly, I should be very surprised. I even speculated on what other disease—perhaps colon cancer—would be the commonest cause of death for a man in the lowest group of cardiovascular risk. The painful truth is that for such an individual in a Western population the commonest cause of death—by far—is coronary heart disease! Everyone, in fact, is a high-risk individual for this uniquely mass disease.

There is another, related reason why the predictive basis of the 'high-risk' strategy of prevention is weak. It is well illustrated

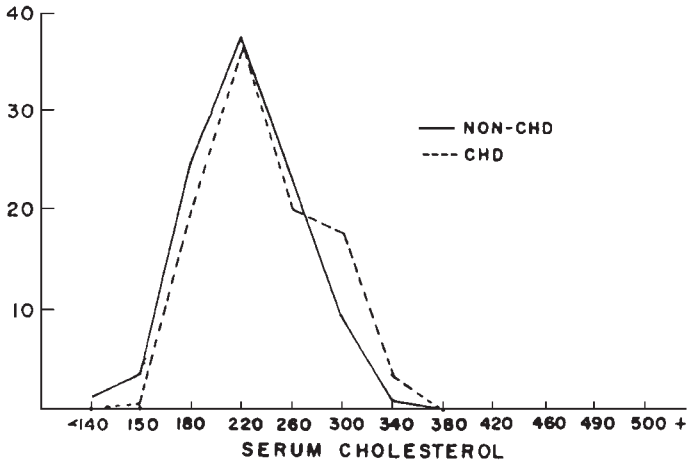

Figure 3 Percentage distribution of serum cholesterol levels (mg/dl) in men aged 50–62 who did or did not subsequently develop coronary heart disease (Framingham Study[5])

Table 3 Five-year incidence of myocardial infarction in the UK Heart Disease Prevention Project

Entry characteristic	% of men	% of MI cases	MI incidence rate %
Risk factors alone	15	32	7
'Ischaemia'	16	41	11
'Ischaemia' + risk factors	2	12	22
All men	100	100	4

Table 4 Incidence of Down's syndrome according to maternal age[7]

Maternal age (years)	Risk of Down's syndrome per 1000 births	Total births in age group (as % of all ages)	% of total Down's syndrome occurring in age group
<30	0.7	78	51
30–34	1.3	16	20
35–39	3.7	5	16
40–44	13.1	0.95	11
≥45	34.6	0.05	2
All ages	1.5	100	100

by some data from Alberman[7] which relate the occurrence of Down's syndrome births to maternal age (Table 4). Mothers under 30 years are individually at minimal risk; but because they are so numerous, they generate half the cases. High-risk individuals aged 40 and above generate only 13% of the cases.

The lesson from this example is that *a large number of people at a small risk may give rise to more cases of disease than the small number who are at a high risk*. This situation seems to be common, and it limits the utility of the 'high-risk' approach to prevention.

A further disadvantage of the 'high-risk' strategy is that it is behaviourally inappropriate. Eating, smoking, exercise and all our other life-style characteristics are constrained by social norms. If we try to eat differently from our friends it will not only be inconvenient, but we risk being regarded as cranks or hypochondriacs. If a man's work environment encourages heavy drinking, then advice that he is damaging his liver is unlikely to have any effect. No-one who has attempted any sort of health education effort in individuals needs to be told that it is difficult for such people to step out of line with their peers. This is what the 'high-risk' preventive strategy requires them to do.

Table 5 Prevention by the 'population strategy': advantages

1. Radical
2. Large potential for population
3. Behaviourally appropriate

The Population Strategy

This is the attempt to control the determinants of incidence, to lower the mean level of risk factors, to shift the whole distribution of exposure in a favourable direction. In its traditional 'public health' form it has involved mass environmental control methods; in its modern form it is attempting (less successfully) to alter some of society's norms of behaviour.

The advantages are powerful (Table 5). The first is that it is radical. It attempts to remove the underlying causes that make the disease common. It has a large potential—often larger than one would have expected—for the population as a whole. From Framingham data one can compute that a 10 mm Hg lowering of the blood pressure distribution as a whole would correspond to about a 30% reduction in the total attributable mortality.

The approach is behaviourally appropriate. If non-smoking eventually becomes 'normal', then it will be much less necessary to keep on persuading individuals. Once a social norm of behaviour has become accepted and (as in the case of diet) once the supply industries have adapted themselves to the new pattern, then the maintenance of that situation no longer requires effort from individuals. The health education phase aimed at changing individuals is, we hope, a temporary necessity, pending changes in the norms of what is socially acceptable.

Table 6 Prevention by the 'population strategy': disadvantages

1. Small benefit to individual ('Prevention Paradox')
2. Poor motivation of subject
3. Poor motivation of physician
4. Benefit: risk ratio worrisome

Unfortunately the population strategy of prevention has also some weighty drawbacks (Table 6). It offers only a small benefit to each individual, since most of them were going to be all right anyway, at least for many years. This leads to the *Prevention Paradox*:[8] 'A preventive measure which brings much benefit to the population offers little to each participating individual'. This has been the history of public health—of immunization, the wearing of seat belts and now the attempt to change various life-style characteristics. Of enormous potential importance to the population as a whole, these measures offer very little—particularly in the short term—to each individual; and thus there is poor motivation of the subject. We should not be surprised that health education tends to be relatively ineffective for individuals and in the short term. Mostly people act for substantial and immediate rewards, and the medical motivation for health education is inherently weak. Their health next year is not likely to be much better if they accept our advice or if they reject it. Much more powerful as motivators for health education are the social rewards of enhanced self-esteem and social approval.

There is also in the population approach only poor motivation of physicians. Many medical practitioners who embarked with enthusiasm on anti-smoking education have become disheartened because their success rate was no more than 5 or 10%: in clinical practice one's expectation of results is higher. Grateful patients are few in preventive medicine, where success is marked by a non-event. The skills of behavioural advice are different and unfamiliar, and professional esteem is lowered by a lack of skill. Harder to overcome than any of these, however, is the enormous difficulty for medical personnel to see health as a population issue and not merely as a problem for individuals.

In mass prevention each individual has usually only a small expectation of benefit, and this small benefit can easily be outweighed by a small risk.[8] This happened in the World Health Organization clofibrate trial,[9] where a cholesterol-lowering drug seems to have killed more than it saved, even though the fatal complication rate was only about 1/1000/year. Such low-order risks, which can be vitally important to the balance sheet of mass preventive plans, may be hard or impossible to detect. This makes it important to distinguish two approaches. The first is the restoration of biological normality by the removal of an abnormal exposure (e.g. stopping smoking, controlling air pollution, moderating some of our recently-acquired dietary deviations); here there can be some presumption of safety. This is not true for the other kind of preventive approach, which leaves intact the underlying causes of incidence and seeks instead to interpose some new, supposedly protective intervention (e.g. immunization, drugs, jogging). Here the onus is on the activists to produce adequate evidence of safety.

Conclusions

Case-centred epidemiology identifies individual susceptibility, but it may fail to identify the underlying causes of incidence. The 'high-risk' strategy of prevention is an interim expedient, needed in order to protect susceptible individuals, but only for so long as the underlying causes of incidence remain unknown or uncontrollable; if causes can be removed, susceptibility ceases to matter.

Realistically, many diseases will long continue to call for both approaches, and fortunately competition between them is usually unnecessary. Nevertheless, the priority of concern should always be the discovery and control of the causes of incidence.

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