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HISTORICAL PAPER

THE AGE SELECTION OF MORTALITY FROM TUBERCULOSIS IN SUCCESSIVE DECADES[1]

By

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As we pass along the age-scale from infancy through childhood, to early adult life, and on to old age, the curve of mortality from tuberculosis shows a continuous movement either upward or downward. This is such a familiar fact that we are apt to take it for granted; to dismiss it as characteristic of the dis-

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[2] This material was assembled by Dr. Frost in 1936 and presented before the Southern Branch of the American Public Health Association. At the time of his death in 1938, it remained unpublished. Because of fundamental implications in regard to the interpretation of age specific mortality rates and particularly in regard to the reaction of the human host to tuberculous infection, his notes are herewith made available, together with the table showing the basic data used in the report.

[3] The following quotation from a letter dated July 29, 1935, to the late Dr. Edgar Sydenstricker from Dr. Frost, is self-explanatory and is reproduced here as a document of scientific as well as historical interest.

" . . . Using the Massachusetts data which you so kindly sent me, extended by the calculation of corresponding rates for 1920 and 1930, I have made up the two enclosed tables which have interested me and may be of interest to you.

"In table 1 the striking fact other than the consistent decline in mortality at every age is the progressive advancement to higher and higher ages of the peak of mortality; in 1880 the peak (or more properly the first peak) in adult life is at age 20–29, whereas, in 1930 it is in the age group 50–59. The same kind of change is, as you know, quite generally shown in other areas.

"For some years I have thought of the high mortality in later life as being related to *escape* from excessive mortality in earlier adult life. I have been thinking of the tuberculosis of today as a disease which has not the killing power to cause much mortality in the vigor of young adult life but becomes fatal in middle age or later when vital resistance has declined. It has seemed to me that it was approaching the age-selection of pneumonia—fatal chiefly at the extremes of life, non-fatal in the more vigorous ages.

"In table 2 I have set up the mortality rates in a different way, in order to show, through successive ages, the mortality of the 'cohorts' of persons who were aged 0–9 years in 1880, 1890, 1900, etc. Thus, persons aged 0–9 in 1880 would be aged 10–19 in 1890, 20–29 in 1900 and so on until in 1930 they would be in the age group 50–59. With this rearrangement table 2 shows what should have been but was not obvious to me from table 1, namely, that in each *cohort*, followed through in this way, the highest mortality has been at the age 20–29. This is perhaps more readily seen from the rough pencil graph which is enclosed.

"Viewed in this light the relatively high mortality rates now exhibited in the higher age groups seem to me to have a significance quite different from what I had attributed to them. They may be interpreted as the residuum of the much higher rates which the now aged cohorts have experienced in earlier life. In general, the rule seems to be that the higher the mortality of any cohort in early life, the higher will it be in later years. Or, to have passed through a period of high mortality risk confers not protection, but added hazard in late life.

"The only other data which I have been able to study so far are for England and Wales, 1850–1930, and for the U. S. Registration Area of 1900, for the years 1900–1930. They show substantially the same relations as the Massachusetts data; also, the records for females show much the same thing, but with a more pronounced peak at the earlier age. I want to get together material for a somewhat more orderly study later.

"All of this seems to me to have a bearing on the question which is raised in the MS I sent you a few days ago—namely, how much if any we may expect adult mortality to be increased as the result of diminished infection in the favor-

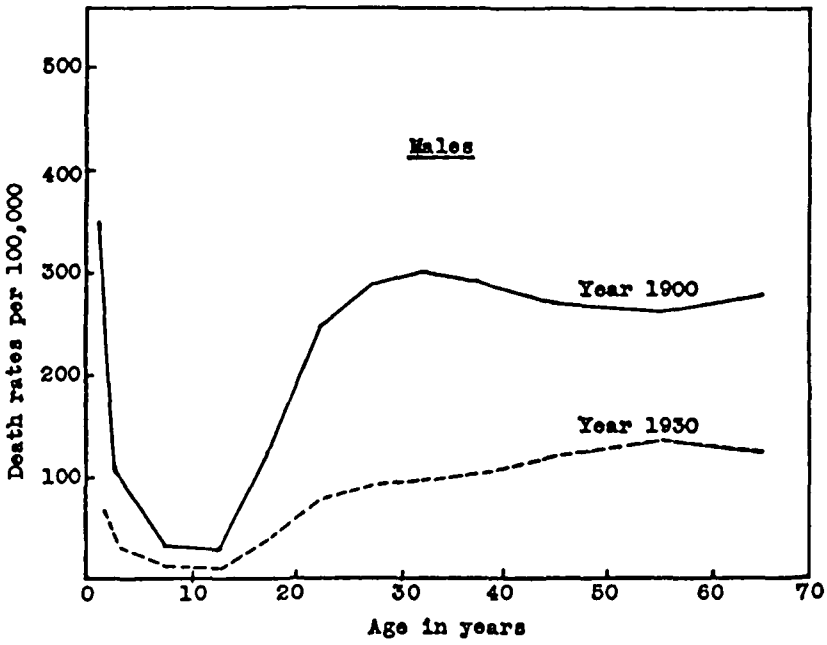

FIGURE 1. U. S. Registration Area of 1900 death rates from tuberculosis—all forms—by age, 1900 and 1930.

ease, and to pass on. But there is perhaps no single statistical record which is potentially of more significance. For every change in the rate of mortality as we pass from one age to another represents a shift in the balance established between the destructive forces of the invading tubercle bacillus, and the sum total of host-resistance. If we could accurately interpret this record, analyzing in detail each movement upward or downward and assigning to each factor its due share in the change, then we would be well on the way to knowing the epidemiology of tuberculosis.

But the record is peculiarly difficult to read with understanding, because it is immediately apparent that the most striking changes in mortality rate do not correspond to reasonably probable changes of like extent in rate of *exposure* to infection. For instance, nothing that we know of the habits of mankind and the distribution of the tubercle bacillus would lead us to suppose that between the first and the second 5 years of life there is, in general, a *diminution* in exposure to infection which corresponds to the decline in mortality rate. And there is little, if any, better reason to suppose that the extraordinary rise in mortality from age 10 to age 20, 25 or 30 is paralleled by a corresponding increase in rate of exposure to specific infection.

We are forced, then, to recognize, as at least highly probable, that the predominant factor in the up-and-down movement of mortality along the age scale is change in human resistance. And this is a complex of which we have very little exact knowledge except the plain fact that age and prior exposure

able years of childhood—from age 3 to 12. It also seems to me to have a bearing on the moot question whether the tuberculosis of adult life is almost wholly exogenous—due to recently acquired infection—or to a considerable extent endogenous—the outcropping to clinical severity of infection which has remained latent or smoldering through the childhood years when vital resistance seems to be at its height. . . ."

bring no such immunity against tuberculosis as they establish against many of the acute infections.

However, my purpose is not to attempt an interpretation of the age selection of tuberculosis; it is merely to call attention to the apparent change in age selection which has taken place gradually during the last 30 to 60 years, and to note that when looked at from a different point of view this change in age selection is found to be more apparent than real. The age specific curve of mortality from tuberculosis for males in the United States Registration Area of 1900 is shown for the years 1900 and 1930 in figure 1 and for Massachusetts males for the years 1880, 1910 and 1930 in figure 2.

The tuberculosis mortality rates for Massachusetts used throughout this paper are shown in table 1. You will note that:

1. At every age mortality is lower in the later period.
2. In each period age selection is generally similar: mortality is high in infancy; declining in childhood; rising in adolescence to a higher level in adult life.
3. In the later period (1930) the highest rate of mortality comes at the age of 50 to 60, whereas formerly it was at age 20 to 40.

These characteristic changes from decade to decade can be demonstrated in the records for many different areas, both for males and females.

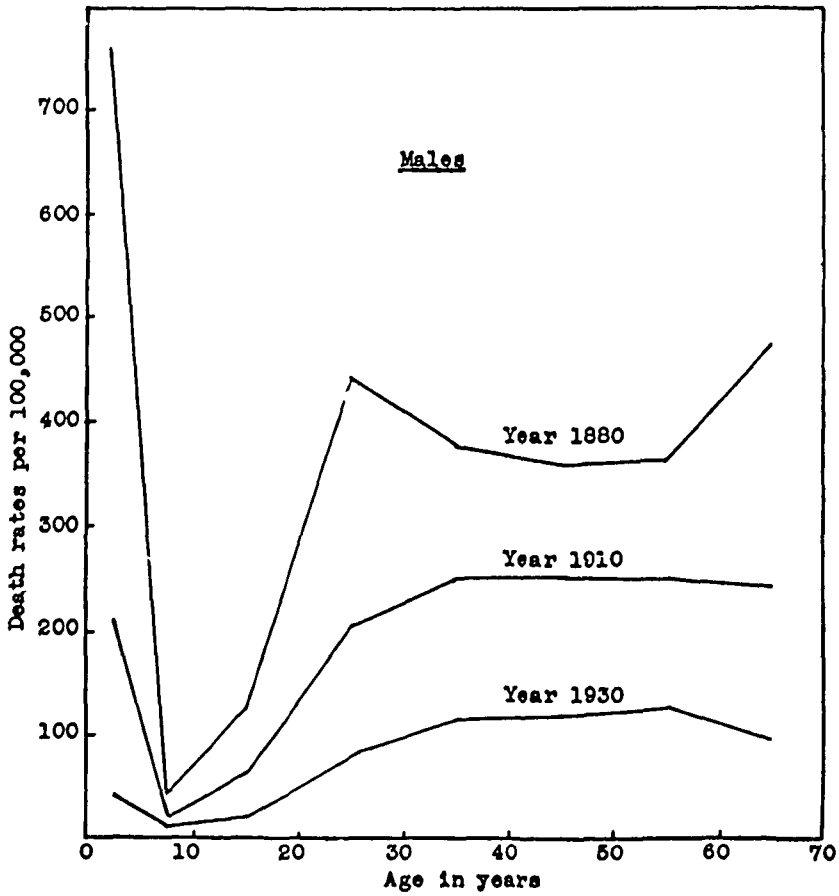

FIGURE 2. Massachusetts death rates from tuberculosis—all forms—by age, 1880, 1910, 1930.

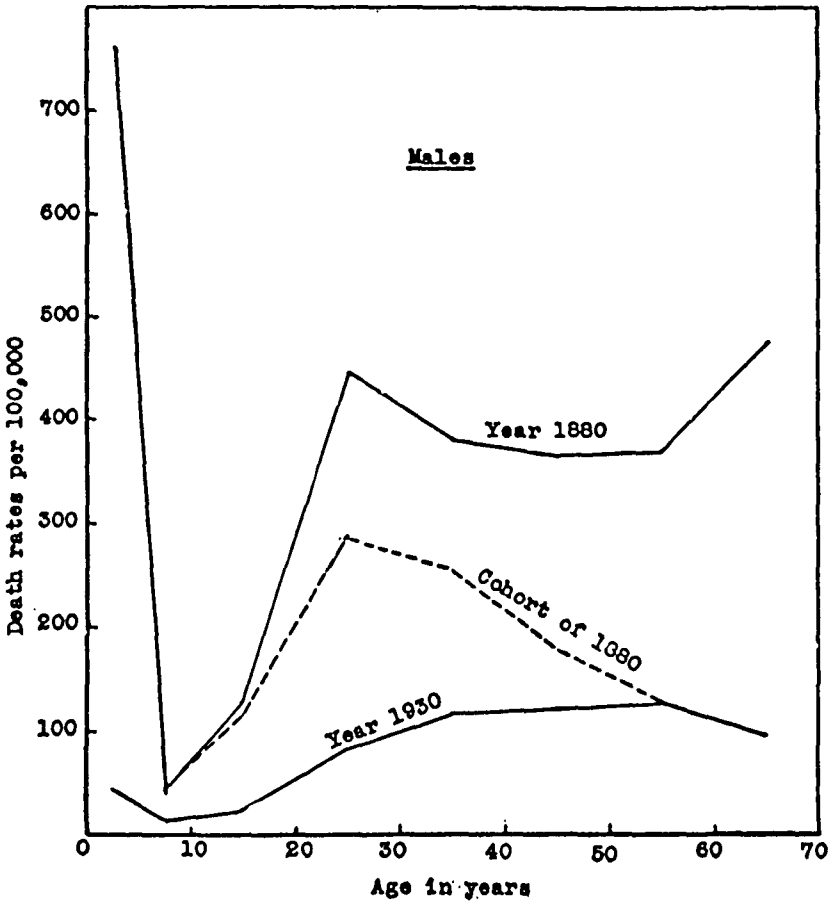

FIGURE 3. Massachusetts death rates from tuberculosis—all forms—by age, in the years 1880 and 1930 and for the cohort of 1880.

Looking at the 1930 curve, the impression given is that nowadays an individual encounters his greatest risk of death from tuberculosis between the ages of 50 and 60. But this is not really so; the people making up the 1930 age group 50 to 60 have, in earlier life, passed through *greater* mortality risks.

This is demonstrated in figures 3 and 3a, which show for males and females in Massachusetts the death rates at specific ages in the years 1880 and 1930, and also those for each age of the cohort of 1880 or that group of people who were born in the years 1871 to 1880. These graphs indicate that the group of people who were children 0 to 9 years of age in 1880 and who are now aged 50 to 60 years (if alive) have, in two earlier periods, passed through *greater* risks. They also indicate that the age selection in the cohort of 1880 is quite different from that *apparently* indicated by the age specific mortality rates for any single year.

Figure 4 shows similarly for males the mortality at successive ages in cohorts of (1870), 1880, 1890, 1900, 1910. Note that "terminal" rates for these cohorts make the 1930 curve, and also that in successive cohorts the age selection has been uniform; with the mortality highest in the first 5 years and again from 20 to 30 years; thereafter it declines.

This fact was previously noted by K. F. Andvord (1930). His interpretation was, in part, that this regularity of

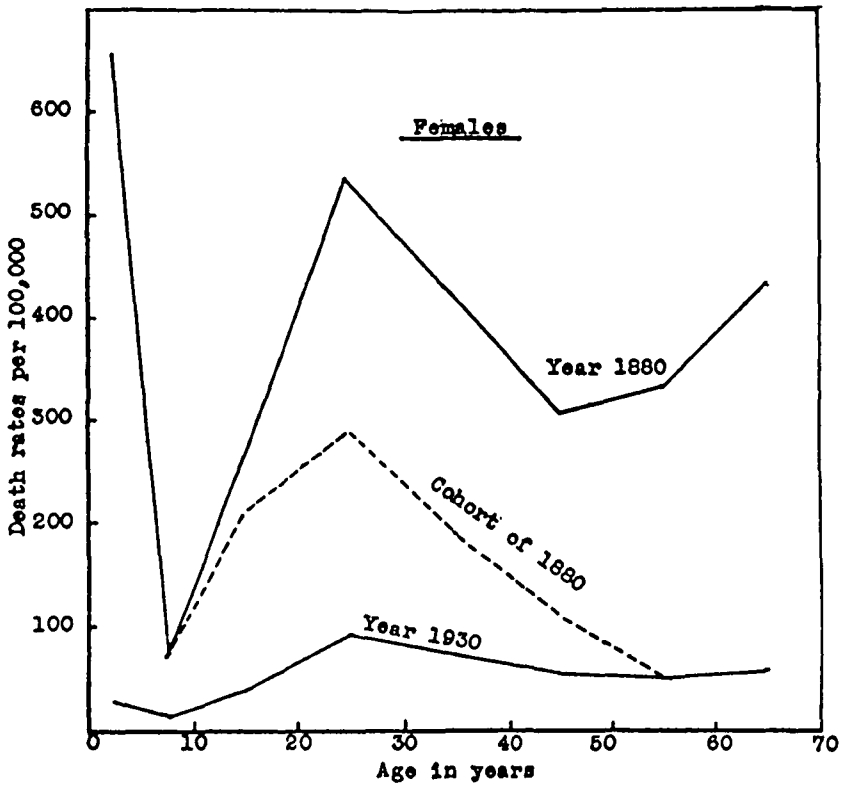

FIGURE 3a. Massachusetts death rates from tuberculosis—all forms—by age, in the years 1880 and 1930 and for the cohort of 1880.

Age	1880	1890	1900	1910	1920	1930
Males						
0– 4	760	578	309	209	108	41
5– 9	43	49	31	21	24	11
10–19	126	115	90	63	49	21
20–29	444	361	288	207	149	81
30–39	378	368	296	253	164	115
40–49	364	336	253	253	175	118
50–59	366	325	267	252	171	127
60–69	475	340	304	246	172	95
70+	672	396	343	163	127	95
Females						
0– 4	658	595	354	162	101	27
5– 9	71	82	49	45	24	13
10–19	265	213	145	92	78	37
20–29	537	393	290	207	167	92
30–39	422	372	260	189	135	73
40–49	307	307	211	153	108	53
50–59	334	234	173	130	83	47
60–69	434	295	172	118	83	56
70+	584	375	296	126	68	40

TABLE 1

*Death rates * per 100,000 from tuberculosis, all forms, for Massachusetts, 1880 to 1930, by age and sex, with rates for cohort of 1880 indicated*

*They were obtained as follows: For the years 1910, 1920 and 1930—based on U. S. Mortality Statistics—deaths from tuberculosis, all forms. For the years 1880, 1890 and 1900 the rates used are calculated from data compiled by the late Dr. Edgar Sydenstricker from the state records. Because of differences of classification in deaths, it has been necessary to base the rates on the deaths recorded as "tuberculosis of the lungs" to get comparable data for these years. The rate calculated from the state records for "tuberculosis of the lungs" has been multiplited by a factor based on the proportion such deaths bore to those from tuberculosis, all forms. This factor varied with the year and age considered.

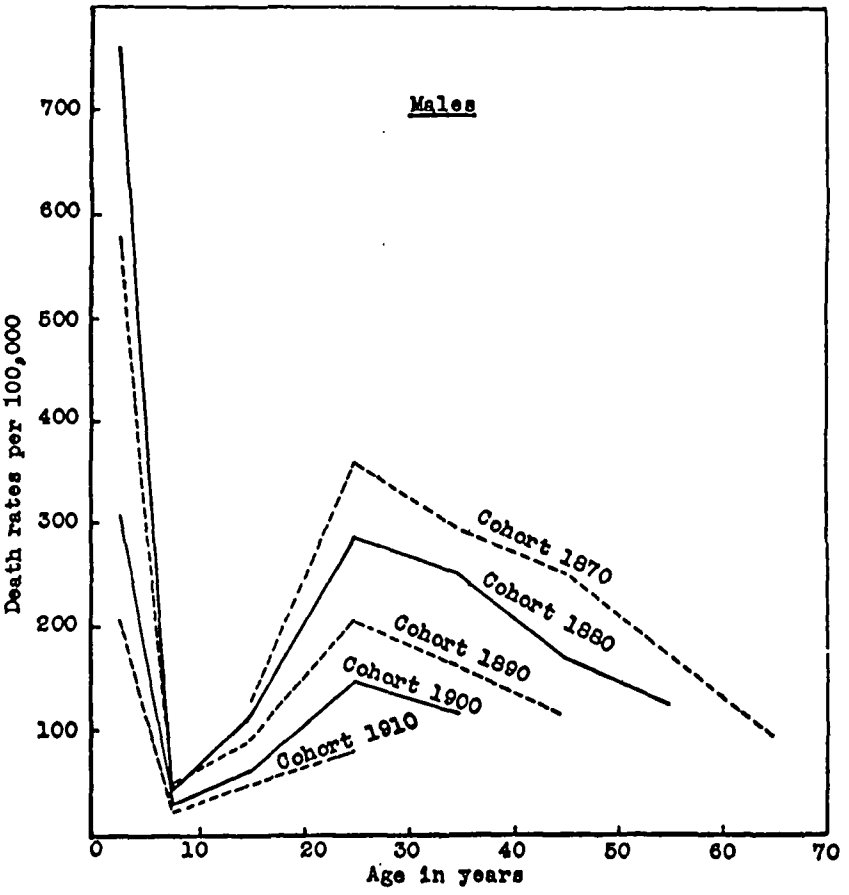

FIGURE 4. Massachusetts death rates from tuberculosis—all forms—by age, in successive 10-year cohorts.

the age curve formed a basis for extending estimates of future mortality in the same cohort at higher ages. Such an interpretation is both tempting and encouraging but perhaps dangerous.

Without attempting to interpret the facts in detail, certain implications are noted.

1. Constancy of age selection (*relative* mortality at successive ages) in successive cohorts suggests rather constant physiological changes in resistance (with age) as the controlling factor.

2. If, as we may suppose, the frequency and extent of exposure to infection in early life has decreased progressively decade by decade, there is no indication that this has had the effect of exaggerating the risk of death in adult life due to lack of opportunity to acquire specific immunity in childhood.

3. Present day "peak" of mortality in *late* life does not represent postponement of maximum risk to a later period, but rather would seem to indicate that the present high rates in old age are the residuals of higher rates in earlier life.

REFERENCE

Andvord, K. F.
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