Principles and Effects of Mass Screening: Danish Experience in Tuberculosis Screening

MASS SCREENING has occupied an increasingly significant role among health services since World War II. Ranging from examinations for all diseases (for example, the routine examination of infants) to disease-specific testing, such screening has either been directed at the total population or restricted to population groups delimited by age, occupation, or social stratum. All these mass screening efforts have two things in common: they take a great amount of time, and they generally disclose a small number of cases. Therefore, for physicians, for nurses, and for the general population as well, preventive casefinding has acquired the character of a sterile routine. In a time when health resources, both manpower and money, are limited, there is a crying need for selective screening aimed at the high-risk groups in the general population. In this paper, the principles of screening, some measures of the effect of screening, and some of its negative aspects are illustrated in relation to tuberculosis. The clinical and epidemiologic features of this disease make it an excellent paradigm for many public health problems.

Present Danish Tuberculosis Program

At the beginning of this century, tuberculosis was almost epidemic in Denmark; about 1 percent of the population suffered from phthisis, and it caused one-sixth of all deaths. At that time, the immediate problem, therefore, was to provide care for the thousands of patients who needed it. Because, however, the results of treatment were so poor, increasing weight had to be placed on prophylactic work. Transmission of infection was controlled by isolating patients in hospitals and sanatoriums; immunity was increased through BCG vaccination. Chest clinics were created to conduct this work, and following a small beginning immediately after the turn of the century, a nationwide system of such clinics was established all over Denmark. Most of them were built in the years 1935–46, and there are now 84, all connected to local hospital systems. In addition, seven mobile X-ray units serve the population.

A prime function of the chest clinics was to serve as diagnostic centers. In the beginning, the clinic staff examined only patients referred, because of their symptoms, by primary care physicians. Since in these patients, however, tuberculosis was often far advanced, the clinics began to examine the general population in order to diagnose cases earlier, when the chances of recovery were better. Initially, this type of screening covered only a limited number of people, but the number covered has been rising continually, increasing from 870,000 in 1955 (the first year for which complete statistics are available) to 934,000 in 1972. At the same time, the actual number of tuberculosis cases found through mass screening has been decreasing, from 452 in 1952 to 180 in 1972. In addition to this screening, which mainly covered persons gainfully employed, mass screening programs during the years 1946–58 were directed toward the total

☐ *Dr. Horwitz is the director of the Danish Institute of Clinical Epidemiology (formerly the Danish Tuberculosis Index), Copenhagen. Dr. Darrow, who at the time the paper was written was with the Tuberculosis Control Division, Center for Disease Control, Atlanta, Ga., is now a health services representative with Regional Office IV of the Public Health Service. Tearsheet requests to Dr. Marilyn Darrow, U.S. Public Health Service, Regional Office IV, 50 Seventh St., NE, Atlanta, Ga. 30032.*

Figure 1. Distribution of 836,800 adults examined for tuberculosis in 1972 in Danish chest clinics, by reason for examination

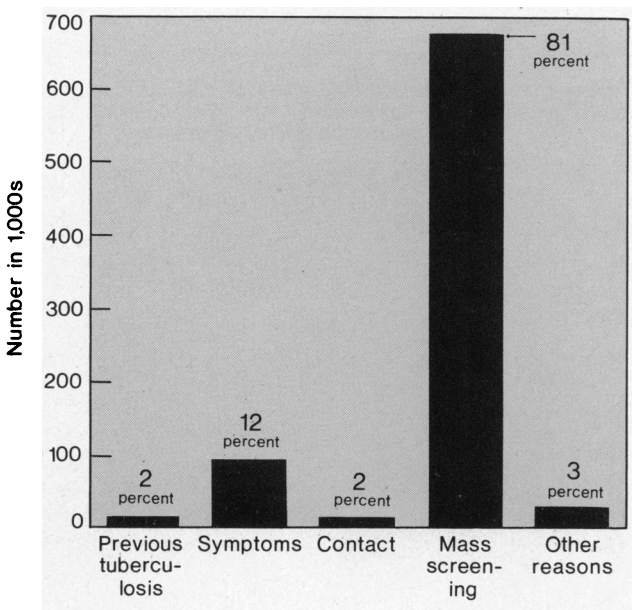
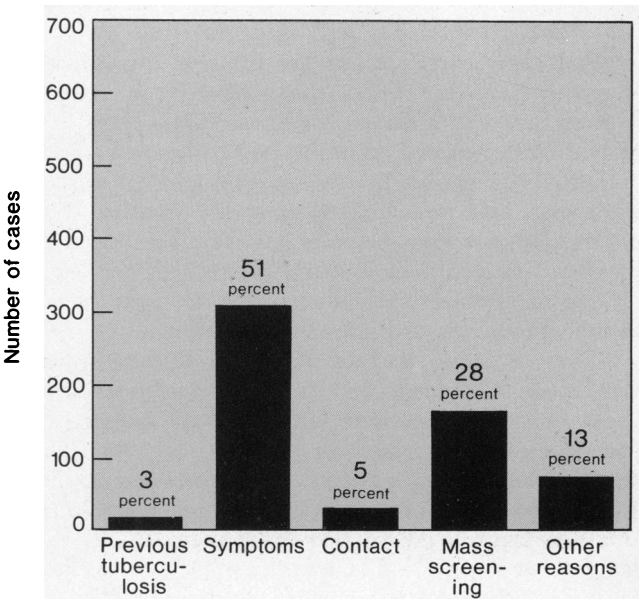


Figure 2. Distribution of 599 cases of tuberculosis among adults examined for the disease in 1972 in Danish chest clinics, by reason for examination



population. They covered about 2 million persons and disclosed 2,000 cases. These programs also served as vaccination campaigns, since all persons found to be tuberculin-negative were offered BCG vaccinations (*1,2*).

In 1972, a total of 933,500 persons were examined in all the chest clinics. Of these, 96,700 were children under 15 years of age; 836,800 were adults. Figure 1 shows the reasons why the adults reported to the chest clinics. Two percent were previous patients being followed in the clinics; 12 percent had been referred because of their symptoms; 2 percent had been in contact with a tuberculosis patient; 81 percent appeared because of the mass screening; finally, 3 percent were examined for other reasons.

Figure 2 shows the number of cases of pulmonary tuberculosis that were found in each of the five groups.

In all, 59 percent of the cases found were among previous patients, contacts of persons with tuberculosis, and persons with symptoms. The persons with symptoms made up by far the greatest part of the patients; mass screening accounted for 28 percent.

Figure 3 shows the incidence of tuberculosis per 1,000 examinees in the five groups. The case rate was highest in the symptoms group, 3.3 per 1,000; it was lowest in the group that had been mass screened, 0.2 per 1,000. In other words, 1 case was found among every 300 persons with symptoms, whereas in the mass-screened group only 1 case was observed per 4,000. The cases that were found through symptoms usually were the most serious; two or three times as many of these patients had cavitary disease as the patients found through routine examinations; this ratio has remained unchanged since the 1960s (*2*). Whereas formerly early diagnosis was critical, with modern chemotherapy the prognosis is now fairly good even for persons with severe cases (*3*).

In summary, one can conclude that persons with symptoms, persons with a history of tuberculosis, and the contacts of tuberculosis patients have the highest morbidity, account for the largest part of the caseload, and represent the most serious disease. One can also conclude that the persons who are mass-screened place the greatest burden on the clinics, have the lowest morbidity rates, and represent the mildest cases. When these facts are brought out, however, an opposing argument often comes up—that the true value of routine chest examinations lies in their capability of diagnosing diseases other than tuberculosis. Ideally, persons in whom a disease is diagnosed at a chest clinic should be distributed according to the means by which the case was detected, whether through the person's symptoms, mass screening, or some other method. Such a procedure was not feasible, however, because of the workload it would have entailed. Instead, the clinics agreed to establish special reporting for lung cancer, chronic bronchitis, asthma, and sarcoidosis.

Figure 4 shows that of 905 cases of lung cancer diagnosed, 90 percent were found by means of symptoms; only 7 percent were found through mass screening. Even if the prognosis is better for the mass-screened lung cancer patients, there are so few of them that the impact of the detection of their cases on the total incidence of lung cancer in Denmark (2,000 cases per year) is negligible. The results for chronic bronchitis, asthma, and sarcoidosis showed the same pattern as those for lung cancer (*2*).

Mass screening in its present form is unsatisfactory. The question is, How can it be improved? The Danish mass survey of 1950–52 was planned to assess the risk of tuberculosis in different groups of the normal population. In the diagram in figure 5 (bar at top), the 286,250 natural tuberculin reactors aged 15-44 years at the time of the campaign are divided by their initial X-ray results. Persons previously vaccinated with BCG have been excluded (*4*). As the diagram

Figure 3. Incidence of tuberculosis among adults examined for the disease in 1972 in Danish chest clinics, by reason for examination

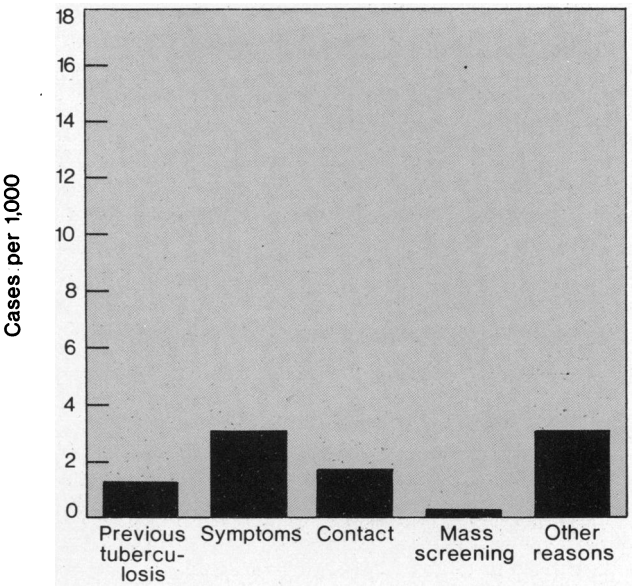
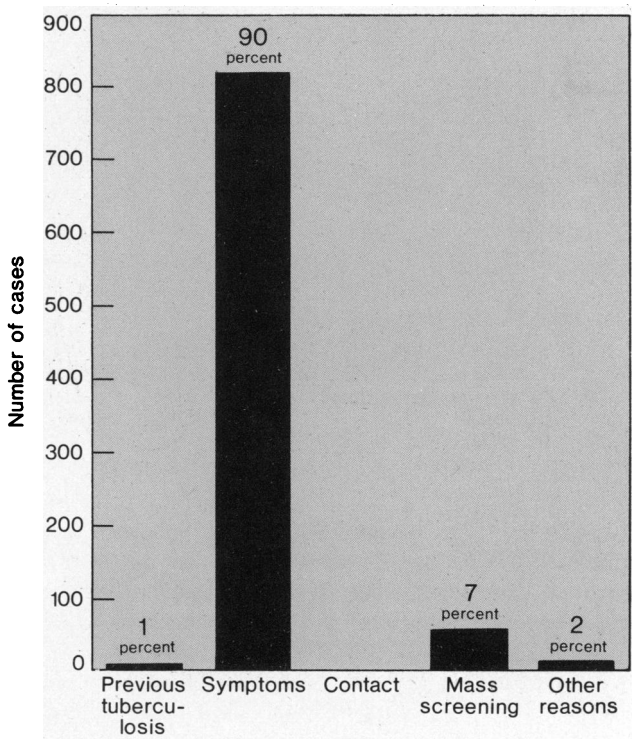


Figure 4. Distribution of 905 cases of lung cancer among adults examined for tuberculosis in 1972 in Danish chest clinics, by reason for examination



shows, a small group of the reactors had suspicious X-ray lesions; a somewhat larger group had inactive lesions (fibrotic or calcified); 93 percent had normal lungs. The pie chart in the middle of the diagram represents the cases of pulmonary tuberculosis that were diagnosed during the 16 years of followup. Of these 1,133 cases, 136 (12 percent) originated among the persons with suspicious lesions and 130 (11 percent) among those with inactive lesions, but 867 cases (77 percent) originated in the group with normal X-ray results. As for annual morbidity (bottom line of the diagram), the persons with suspicious lesions had the highest rate, and the persons with normal lungs had the lowest. Even if all the cases of tuberculosis among the persons with suspicious lesions had been prevented by chemoprophylaxis (as a result of prior identification through a campaign covering a million people), tuberculosis would have been reduced by only one-tenth. Moreover, because, prophylaxis actually fails in a number of cases, ranging from 12 to 85 percent in different trials (*5*), its actual effect would have been even smaller.

Most cases of tuberculosis arise among persons with normal lungs, whose annual incidence of 0.2 case per 1,000 is too low to warrant action. To identify any possible subgroup with a high incidence, the normal group was divided according to a series of factors such as sex, age, tuberculin reaction, and exposure. This analysis disclosed some differences among the subgroups in incidence, ranging from zero to 0.6 case per 1,000 (*4,6*). None of the subgroups, however, had a morbidity high enough to justify regular control, not to mention chemoprophylaxis.

The problem has to be attacked from a different angle. One possibility is the one shown in figure 6. This figure is based on all cases of pulmonary tuberculosis reported in Danish males in the years 1960–68 (*7*), divided by the patients' residence, age, and marital status. The figure contrasts the morbidity of middle-aged unmarried men in Copenhagen with that of married men in rural districts, showing that the unmarried urban men had a rate eight times higher. Even though the number of urban unmarried men is small, the morbidity of this group is so high that no

Figure 5. Incidence of tuberculosis among 286,250 natural tuberculin reactors during 16-year followup of 1950–52 Danish mass campaign, by initial X-ray results

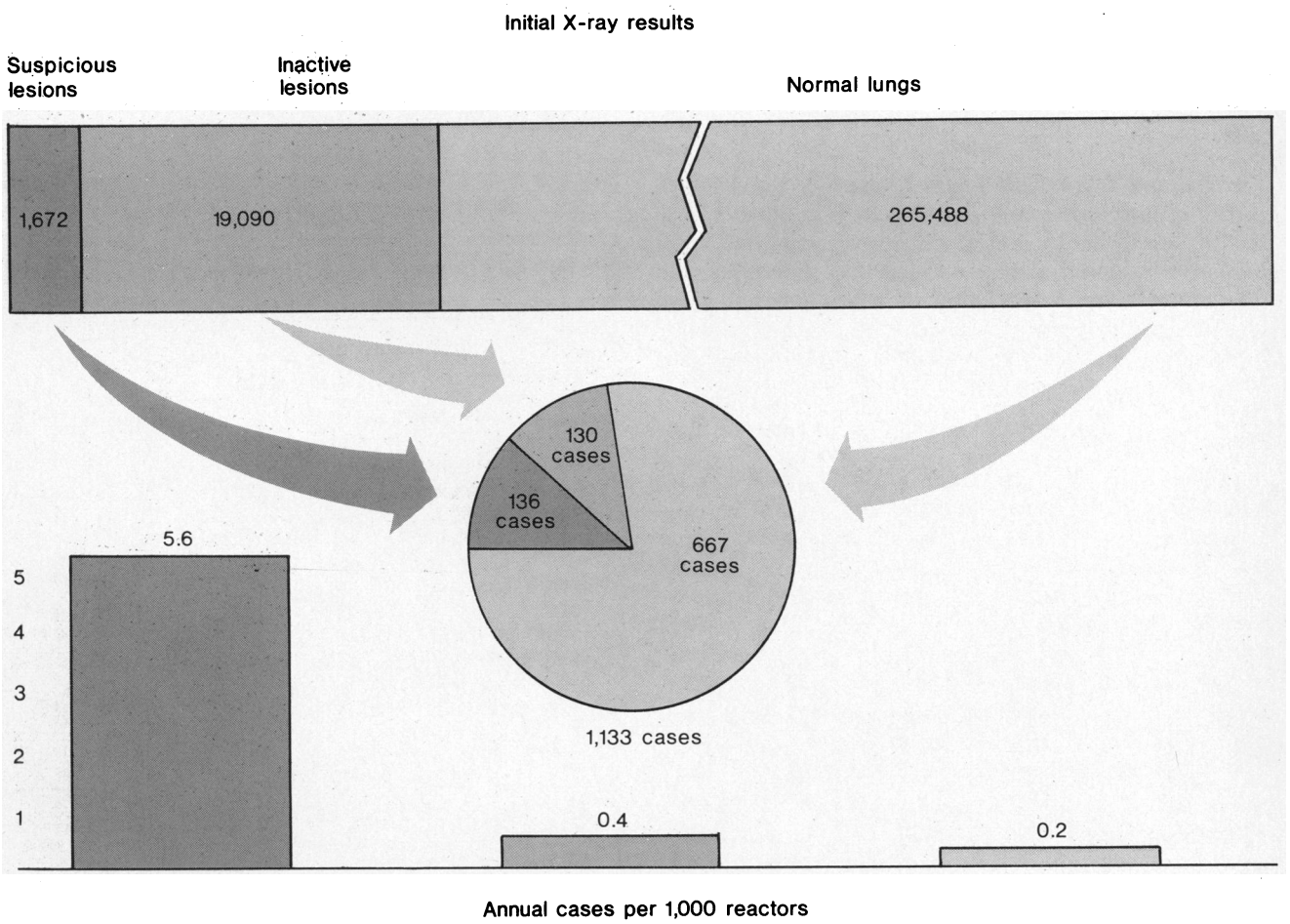
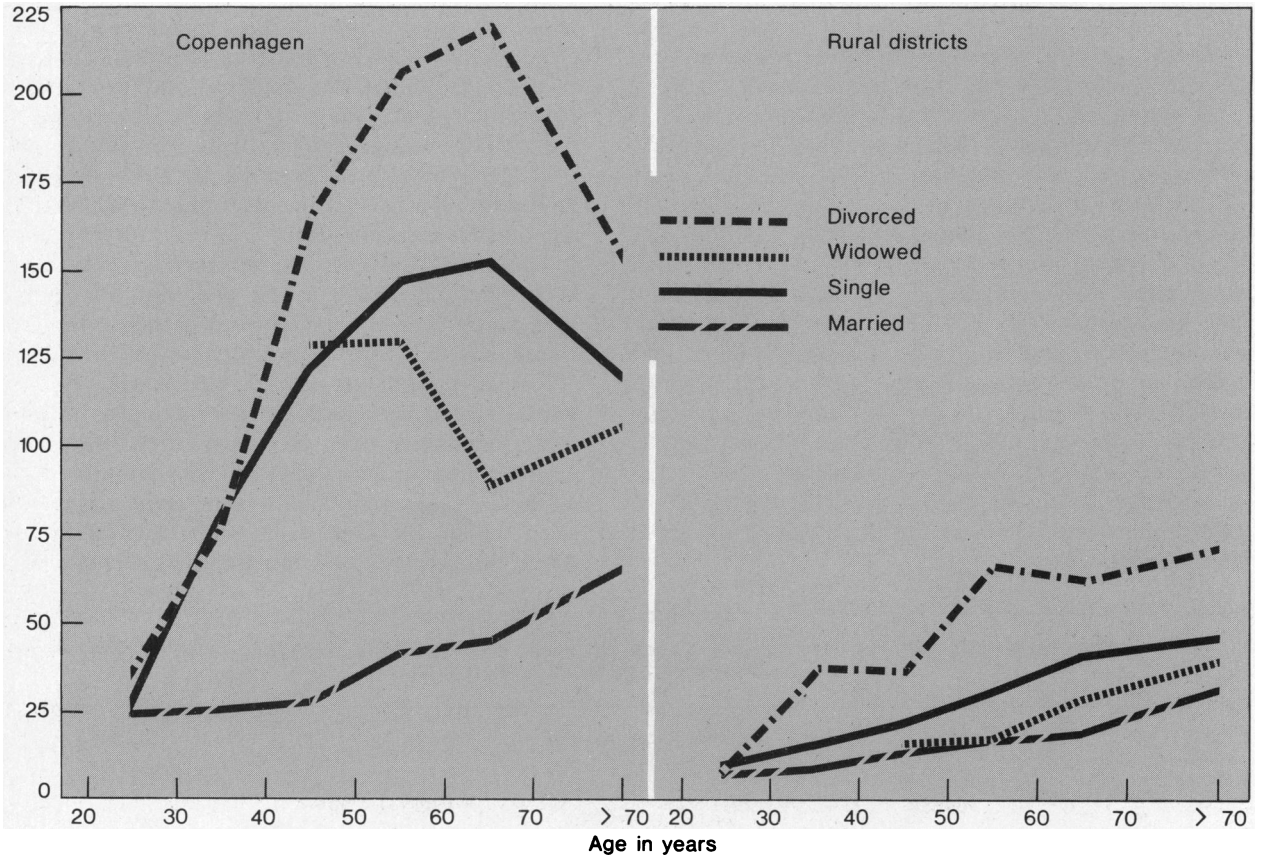


Figure 6. Average annual incidence of respiratory tuberculosis among men in Denmark, 1960–68, by residence, age, and and marital status



less than one-third of all tuberculosis cases among men in Copenhagen arise from it. Thus, it is an ideal group for the chest clinics' casefinding programs (see next section). It should also be stressed that the unmarried man suffers from a succession of other illnesses, as is reflected in his general mortality. Thus, he needs a wide-spectrum medical examination, one very different from the kind given today.

Future Program

A risk group that is to be subjected to selective screening must fulfill three requirements: (*a*) it must be easy to identify, for example, by applying electronic data processing methods to population registers or hospital records; (*b*) it must be small enough so that its members can be brought in for screening since, as is well known, the people who stay away often have the highest morbidity; and (*c*) its morbidity rate must be high enough that the group will produce a significant number of cases, since otherwise their prevention would have no impact on the overall incidence.

The table "Future tuberculosis program in Denmark" shows the groups that fill these three requirements (based on existing data), and they were therefore selected by the Danish National Health Service's special

Future tuberculosis program in Denmark

Groups to be screened	*Population (In 1,000s)*	*Cases*[1]	*Rate per 1,000*
Persons referred because of symptoms	93	315	3.4
Risk groups:[2]			
Contacts of tuberculosis patients	20	31	1.6
Previous patients without chemotherapy	20	83	4.2
Foreign workers	40	33	0.8
Single males	23	18	0.8
Danger groups[3]	16	2	0.1
Other groups:[4]			
Teachers, upon employment	2	0	0.1
Fishermen and sailors	25	11	0.4
Employees in food industry	20	6	0.3
Home help, home nurses, day nurses, and so forth	10	2	0.2
Total	269	501	1.9

[1] At present, based on existing data.
[2] Groups that should be subject to casefinding programs because of their high annual rates, that is, approximately 1 case or more per 1,000.
[3] Persons who should be axamined because, if infected, they would be dangerous to others (for example, midwives).
[4] Persons who must be examined under existing Danish laws (2).

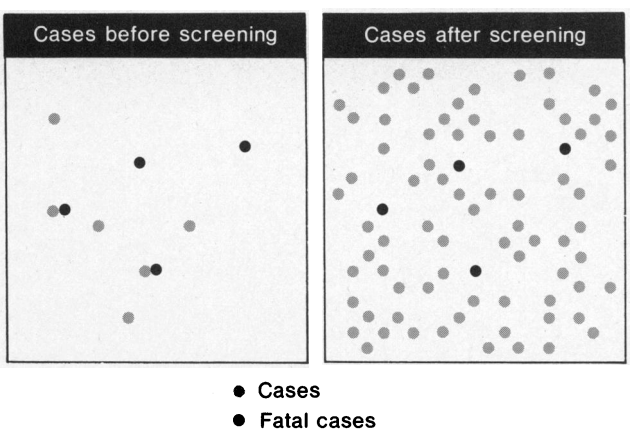
committee as the targets for screening. The projected screening program would include, in all, 269,000 persons—70 percent fewer than the present one. Yet, as the table shows, it would identify most of the annual tuberculosis caseload in Denmark.

Evaluation of a Program's Effect

Figure 7 shows a hypothetical population group of 1,000 persons. Cases of definite disease occur in eight persons, of whom four die, so that the mortality rate is 50 percent. If mass screening were to be carried out in this population, it would raise the figures. Some cases would be found earlier, and some illnesses that normally would never come to light would be disclosed. Let us assume that the number of fatal cases is unchanged; that is, there are still four. Although it appears now that the prognosis for the illness is getting much better, since the mortality among patients has dropped from 50 percent to 5, this is only an apparent improvement. From a public health standpoint, conditions are entirely unchanged since the number of lethal cases is the same. The mortality in the normal population is unchanged in spite of the mass campaign. In other words, the effect of a mass campaign should not be assessed by the number of cases diagnosed and the number of patients put on treatment but by an "independent" parameter that actually measures the public's health.

The Danish mass campaign of 1950–52 was directed at 729,802 persons 15–44 years of age. A large part of this group, 463,009 persons (or 63 percent), participated in the screening. When the index cards for both the group that participated and the group that did not were compared with all death certificates in Denmark for a 12-year followup period, the mortality from tuberculosis among participants was found to be much lower than that among the persons who failed to appear for screening (fig. 8).

Figure 7. Case yield of mass screening for tuberculosis in a hypothetical population of 1,000 persons



Assuming that this difference was due to the mass campaign (early diagnosis and vaccination), we can calculate that during the followup period 50 fatal cases of tuberculosis were prevented among the participants (*8*).

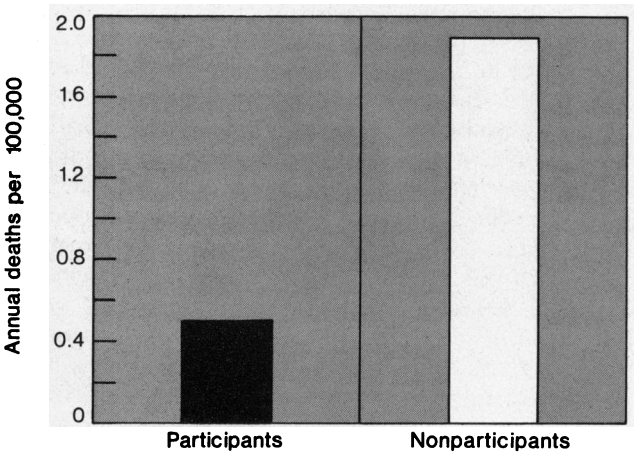
For each of these 50 persons, the campaign had great significance. From the country's point of view, however, the rescue action required the organization of a nationwide campaign covering three-quarters of a million persons, the examination and vaccination of half a million participants, the followup of 1,672 suspects, and so forth. Also, it required a large indirect expenditure, since the half million participants had to appear twice for the tuberculin test, and each probably spent 1 or 2 hours taking them. As a group, they thus probably invested 1 to 2 million hours in the mass survey, time that was often withdrawn from productive work. There was also a considerable expenditure for investigation of suspicious results. In addition, the procedures may have placed an emotional burden on some patients. Finally, there was the expense of treating people who would have recovered spontaneously. Moreover, the risk from radiation should be mentioned; there is a personal risk to the patient in that about 4 cases of cancer occur per 1 million exposures (*9*), and there is an additional risk to the gene pool.

The following table demonstrates the estimated percentage reductions in mortality in various groups that can be attributed to the campaign, based on the assumption that 50 deaths were prevented.

Deaths (expected or actual numbers)	*Percentage reduction (estimated)*
From tuberculosis among campaign participants (75 expected)	67
From tuberculosis among persons eligible for campaign (136 expected)	37
From all causes among participants (4,973 actual)	1
From all causes among persons eligible for campaign (8,775 actual)	1
From tuberculosis in all Denmark (3,019 actual)	2
From all causes in all Denmark (492,532 actual)	0

As the table shows, if the 50 tuberculosis deaths prevented by the campaign are compared with the 75 deaths from tuberculosis that would ordinarily have been expected among the campaign participants, the effect of the campaign in reducing tuberculosis mortality was 67 percent. The object of the campaign, however, was to cover all people 15 to 34 years. It would therefore be more relevant to evaluate the campaign's effect by relating the 50 tuberculosis deaths that it prevented to the 136 tuberculosis deaths that normally would have occurred in the target population, an evaluation that gives a percentage reduction in tuberculosis mortality of 37 percent. It is reasonable also to assess the campaign's effect from a still broader stand-

Figure 8. Mortality from tuberculosis among participants and nonparticipants in Danish mass campaign during 12-year followup



point—the effect on overall mortality. Since among the campaign participants, 4,973 persons died of all causes in the course of the followup period, the effect of the campaign on the reduction of overall mortality among participants was 1 percent. When the 50 deaths prevented are compared with all deaths in the target population, the effect of the campaign is found to be less than 1 percent. A comparison of the 50 deaths prevented with all tuberculosis deaths that took place in Denmark in the same period (3,019) shows that the effect of the campaign on the reduction of tuberculosis mortality was 2 percent; when compared with deaths in Denmark from all causes, the effect is found to be 0 percent.

One might object to this analysis on the grounds that mortality alone is not a sufficient indicator, that the quality of life ought also to be taken into account. In other words, it might have been better to measure the campaign's effect on morbidity, for example, by studying changes in the frequency of cases of bilateral cavitary disease. The effect of the mass campaign could have been measured by this parameter if one geographic area had received mass screening and another area had not. The effect of the program would then have manifested itself through lower bilateral cavitary disease rates in the ensuing period. Since, however, all Denmark was covered by the mass screening program, no control area was available, and nonparticipants had to be used as a standard. The nonparticipants differed a little from the participants in sex and age, but we corrected for these differences. The nonparticipants, however, distinguished themselves in other ways; more of them were sickly, as is evidenced by their excess mortality from all diseases (fig. 9). The tuberculosis mortality rate among the nonparticipants could be corrected for the general excess in deaths that was observed so that it would be directly comparable with the rate for participants. Because, however, there is no generally accepted index for the health status of a population, no corresponding correction factor for tuberculosis morbidity could be established, and meaningful comparisons could not be made.

Benefits and Costs of Present Program

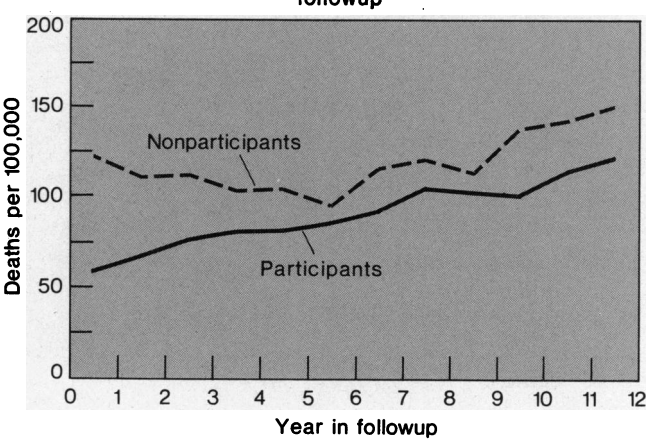
An economic evaluation of the benefits and costs of the present mass screening program in Denmark is essential since funds available for the health sector are limited or are being reduced.

The following table shows the benefits and costs of mass screening.

Relationship of benefits to costs	*Value in million Danish kroner*
Benefits	
Early diagnosis	1 to 2
Decreased infection rate	?
Total benefits	1 to 2
Costs	
Administration	?
X-ray screening	23
Tuberculin testing	0
Followup of suspects	?
Treatment of lesions that would have healed spontaneously	?
"False negatives"	?
Patients whose diagnosis was delayed until screening	?
Radiation hazard	?
Lost working hours	42
Total costs	65
Balance (benefits minus costs)	−63 to −64

The first benefit listed is "early diagnosis." When cases are found earlier, less money is spent on hospitalization, disability pensions, and so forth. The value of this benefit, as the preceding table shows, is estimated to be 1 to 2 million Danish kroner. The second benefit

Figure 9. Mortality from all cases among participants and nonparticipants in Danish mass campaign during 12-year followup



is a "decreased infection rate," which results from faster removal of people from the reservoir of infective patients. According to present knowledge (*10*), the average patient infects about three other persons. Thus, for every 100 persons whose cases are diagnosed, about 300 infections are prevented. The morbidity among the infected, however, is so low that the value of this benefit is negligible.

The figures for the costs of mass screening that are known are shown in the table. The large number of unknown costs (indicated by a question mark) reflects a shortcoming in health systems management that will need to be overcome when new programs are launched.

Among the costs for which the figures are not known is one for administration (for example, telephoning patients and clerical work). The 23 million kroner for X-ray screening includes the cost of film, technicians, and reading. Again, the cost for followup of suspects is unknown. In the Danish mass campaign of 1950–52, fully 69 percent of the persons with suspicious lesions upon X-ray examination turned out to be healthy (*11*). The cost is also unknown for the treatment of patients whose lesions would have healed spontaneously. In this connection, only 8 percent of the persons classified as "suspects" in the Danish mass campaign of 1950–52 contracted tuberculosis during the 16 years of followup (compare figure 5). The remaining 92 percent would therefore not have benefited from treatment. False negatives are the patients who actually had tuberculosis at the time of the examination but were overlooked. In the Danish mass campaign, 19 percent of the tuberculosis cases were missed by the local reader (*11*). The patients whose diagnosis was delayed until the time of screening actually had symptoms but did not go to their family physicians because they expected to participate in the mass screening. "Radiation hazard" implies a personal risk as well as a risk to the gene pool. As to "lost working hours," each worker's trajectory between leaving his job and resuming productive work was estimated to take an average of 1 to 2 hours. As a result, 1 to 2 million working hours were lost every year, which cost a good 40 million Danish kroner.

The balance between benefits and costs (bottom line of preceding table) is negative—minus 63 or minus 64 million kroner.

Summary and Conclusion

When the long-range effect of the current mass screening for tuberculosis in Denmark is evaluated by means of an independent parameter (mortality), its impact on the public's health is found to be almost nil. When the program's economic costs and benefits are estimated, the balance is negative.

A mass screening program helps the patients whose disease is diagnosed at an early stage. It also may disclose clinically silent disease and prevent disability and early death. Expenditures for nursing care may be reduced through it, and the productivity of the labor force increased. The transmission of communicable disease also is reduced.

The disadvantages of a mass campaign, however, are many. They include the false positives and false negatives, as well as the treatment of patients who would normally have gotten well spontaneously. Also, a medical examination is an emotional burden for many people; the demonstration of an incipient or healed lesion may cause a long-standing neurosis. Some examinations, such as roentgenographic, may have harmful physical effects. A mass program entails direct expenditures for administration and medical and technical personnel. Indirect costs are also incurred, since many screening programs operate during the general population's working hours.

In determining the benefits and disadvantages of a screening program, all the pertinent factors need to be considered. Epidemiology, statistics, and economics all should be represented when a program is evaluated. Only after weighing the total impact, costs, and benefits against all the other needs of the community can the priorities for a future mass screening program be determined.

The selective, future program for Denmark that is outlined in this paper is expected to reduce the scope of tuberculosis examinations by 70 percent and still identify most of the present caseload.

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