Risk of Persons in Familial Contact with Pulmonary Tuberculosis*

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DURING the past 2 years various workers in this department have collaborated in two epidemiological studies of tuberculosis; one concerned with the families of children registered in Dr. Edwards A. Park's clinic for tuberculous children at the Johns Hopkins Hospital; the other a series of studies carried on by a special unit of the State Department of Health of Tennessee in various localities in that state. The several studies have varied in scope and in certain details of method, but a purpose common to all of them has been to ascertain the mortality and specific morbidity in familial contacts of persons suffering from pulmonary tuberculosis, for comparison with the experience of suitable control populations.

The data so far accumulated are not sufficient to be of much significance as actual measures of even the gross average risks. They are sufficient, however, to afford material for preliminary investigation of the antecedent question whether records of the kind represented are at all suitable for the purpose in view. It is to this question that the present discussion is directed, the actual records of a small group of families being introduced only for purposes of illustration.

For the acute communicable diseases, such as diphtheria, scarlet fever, and measles, measurement of the morbidity risk of familial contacts is a simple procedure, because the excess risk is concentrated within the few weeks following invasion of the household. As was pointed out by Chapin years ago, all that is necessary is to ascertain, in each invaded household, the number of persons present, other than the one first attacked, with particulars as to sex, age, and many other variables which are to be considered; then to ascertain the number of cases of the same disease subsequently occurring in the various exposed groups within a stated period of, say, 4 to 6 weeks. This attack rate may then be compared with the average rate in the community at large for a like period of time. Collection of the data is simple because, for any family, the required period of observation is brief; and compilation is simple because the period to which the attack rate refers may be taken as the same for all families.

For tuberculosis the requirements are essentially the same, but are more difficult to meet, chiefly because the disease is of slow evolution, and we cannot assume that the risk with which we are concerned is concentrated within the year or even the decade following establishment of the known exposure. It may, perhaps, be manifested by excessive morbidity or mortality in any

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subsequent period of life. Hence, observation of the exposed group must extend over a sufficient number of years to define the rates of morbidity and mortality prevailing in successive periods throughout the usual span of life. To keep a sufficiently large group of people under systematic, exact observation for such length of time is a difficult task which has, indeed, been undertaken in various places, but to the best of my knowledge has not been carried much beyond a decade. However, such simple facts as lie within the knowledge and memory of the average householder may be obtained by *retrospective* investigation, tracing familial histories backward into the past. The procedures followed in a preliminary attempt to apply data collected in this way and to check their reliability may be described best by referring to a concrete example.*

The available records which best serve the purpose of illustration are from a survey of the negro population of Kingsport, Tenn., made during 1930 and 1931 by a special unit of the Tennessee State Department of Health.†

The survey covered 132 families, constituting practically the entire negro population of the city.‡ For each family the investigation included a detailed familial history, extending as far back as practicable, and examination of every present member in a special clinic, where the routine procedure was: physical examination, roentgenogram of the chest, and tuberculin test. With very few exceptions, the full schedule of examinations was carried out for all persons, regardless of whether or not there was any reason to suspect tuberculosis.

In addition to numerous other items which do not come into the present discussion, each family schedule gave the following:

1. Date of establishment of the household, which may be defined more exactly as the date when the present head of the household came into that position. This is an important item, as it marks the date from which at least one informant may be expected to have first-hand knowledge of occurrences within the household.

2. A list, by name, of all persons present in the household when the schedule was made out, giving, for each person: familial relationship, date of entrance into household, age at time of investigation, record of any present or past illness diagnosed as certain or probable tuberculosis, record of clinic examination, and a detailed account as to time and circumstances of any known household contact with antecedent cases of pulmonary tuberculosis.

3. A list, by name, of all former members of the household, giving, for each: age at which entered the household, record of known or suspected tuberculosis while in the household, record of household contact with antecedent cases of phthisis; age at which withdrawn from the household, status when withdrawn—whether living or dead—and, if dead, date of death, with ascribed cause.

These records were made with great care, each family being revisited as often as necessary to check and complete the information; and as the families were thoroughly coöperative, it is believed that the facts within their knowledge were stated with fair accuracy. From the histories obtained, it is probable that the deaths ascribed to pulmonary tuberculosis actually were due to that cause; but it is by no means certain that these were all the deaths attributable to tuberculosis, and as to non-fatal cases of this disease the histories, both negative and positive, obviously are subject to considerable error. Also, the *early* history of *former* members, who were born outside of the households in which they were recorded,

* The procedure, except in collection of data, would be essentially the same in analysis of records obtained by keeping a group under planned observation.

† It is expected that a detailed report of the studies in Kingsport will be made from the State Department of Health of Tennessee.

‡ The federal census of 1930 gives the negro population of Kingsport as 596. The persons living and present in the families surveyed numbered 556. Only 3 families are known to have been omitted (because of unwillingness to be examined), but it is probable that a few others may have been missed.

must often be unknown. However, in general, the facts are simple and, for the period since establishment of each household, presumably within the knowledge of the informant.

The whole group of 132 families furnished records of 794 present and former members, classified as follows:

(1) Living and present at time of survey		556
(2) Former members of same households, not present at time of survey		
(a) removed, living	142	
(b) dead, (27 of tbc., 69 of other causes)	96	
		238
Total: present and former members		794

Before discussing mortality and morbidity from tuberculosis as related to history of known household contact with the disease, it is desirable, as a description of method and a check of the data, to compare the mortality from all causes in the entire group with the current mortality in the negro population of the state as a whole. The force of mortality in the population of the state is expressed in terms of the annual death rate, that is, the ratio of deaths to persons under observation for a period of 1 year and, since this rate varies widely with age, it is necessary for significant comparisons that it be stated separately for each age group. We need, therefore, to reduce the mortality of the Kingsport families to these same terms, namely, age-specific annual death rates. To accomplish this, it is necessary to convert the observations on the family group to terms of life-experience, of which the unit is 1 person under observation for 1 year, or 1 person-year. The procedure to this end, which is an application of the familiar principles of life-table construction, is illustrated in Table I, which shows in detail the summation of life-experience within the age-limits 0–5 years.

As indicated in this table, 363 children, born in the families to which they are allocated, came under observation at the beginning of the first year of life. Of these, 18 died within their first year, and 15 others were less than 1 year old when the record was taken, so that a total of $18 + 15 = 33$ were withdrawn from observation before completing the year. Counting each person withdrawn before the end of the year as having been in the household ½ year, we have as the aggregate

TABLE I

SUMMATION OF LIFE-EXPERIENCE AND MORTALITY BETWEEN THE AGE-LIMITS 0–5 YEARS IN 132 NEGRO FAMILIES

Year of Age x to x+1	*Number present at beginning of year* l_x	*Number added during year* n_x	*Number withdrawn (living) during year* w_x	*Number dying during year* d_x	*Mean number present during year* L_x	*Death rate per 1,000 during year* m_x
0–1	363	0	15	18	346.5	51.9
1–2	330	3	3	4	328.0	12.2
2–3	326	3	16	6	316.5	19.0
3–4	307	4	12	0	303.0	....
4–5	299	5	14	3	293.0	10.2

The derivatives from the primary figures (l_x, n_x, w_x, d_x) are:

$l_{x+1} = l_x + n_x = w_x - d_x.$

$L_x = l_x + \frac{1}{2}(n_x - w_x - d_x).$

$m_x = \frac{1000.\ d_x}{L_x}$

TABLE II

MORTALITY FROM ALL CAUSES, BY AGE, IN NEGRO FAMILIES OF KINGSPORT, FROM DATE OF ESTABLISHMENT OF EACH FAMILY TO DATE OF EXAMINATION, AND MORTALITY RATES IN NEGRO POPULATION OF STATE, 1920

	Negro families of Kingsport			*Negro population of Tennessee.*
Age	*Person-years of life-experience*	*Deaths, all causes*	*Annual Death rates per 1,000*	*Death rates per 1,000, 1920* *
Under 1	346.5	18	51.9	120.0*
1–4	1,240.5	13	10.5	14.0
5–9	1,259.0	7	5.6	4.0
10–19	1,916.5	17	8.9	7.1
20–29	2,190.5	15	6.8	15.0
30–39	1,557.5	13	8.3	17.0
40–49	764.5	1	1.3	17.4
50–59	308.5	8	25.9	26.1
60+	88.0	4	45.5	67.0
Total	9671.5	96	9.9	18.0

* From U. S. Mortality Statistics, 1920.

of life experience between the age-limits 0–1 year, $363 - 33/2 = 346.5$ person-years.

In the second year of life, we begin with 330 (363 — 33) children remaining under observation from the preceding year; and during the year 3 new children are added, while 7 are withdrawn. Allowing ½ year as the mean time spent in the household for each newly added person and each one withdrawn, the total life-experience in the second year, between the age-limits 1–2 years, is $330 + \frac{3 - 7}{2} = 328$.

In the same way, taking account of all additions and withdrawals, the life-experience in each successive year is summed up, until we have entered in the table a total of 378 individuals—the 363 present at birth plus 15 added at various times—of whom 91 have been withdrawn before reaching the age of 5 years, 31 by death and 60 for other reasons. In terms of person-years, where the unit is 1 person observed for 1 year, the aggregate life-experience between the age limits 0–5 years, is the sum of the five L_x values in the table, namely, 1,587 person-years. Within this experience 31 deaths occurred, hence the *annual* death rate between the age-limits 0–5 years is: $31/1{,}587 \times 1{,}000 = 19.5$ per 1,000.

Table II, constructed by continuation of the process illustrated in Table I, shows the entire-life experience of the 794 present and former members of the 132 families at successive ages from infancy to old age. The aggregate is 9,671.5 person-years; and in each age class except the oldest, the experience comprises several hundred person-years. Opposite each age-group are set the deaths which occurred at that age, and the next column gives the annual death rate per 1,000 in the age class, calculated as the ratio of deaths to person-years. The last column shows, for comparison, the annual death rates at corresponding ages in the negro population of the state in 1920.

The death rates in the Kingsport families are approximately equal to those in the negro population of the whole state in the age group 1–19 years, and at ages over 50, but are very much below the state experience in the first year of life, and in adults aged 20–49 years. The low infant mortality in the Kingsport families is probably

TABLE III

MORBIDITY AND MORTALITY FROM TUBERCULOSIS IN NEGRO FAMILIES, KINGSPORT, BY AGE, TOGETHER WITH MORTALITY IN THE NEGRO POPULATION OF THE STATE, 1920

Age periods	Life-experience Kingsport families person-years	Cases of tuberculosis † Number	Cases of tuberculosis † Attack rate per 1,000	Deaths from tuberculosis: Kingsport families Number	Deaths from tuberculosis: Kingsport families Rate per 1,000	Negro population of State rate per 1,000 *
Under 1	346.5	2	5.8	1	2.9	2.8
1–4	1,240.5	2	1.6	1	0.8	1.1
5–9	1,259.0	5	4.0	2	1.6	0.7
10–19	1,916.5	19	9.9	8	4.2	2.2
20–29	2,190.5	17	7.8	7	3.2	5.8
30–39	1,557.5	18	11.6	4	2.6	4.0
40–49	764.5	6	7.8	1	1.3	2.8
50–59	308.5	4	13.0	2	6.5	3.0
60 & over	88.0	4	45.5	1	11.4	3.7
All ages	9,671.5	77	8.0	27	2.8	3.1

* From U. S. Mortality Statistics, 1920.
† Cases classed as "suspected" make up about one-third of the total.

due in part to the fact that the standard of living of the negroes in that city was well above the average; but it may be attributable in part to failure of informants to note some of the deaths of infants at very early ages, this being an error not unlikely to occur. The low mortality in adults aged 20–50 can hardly be attributable to any similar error. It more probably reflects the selective character of the life-table experience, which, being made up from the records of persons residing in established families, largely excludes certain classes of young adults suffering excessive mortality, namely, married couples of which both members have died young, residents of institutions, vagrants, and transients. With due regard to these considerations and to the small number observed, the agreement between the Kingsport mortality record and state-wide experience is close enough to indicate that the familial records are not grossly erroneous. At the same time, it needs to be clearly recognized that in certain important respects the method employed is selective with respect to mortality.

The 132 families furnished records of 27 deaths ascribed to tuberculosis. In addition to these, the clinic examinations revealed 50 more or less definitely diagnosed cases of pulmonary tuberculosis in living members of the families, making a total of 77 cases living and dead.* Distributing these 77 cases according to age at onset of illness—as nearly as this could be ascertained—and distributing the fatal cases according to age at death, age-specific annual morbidity and mortality rates are derived as shown in Table III, which also shows corresponding death rates in the negro population of the state. It will be observed that the tuberculosis mortality rates are very similar to those prevailing in the state at large, and that the morbidity rates, though much higher than usually shown in official records, are reasonable in relation to the mortality.

The foregoing tables of mortality and

* A majority of the 50 cases recorded in living members were judged to be inactive at the time of examination, and of these a considerable proportion were classed as "suspected." A reëxamination of the suspected cases, which is now in progress, indicates that some 10 to 15 of this group may eventually be classified as negative, making a proportionate reduction in the morbidity rates of Tables III and IV.

morbidity in the whole group of families have been included only to illustrate the data and methods used and to check the reasonableness of the results (as to mortality), by comparison with current experience in the negro population of the state at large. We come now to the question of morbidity and mortality in familial contacts of known cases of tuberculosis.

When the population is thus subdivided, the numbers upon which age-specific rates must be calculated become so small that for significant comparisons it is necessary to summarize the results. For this the most convenient form is a statement of annual morbidity and mortality rates at all ages, adjusted to a

TABLE IV

MORBIDITY AND MORTALITY IN RELATION TO HISTORY OF FAMILIAL CONTACT WITH PULMONARY TUBERCULOSIS. NEGRO POPULATION, KINGSPORT, TENN.

	Contact history	
Basis of Comparison	*Positive*	*Negative*
Person-years in classification	2,199	7,472.5
Cases of tuberculosis: number	26	51
annual attack rate per 1,000	12.9±1.7	6.8±0.64
Deaths from tuberculosis: number	10	17
annual death rate per 1,000	4.6±1.01	2.3±0.38
Deaths, all causes: number	28	68
annual rate per 1,000	12.8±1.62	9.2±0.67

All morbidity and mortality rates adjusted to age-distribution of the entire life-experience in the **whole** group of 132 families.

Of the 794 persons included in the study, 299 gave a history of having been, at some time, in household contact with a case of certain or probable pulmonary tuberculosis. The mortality and morbidity rates in these known "contacts" subsequent to their exposure have been calculated by making up a life-table in which each contact is entered only for that period of his residence in the family after the known household exposure began, recording against this experience the subsequently observed mortality and morbidity.* As a control, a similar table has been made, dating from entry into the household, for all persons who gave no history of known household contact, plus the preëxposure experience of those who came into household exposure subsequent to entry into the family.

* Where the known exposure occurred before entrance of the individual into the household in which he is listed, the post-contact life-experience is dated from entry into present household.

population of standard age-distribution. The comparisons made on this basis, in Table IV, indicate that the persons with a positive history of household contact suffered thereafter tuberculosis morbidity and mortality rates about double those of the control population, and in addition, suffered a materially higher mortality from other causes.

The figures given in Table IV show only the *average* morbidity and mortality risk for all familial contacts in this group of families, as measured by comparing their morbidity and mortality rates with those of a control drawn from the same universe. Given sufficiently extensive and exact data, it would be quite possible, by similar processes, to measure the variations in this risk as related to numerous circumstances which presumably are of importance, as, for instance, the age at which exposure first took place, its

duration, the activity of the case to which the individual was exposed, parental history, etc. The number of persons included in this particular set of records is too small for such subdivisions as these more detailed studies would require and, indeed, is so small that no special significance should be attached to the result given as a measure even of the average risk to contacts in negro families. It is, however, of interest to note that the relative rates of mortality in the contact and control groups, respectively, are in reasonable agreement with the observations of Weinberg (1913, pp. 123–129) who, in his extensive study found that the children of tuberculous parents suffered rates of mortality (at ages under 20 years) from all causes about 1.28 times and from tuberculosis about 2.16 times the rates prevailing in the community at large.

It should perhaps be added, though it is sufficiently obvious, that in the procedure applied here, no attempt is made to distinguish between the risk resulting directly from exposure and that which may be due to constitutional weakness or generally unfavorable environment. These questions may be approached by the same general method, but require much more extensive data.

The method which has been described is in no sense new in its application to studies of tuberculosis. It has been used by Elderton and Perry, in their studies of the mortality of persons treated in sanatoria; by Weinberg, in his excellent and extensive study of the mortality of children born of tuberculous parents; and by others. It appears, however, to have been applied little, if at all, to retrospective records of the kind here discussed; and since it is records of this character which are most readily available from the experience of public health organizations and clinics, it has appeared worth while to call attention to this general method for the study of material which at present too often remains unassembled.

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