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A Mortality Index for Use in Place of the Age-Adjusted Death Rate*

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THE purpose of this paper is to show that the age-adjusted rate, as presently employed, is inadequate for mortality comparisons of different groups; to determine the reasons for the inadequacy; and to construct a new index as a substitute for the age-adjusted rate.

Because the above statements have far-reaching implications, it is imperative to review the voluminous and interesting literature on the subject. Fortunately, this task was performed in a masterly fashion by Theodore D. Woolsey in a chapter titled "Adjusted Death Rates and Other Indices of Mortality" which was published in *Vital Statistics Rates in the United States, 1900–1940*.[1] Woolsey presents not only a description of the different methods of adjustment, but provides also a comprehensive discussion of the literature and points up the main issues encountered in evaluating the different indices. In addition, committees of the Statistics Section of this Association, under the chairmanship of A. W. Hedrich, dealt with a number of phases of the problem and prepared several lucid and comprehensive reports.[2-4] It is therefore unnecessary to duplicate these excellent publications, but rather to utilize them as background for the present report.

It is desirable, however, to repeat two fundamental notions which emerge from the many discussions on the subject:

1. The age-adjusted rate has no inherent value in itself. The actual numerical value of the rate has no absolute meaning. It is not designed to measure the mortality risk of a group. Its purpose is to render different groups more comparable in order that their relative mortalities can be evaluated.
2. The age-adjusted rate is not a substitute for the age-specific rates. A complete and satisfactory comparison of mortality between two groups can be obtained only by a detailed study of the age-specific rates. This thought is paramount in nearly all the discussions on the subject. However, there appears to be a definite need for a single figure which summarizes the pertinent comparisons contained in two sets of age-specific rates. As Greenwood very aptly put it, "The numerical statistical method, as distinct from the tabular statistical method of our ancestors, has been introduced precisely because the power of the human mind to grasp a number of particulars is limi-

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ited. . . . It was not until the 17th century that it was realized that in seeking to grasp everything, one tended to grasp nothing." [5] In addition, there is a practical need for a single figure which summarizes the age-specific rates for use in routine public health activities. Such a need was expressed by a committee of this association as follows: ". . .The problem is to suggest as substitutes for the crude death rates the simplest practicable rates, such as might be used by a health officer who is asked at a meeting how the city death rate compares with the rural, or whether it is true that mortality in the state is rising." [4]

It is realized that whatever index is to be used for the purpose, much of the detail available in the age-specific rates will of necessity be lost, and often the index comparison will have to be supplemented by a more detailed study of the rates, age for age. The function of the age-adjusted rate must therefore be viewed as a device which, through an averaging process, presents in a single figure the pertinent information in a set of age-specific rates, in order that it may be compared with a similar figure obtained from another set of age-specific rates.

If this be the function of the age-adjusted rate, then it is necessary to determine what type of information is usually looked for in a detailed comparison of death rates, age for age, and to judge the different methods of adjustment on the basis of how closely they approach the detailed comparison. The pertinent question is whether, in a comparison of two sets of age-specific rates, attention is generally focused on *absolute* or on *relative* differences between the individual rates. In other words, is it likely that a drop of one unit, from 50 to 49, in infant mortality assumes the same importance as a drop of one unit, from 2 to 1, at age 20,* or is it more likely that the level of the rate is a basic element in the comparison? The answer depends on the use that is likely to be made of the comparison.

In general, it may be stated that when the purpose of the analysis is to provide measures such that the absolute value of each is meaningful in itself, then the number of deaths, and therefore the absolute differences in the rates, are the more important. However, when the analysis is for purposes of comparing different risks, the actual numerical values of the resulting index are meaningless, and attention is directed primarily to relative differences. For example, the use made of age-specific rates in life table construction is to derive certain functions such as "expectation of life" which are meaningful in themselves. Moreover, the meaning inherent in these functions is derived from a summarization of absolute numbers of deaths and years of life lived. But when two sets of age-specific rates are viewed for the purpose of comparing the forces of mortality exhibited in them, the relative risks at each age are of more importance, and attention is generally focused on proportionate differences between the individual rates.

CRITERIA FOR AGE-ADJUSTED RATES

The desirable characteristics which an age-adjusted rate should possess have been discussed by a number of writers on the subject from several points of view. In all cases, however, the age-adjusted rate was required to satisfy only very mild conditions. In addition to such obviously desirable qualities as would be required of any average, the main criteria may be summarized as follows:

1. That the age-adjusted rates for two groups having the same age-specific rates be identical.
2. If each of the age-specific rates in community A is higher than the corresponding one in

* In this, and throughout this paper, it is assumed that the rates are based on very large population groups and that the differences are therefore real. The problem of reliability and standard error is not dealt with in this discussion.

community B by a constant proportion, then the age-adjusted rate for A should be higher than that of B by the same proportion.

These requirements are satisfied for nearly all methods of adjustment proposed, irrespective of the specific standard population employed. It may, however, be just to inquire whether these conditions are adequate for the purpose. They no doubt are necessary conditions, but are they sufficient? It must be realized first that the requirements are artificial and unrealistic. It would be rare indeed to find two communities in which the age-specific rates for one bear a constant relationship to those of the other throughout the entire life span. More often, the age-specific rates differ in two communities by variable proportions and the differences are not always in the same direction.

If the age-adjusted rate is to serve as an index which summarizes adequately the set of age-specific rates, it must satisfy much stronger conditions. If it is to be used as a yardstick for comparison it should satisfy the elementary requirements of any measure—namely, that it be both *specific* and *sensitive*. It is not sufficient that certain relationships present in the age-specific rates be reflected in the age-adjusted rates, but the reverse must also be true—the information obtained from the index needs to be confirmed by the age-specific rates.

In other words, if the index is higher for one community than for the other, the same situation must exist in the two sets of age-specific rates. This obviously does not mean that each of the age-specific rates in one community must be higher than the corresponding one in the other, but it must be true from an overall summarization point of view. Moreover, there must be a reasonable numerical relationship between the relative values of two index numbers and the two sets of age-specific rates from which they were constructed. If the index for one community is higher by p per cent than that for another, then it should reflect the fact that the age-specific rates in the first community are higher by p per cent than those in the other. Again, this need not be true for each age-specific rate but it must be true in a statistical sense when evaluated according to predetermined criteria.

None of the methods of adjustment in common use, irrespective of the specific standard population used, satisfies these elementary requirements. The main limitation, as will be shown later, is that they evaluate differently similar relative changes in the age-specific rate, depending on the position of the rates in the age scale.

RELATIVE RISKS AT DIFFERENT AGE LEVELS

The following simple illustration shows that the present method of adjustment evaluates differently equal relative changes if they occur at different parts of the age scale. The age-adjusted rate for white males in Alabama according to the direct method of adjustment and the use of the 1940 U. S. population as a standard was 11.8. If, in 1941, the age-specific rates for every age group were identical with those of the preceeding year but the rate for ages 15–24 was reduced by 50 per cent, the effect would have been to reduce the age-adjusted rate from 11.8 to 11.6. However, if the 50 per cent reduction had occurred in the age group 55–64 instead of 15–24, the resultant reduction in the age-adjusted rate would have been from 11.8 to 10.8. Similar discrepancies would result if comparisons were made by any other method of age adjustment or by the use of different standard populations. Nearly all methods have the common characteristic that they put very heavy penalties on increased rates when they occur at the tail end of the life span as compared with proportionate increases in the pro-

TABLE 1

Per Cent Increase in Age-Adjusted Rates Resulting from a 50 Per cent Increase in Age-Specific Rates; Total Population, United States, 1940

Method of Adjustment and Standard Used	*Per Cent Increase in Age-Adjusted Rate Caused by a 50 Per Cent Increase in Specific Rate, for Ages—*										
	Under 1	*1–4*	*5–14*	*15–24*	*25–34*	*35–44*	*45–54*	*55–64*	*65–74*	*75–84*	*85 +*
Direct method and Indirect Method:											
U. S., 1940	4.7	0.9	0.9	1.9	2.8	3.7	6.5	8.4	11.2	9.3	3.7
England and Wales, 1901	7.9	2.2	1.1	2.2	3.4	3.4	5.6	7.9	9.0	7.9	2.2
Equivalent Average Death Rate (to age 65):											
U. S., 1940—Specific Death Rates	5.4	1.2	1.0	2.0	3.1	5.1	10.4	22.0	—	—	—
Relative Mortality Index											
U. S. 1940—Deaths	0.8	3.2	8.5	9.1	8.1	7.0	5.9	4.0	2.4	0.9	0.1

ductive periods of life. Conversely, lower rates in the older ages reduce the age-adjusted rate by a greater margin than proportionate lower rates in the younger ages.

This unequal evaluation of relative changes at different age levels is demonstrated in Table 1 for several methods of adjustment. It was constructed to show the effect on the age-adjusted rate which results from a 50 per cent increase in the rate for the different age groups. It will be seen that all methods of adjustment but one show a much larger increase in the age-adjusted rate when the 50 per cent increase occurred either in infancy or in old age than when it happened in early adulthood and the middle range of life. The single exception is for the Relative Mortality Index, for which the reverse is true. The figures for under 1 year and for ages 1–4 are gross underestimates, because in these cases the 50 per cent increases relate to a single year and to 4 years respectively, while for each of the other age groups the 50 per cent rise operates for 10 years.

Figure 1 illustrates this unequal weighting for the direct method of adjustment using the 1940 U. S. total population as a standard. Thus, when the 50 per cent increase is in age group 5–14, the resultant increase in the age-adjusted rate is less than 1 per cent, while if it is at ages 65–74, the age-adjusted rate rises by over 11 per cent.

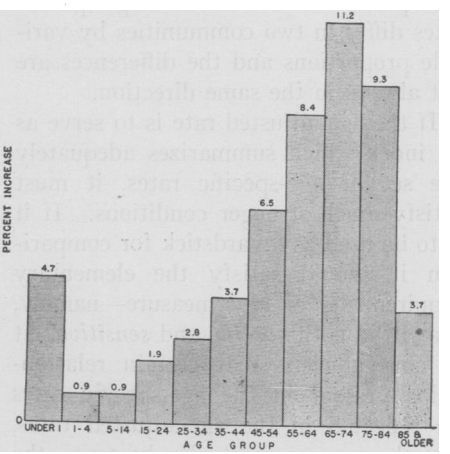

FIGURE 1—Percentage increase in the age-adjusted rate which results from a 50 per cent increase in the different age-specific rates. (Direct method of age adjustment, standard U. S. total population, 1940.)

One might question the wisdom of allowing the index to assign such heavy weights to the period of old age. Some might argue, as Derrick did, that "the importance of identifying one death at 20 might be many times as great as a similar one at 65, for the one ought not to have occurred whereas at 65 we are approaching the region of inevitability," [5] and consequently they may prefer to reverse the procedure and assign greater weights to the younger

ages. Either of these involves judgment and a degree of arbitrariness which dulls the specificity and sensitivity of the index.

It would appear that the index could best serve its purpose of providing in summary form a comparison of age-specific rates if it were freed from the burden of prejudging the relative importance of mortality at different ages but would assign equal weight to equal proportionate changes in the risk of dying at each year of age in the entire life span.

Consider two states which have identical rates in all but two of the age groups, but at ages 15–24 the rate is 50 per cent higher in state A, and at ages 55–64 the rate is 50 per cent higher in state B. What should the relative values of a satisfactory index be? Nearly all present methods will show the age-adjusted rate for B higher than that for A; yet both intuition and logic compel the conclusion that community B is no worse off than community A. In fact, some might feel that state B should be given the more favorable rate. A more rational approach would be to impose on the index the single task of summarizing the age-specific rates as they stand, and to require it to assign identical ratings to the two states.

It has been stated by some that a desirable index should satisfy the requirement that two communities with identical per cent distributions of population at specific ages and the same crude death rates should also have the same index of mortality. The direct method of adjustment does not satisfy this requirement, but it may be questioned whether this is a desirable characteristic for the index to possess. Consider groups A and B which are identical in their age composition. In A, the rates for the *30* year age period 15–44 are lower by 10 per cent than those of B. But B could have the same crude rate as A if during the *20* year age period 45–64 it had rates which were lower by only 5 per cent than those in A. Should the index give equal ratings to the two groups, or is it more reasonable to say that B can make up its deficit either by having a 10 per cent lower rate for an equally long span of life, namely 30 years, or by having rates which are lower by 15 per cent for a period of 20 years in the life span? If the index is to summarize the different risks it should produce ratings which are more in conformity with the latter than the former.

EXAMPLES OF LACK OF SPECIFICITY AND SENSITIVITY OF THE AGE-ADJUSTED RATE

It may be desirable to view several examples encountered in actual practice in order to evaluate better the lack of specificity and sensitivity of the age-adjusted rate which results from the unequal weighting of relative changes in the age-specific rates.

Consider the simpler situation where the rates in one group are consistently lower than those in another group, such, for example, as is revealed by comparing the mortality for white males in the United States in 1940 and 1920. The age-specific rates for the two periods and the per cents by which the rates for 1940 were lower than those for 1920 are shown in Table 2 and are illustrated in Figure 2.

The question for which an answer is sought is what per cent reduction in mortality has occurred in the 20 year period, or as Yule put it, we look for "an average which will measure in summary form the general fall in mortality." [5] By the use of the age-adjusted rate direct method as the measuring rod, and the 1940 U. S. population as the standard, the answer is 19 per cent. Does this figure of 19 per cent portray adequately the reduction that has occurred, and does it summarize the data reflected in the age-specific rates?

When the percentage reductions in the individual age-specific rates are

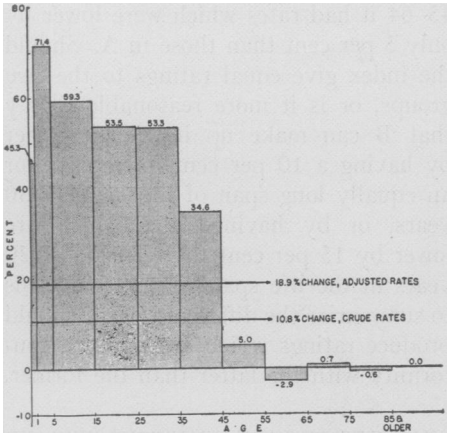

FIGURE 2—A comparison of the age-specific rates for white males 1940 and 1920. The per cent by which the rates for 1940 were lower than those for 1920.

TABLE 2

A Comparison of the Age-Specific Death Rates and the Age-Adjusted Rates by the Direct Method for White Males in the United States 1920 and 1940

Age Group	*Age-Specific Rates Per 100,000 United States*		*Per Cent Difference 1940*
	1920	*1940*	*1920*
Under 1	103.7	56.7	—45.3
1– 4	9.8	2.8	—71.4
5–14	2.7	1.1	—59.3
15–24	4.3	2.0	—53.5
25–34	6.0	2.8	—53.3
35–44	7.8	5.1	—34.6
45–54	12.0	11.4	— 5.0
55–64	24.5	25.2	+ 2.9
65–74	54.4	54.0	— 0.7
75–84	121.5	122.2	+ 0.6
85 and over	249.2	249.3	— 0.0
Crude Rate	13.0	11.6	—10.8
Age-Adjusted Rate U. S., 1940	14.3	11.6	—18.9
E and W, 1901	12.9	9.5	—26.4

viewed, the very impressive picture is revealed that during the long period from birth to age 45 the per cent reductions were far above 19; they ranged from 35 to 71 per cent. But at the later ages the reductions were relatively small and in some age groups there has been a slight increase. However, these small reductions in the older ages were sufficient to outweigh the extraordinary progress portrayed in the age-specific rates for the younger ages. While the age-adjusted rate in this case may be considered to be specific in that it shows that the rate for 1940 was lower than that for 1920, it may not be sufficiently sensitive in that it may lack the ability to reveal adequately by *how much* the rate for 1940 was lower than that for 1920.

The more usual comparisons are more complicated than the above in that it is not often that the age-specific rates for one group are consistently higher or lower than those for another group. The more common comparison involves two groups in which the rates for one are higher at certain ages and lower at other ages than those for the other. In a review of the age-specific rates for sets of two among the 48 states, the pattern most often encountered was the following: State A has higher rates than state B over a relatively long band of the life span, for example, throughout childhood and middle age; then after a certain age a switch occurs and the rates for state B are higher than those for state A.*

With present methods of adjustment the states in which the lower rates are in the older ages will generally have lower age-adjusted rates. Moreover, in these situations the standard population used will have considerable effect on the final comparison.

As an illustration, consider the states of Louisiana and New Mexico. The age-specific rates for white males in these states for 1940 present the following

* That this is a very common occurrence might be seen from the following general consideration: When the four quartiles are determined for the age-specific rates in the 48 states for each age group, it is found that no single state had all its 11 age-specific rates in one quartile, only 5 were represented in two quartiles only, and more than one-half the states had rates in all four quartiles. Even if a stronger requirement is made, namely, not to count any quartile in which the state is represented by only a single age-specific rate (that is, if a state is considered to have rates in a given quartile, it must have two or more of its age-specific rates in that quartile), there are only three states which had all their rates in one quartile and more than half of them had rates in at least three quartiles (see Table 3). It is therefore obvious that in state-to-state comparisons, the two sets of age-specific rates would present rather complicated situations, with several of the age-specific rates being higher for one state than for the other, while for another number of the rates the reverse is true.

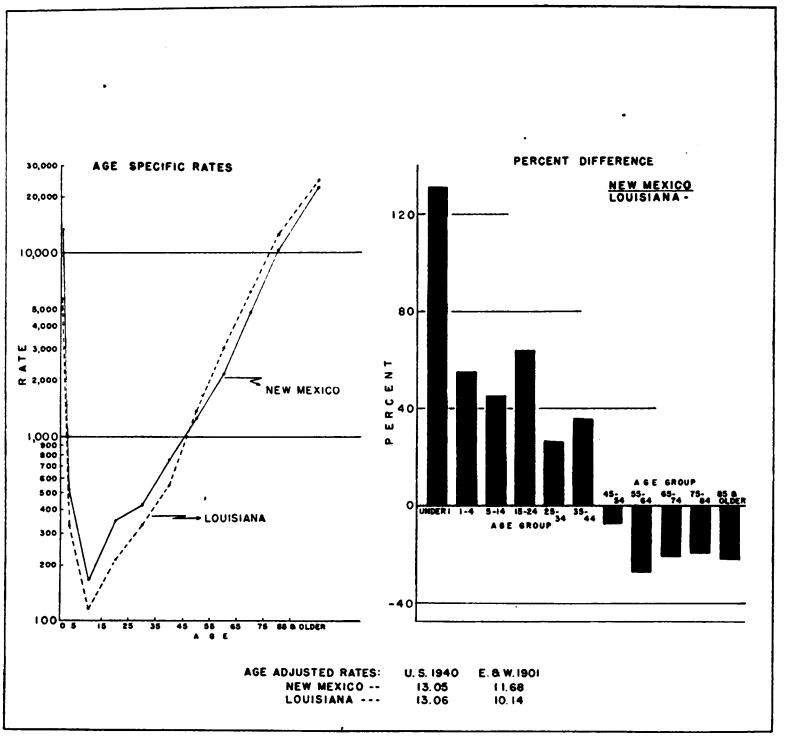

FIGURE 3—A comparison of the age-specific rates for white males in Louisiana and New Mexico 1940, and the per cent difference in the rates for New Mexico to those of Louisiana.

TABLE 3

Distribution of the 48 States According to the Number of Quartiles in Which Their Age-Specific Rates Fell; United States, 1940

Number of Quartiles	Number of States Having Age-Specific Rates in the Specified Number of Quartiles: Including cases when only a single rate is represented in a quartile	Under the requirement that at least 2 of the age-specific rates be in a given quartile
1	0	3
2	5	19
3	17	21
4	26	5
Total	48	48

situation: The rates are consistently higher for New Mexico up to age 45, but from that age on until the end of the life span a complete reversal takes place and the rates for New Mexico are consistently lower than those for Louisiana (see Table 4 and Figure 3). When the rates for these states are adjusted with the use of the 1940 U. S. population, almost identical rates are obtained—13.06 for Louisiana and 13.05 for New Mexico. However, if the 1901 population of England and Wales is

TABLE 4

A Comparison of the Age-Specific Death Rates and the Age-Adjusted Rates by the Direct Method for White Males in Louisiana and New Mexico, 1940

Age Group	Age-Specific Rates per 100,000: Louisiana	New Mexico	Per cent Difference New Mexico Louisiana
Under 1	5693.1	13146.8	+ 130.92
1 – 4	333.3	518.1	+ 55.45
5 –14	112.4	163.0	+ 45.02
15–24	217.8	356.7	+ 63.77
25–34	338.7	428.1	+ 26.40
35–44	550.4	751.5	+ 36.54
45–54	1389.8	1289.1	— 7.25
55–64	3029.3	2200.9	— 27.35
65–74	6048.1	4796.5	— 20.69
75–84	12602.6	10196.5	— 19.09
85 and over	28959.7	22633.7	— 21.84
Crude Rate	1059.7	1203.1	+ 13.53
Age-Adjusted Rate			
U. S., 1940	13.06	13.05	— 0.1
E and W, 1901	10.14	11.68	+ 15.2

used as the standard, the age-adjusted rates are 10.14 for Louisiana and 11.68 for New Mexico, a difference of 15.2 per cent. It is seen that not only is the age-adjusted rate deficient in its sensitivity, but its specificity is also in question since, by the use of different standards, different results are obtained for the relative standing of the two states. Moreover, no objective yardstick is available for determining which of these, if any, summarizes more adequately the complicated situation inherent in the two sets of age-specific rates.

The dilemma resulting from situations such as this may be viewed from several points of view. Probably the most sensible is that the two states exhibit such different patterns of mortality that they cannot be compared by a single measure; the comparison between these states can only be accomplished by a very detailed study of the specific rates, age for age. However, if this point of view is adopted, then the logical conclusion is to drop completely the use of age-adjusted rates because, as was pointed out several times, the pattern of the age-specific rates for these states is not the exception but is more nearly the mode. Moreover, as was noted previously, there exists a real need for a single index for use in comparing group mortalities.

Another approach is an attempt to determine which of the comparisons provided by the different standards is more desirable. This inevitably leads to a prejudgment on the relative importance of death in the different parts of the age scale. It is unlikely that different investigators will arrive at similar evaluations, and the measure, of necessity, will degenerate into a reflection of the likes and dislikes of the evaluaters.

A third approach is to question, not so much the differing results obtained by the different standards, but to inquire into the entire mechanism of age adjustment to determine whether or not it accomplishes what it was presumably designed to do. In other words, is the procedure of selecting an arbitrary population merely because it is or was a living population likely to produce sensible comparisons between two sets of age-specific rates? This last approach deserves further exploration.

RELATIVE RISKS AND ABSOLUTE NUMBERS OF DEATHS

The dilemmas and paradoxes revealed by the foregoing examples result mainly from the fact that while the age-adjusted rate is generally interpreted as an instrument for comparing relative risks, its actual value is dominated by *absolute number* of deaths. It evaluates the age-specific rates in terms of absolute rather than relative differences. This may perhaps be seen more clearly from the following example:

If, in each age group, we select the highest rate experienced by any state in 1940, and the lowest rate, two sets of age-specific rates are obtained reflecting the maximum variation in the rates in that period. Considering these two sets of rates as belonging to two hypothetical population groups, and adjusting them by the direct method and the use of the 1940 U. S. population as a standard, the resultant age-adjusted rates are 17.3 for the high group and 8.3 for the low one. The former is therefore higher than the latter by 108 per cent. What are the components which entered into the creation of this difference of 108 per cent? In Table 5 and Figure 4 an attempt is made to answer this question.

The right hand side of Figure 4 shows the contribution which each age group makes to the total number of expected deaths in the standard population for both the high and the low groups. The difference between the two (the dark bars) represents the excess in expected deaths resulting from the difference be-

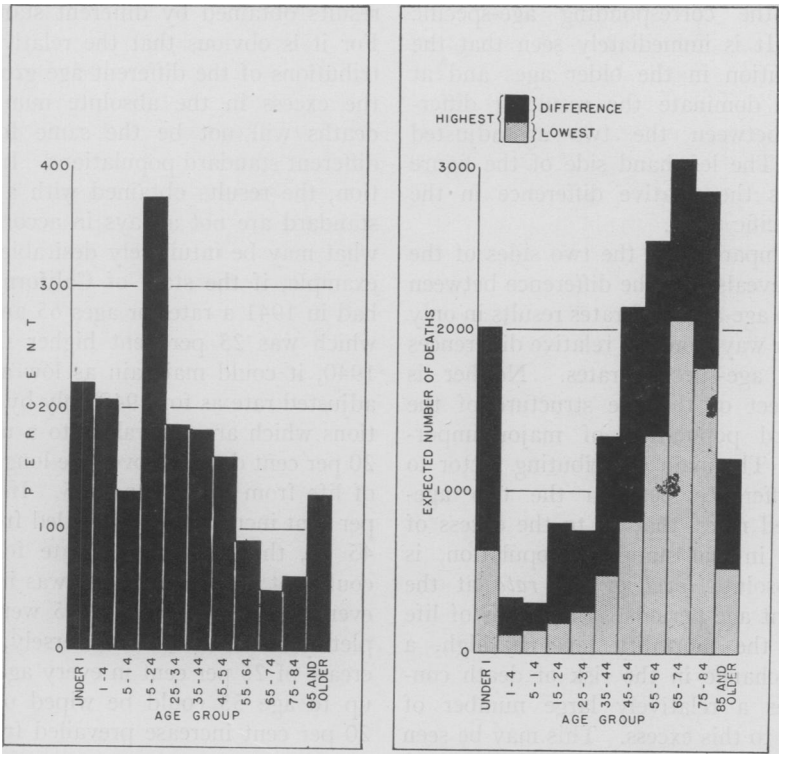

FIGURE 4—The per cent by which the age-specific rates in the high * group were higher than those in the low * group and the distribution by age of the expected number of deaths in the standard U. S. 1940 population.

TABLE 5

*A Comparison of the Age-Specific Rates and the Age-Adjusted Rates for White Males in the High and Low Groups * and the Percentage Distribution by Age of the Excess of Deaths in the Standard United States 1940 Population*

Age Group	*Age-Specific Rates*		*High Group Compared to Low Group*	
	High Group *	*Low Group* *	*Per cent difference in age-specific rates*	*Per cent of excess of deaths in standard population*
Under 1	131.5	41.0	220.7	15.3
1– 4	5.2	1.7	205.9	2.5
5–14	1.8	0.8	125.0	1.9
15–24	4.4	0.9	388.8	7.0
25–34	4.6	1.6	187.5	5.4
35–44	9.6	3.4	182.4	9.5
45–54	18.1	7.0	158.5	14.4
55–64	31.7	16.7	89.8	13.3
65–74	63.1	42.2	49.5	11.2
75–84	164.9	102.0	61.7	12.0
85 and over	434.2	190.5	127.9	7.5
Age-Adjusted Rate				
U. S. 1940	17.3	8.3	108.4	100.0
E & W 1901	15.1	6.7	125.3	

* For definition of high and low groups, see text.

tween the corresponding age-specific rates. It is immediately seen that the contribution in the older ages and at infancy dominate the resulting differences between the two age-adjusted rates. The left-hand side of the figure presents the relative difference in the age-specific rates.

A comparison of the two sides of the chart reveals that the difference between the two age-adjusted rates results in only a minor way from the relative differences in the age-specific rates. Neither is the effect of the age structure of the standard population of major importance. The main contributing factor to the difference between the two age-adjusted rates, that is, to the excess of deaths in the standard population, is the absolute *level of the rate* at the different age periods. In periods of life where the mortality level is high, a slight change in the risk of death contributes a relatively large number of deaths to this excess. This may be seen also from the last two columns in Table 5, which compare for each age group the per cent by which the high group exceeds the low group in age-specific rate, with the per cent contribution which the age group made to the excess of deaths in the standard population. For example, at age 15–24 the rate in the high group was nearly 400 per cent higher than that in the low one; however, of the total number of additional expected deaths in the standard population, only 7 per cent are due to that age group.

The comparison of mortality by means of two age-adjusted rates is much like attempting to derive a general impression of death rates in two communities of the same size by plotting the numbers of deaths on an *arithmetic* instead of a *logarithmic* scale.

The fact that the age-adjusted rate is allowed to be influenced to such a great extent by the absolute number of deaths is responsible first for the different results obtained by different standards. For it is obvious that the relative contributions of the different age groups to the excess in the absolute number of deaths will not be the same for two different standard populations. In addition, the results obtained with a single standard are not always in accord with what may be intuitively desirable. For example, if the state of California had had in 1941 a rate for ages 65 and over which was 25 per cent higher than in 1940, it could maintain as low an age-adjusted rate as for 1940 only by reductions which are equivalent to a uniform 20 per cent decrease over the long period of life from birth to age 65. If the 25 per cent increase had prevailed from age 45 on, the age-adjusted rate for 1941 could not be as small as it was in 1940, even if deaths up to age 45 were completely eliminated. Conversely, a decrease of 25 per cent in every age group up to age 55 could be wiped out if a 20 per cent increase prevailed from age 65 on.

A MORTALITY INDEX AS A SUBSTITUTE FOR THE AGE-ADJUSTED RATE

It is abundantly evident from the foregoing that the age-adjusted rate, whatever other qualities it may possess, is not a suitable index for comparing two sets of age-specific rates, if interest is centered on evaluating the comparative risks exhibited in the two sets. If an index is to accomplish this latter end, it must be so constructed that its numerical value will be affected to the same degree by proportionate changes in the age-specific rate, no matter on what point of the age scale they happen to fall. That is, the index must be such that it will evaluate reductions or increases at any age of life as carrying the same weight as similar proportionate reductions or increases at any other age of life.

A set of weights which would accomplish this objective is one whose weights

are proportionate to the reciprocals of a set of age-specific rates of a given population. Such a set of weights may be viewed as representing groups in which a *constant* number of deaths would occur in each age of life, according to the mortality schedule of the selected population. Consequently, an increase of p per cent in any age-specific rate will result in an increase of p per cent in that constant number of deaths, irrespective of the position on the age scale where the increase occurred. The weights are therefore much larger for ages at which mortality is generally low and smaller at ages of higher mortality.

The algebraic expression for this index, in the usual notation, is as follows:

$$ {}_sMI_u = A \Sigma \frac{m_{ui}}{m_{si}} d_i $$

where

${}_sMI_u$ = Mortality Index for population u derived from age-specific rates of standard population s

m_{ui} and m_{si} = Specific death rates for the i-th age group in community u and in standard population s respectively

d_i = Length of the i-th age interval

A = A constant selected to make the value of ${}_sMI_s = 100$

A sample set of weights for the construction of a Mortality Index is shown in Table 6. These were constructed according to the schedule of mortality of the 1940 total population of the United States. The basic elements are the reciprocals of the age-specific rates for this population. They are presented in age groups corresponding to those found in many publications of the National Office of Vital Statistics and have been multiplied in each case by the appropriate length of interval. One adjustment was made in the last age group (85 and over) which is an open interval. Although this interval may cover a relatively long period, the reciprocal was multiplied by 10 in order to avoid assigning to this last age group a greater weight than is reasonable.

TABLE 6

Weights for Mortality Index

Based on the Age-Specific Rates for the Total Population of the United States, 1940

Age Group	*Weights*	*Expected deaths according to 1940 age-specific rates*
Under 1	19	1.04
1– 4	1,454	4.21
5–14	10,160	10.53
15–24	5,140	10.53
25–34	3,441	10.53
35–44	2,024	10.53
45–54	993	10.54
55–64	473	10.53
65–74	220	10.56
75–84	93	10.47
85 and over	46	10.53
		100.00

The constant "A" was selected in such a way as to make the total number of deaths for the selected standard equal 100. This was done because the purpose was to construct an index number rather than a rate in a hypothetical population. In other words, when these weights are used for any other group, the resultant index number will indicate in percentage form the relation of the age-specific rates for the group to that of the 1940 total U. S. population, which has the value 100.

It is important to emphasize that while the actual operation with these weights is the same as that of age adjustment by direct method, the figures in the table are to be interpreted as *weights* and not as representing any population group. They are not intended to approximate any population and, indeed, they are different from any conceivable population. The index which is constructed by these weights may be termed a Mortality Index. It satisfies all the conditions which the age-adjusted rate does, but has in addition the properties of specificity and sensitivity, in the sense that it reflects both the relative differences in the age-specific rates, and the

length of the period in the age span in which these differences prevailed. When, for example, the index for white males in 1940 is compared to that for 1920, revealing a reduction of 35 per cent, it not only presents a figure which intuitively is more in keeping with the actual reduction that occurred during the 20 year period, but it also conveys a meaning which can be definitely stated —namely, that when each per cent change had been weighted by the length of the age scale in which it operated, the overall reduction in the death rate is equivalent to a uniform 35 per cent decrease in each age group all along the age scale.

It may be of interest to derive the values of the Mortality Index for the 48 states and to compare the resultant relative standing of the states with that obtained by the age-adjusted rate. Such a comparison is presented in Table 7 for white males in 1940. The range of the values was from 82.59 for North Dakota to 142.71 for Arizona.

It will be noted that on both ends of the table, only minor changes in rank order occur. This is due to the fact that states with very low or very high rates on a major portion of the age scale can easily be compared and ranked.

In the middle range, however, changes of considerable magnitude in the rank order occur. For example, Rhode Island is ranked 10th lowest by the Mortality Index and 35th according to the age-adjusted rate. Similar changes may be noted for Massachusetts, New Jersey, and New York. On the other end of the scale, Idaho is ranked 17th lowest according to the age-adjusted rate and 40th by the Mortality Index.

In evaluating the two lists of rank orders, attention is directed to the fact that when the ranking is performed by means of the Mortality Index it is at least possible to state, in terms of the corresponding sets of age-specific rates, what meaning may be attached to the relative rank order; while no similar clear-cut statement can be made with respect to the rank order obtained by the use of the age-adjusted rate.

It may, however, be desirable to obtain, by means of an example, a general

TABLE 7

Mortality Index for Each State, and the Ranking of the States According to Mortality Index and According to the Age-Adjusted Rate Based on 1940 Total United States Population as a Standard

(White Males, United States, 1940)

State	Mortality Index	Rank, by— Mortality Index	Rank, by— Age-Adjusted Rate
North Dakota	82.59	1	1
South Dakota	82.72	2	2
Nebraska	85.75	3	3
Minnesota	88.35	4	6
Iowa	88.90	5	4
Kansas	90.06	6	5
Wisconsin	91.99	7	9
Connecticut	93.86	8	13
Oklahoma	93.98	9	7
Rhode Island	95.95	10	35
Arkansas	97.24	11	8
Massachusetts	99.02	12	30
Michigan	99.34	13	12
Missouri	99.84	14	10
New Jersey	100.16	15	36
Delaware	101.15	16	18
New York	102.52	17	38
Ohio	102.91	18	23
New Hampshire	103.53	19	29
Vermont	103.56	20	26
Maine	104.25	21	25
Indiana	104.35	22	16
North Carolina	105.46	23	28
Illinois	105.85	24	33
Washington	107.02	25	19
Oregon	107.27	26	11
Tennessee	107.76	27	27
Virginia	108.34	28	37
Montana	108.91	29	15
Pennsylvania	109.03	30	39
Wyoming	109.28	31	14
Alabama	109.40	32	34
Mississippi	109.75	33	24
Kentucky	109.76	34	20
West Virginia	110.71	35	21
Texas	112.55	36	32
Maryland	112.64	37	43
Utah	113.37	38	22
California	113.77	39	41
Idaho	114.73	40	17
South Carolina	115.21	41	44
Georgia	115.51	42	40
Colorado	116.09	43	31
Louisiana	117.68	44	46
Florida	117.85	45	42
New Mexico	128.47	46	45
Nevada	141.43	47	47
Arizona	142.71	48	48

impression of the difference between the two rankings. The States of Rhode Island and Utah were ranked much differently by the Mortality Index than by the age-adjusted rate. According to the Mortality Index, Rhode Island ranks 10th lowest, while according to the age-adjusted rate it occupies position No. 35. Conversely, the State of Utah is in position No. 38 among the states according to the Mortality Index, while the age-adjusted rate ranks it as 22nd lowest. A direct comparison between the two states is shown in Table 8.

TABLE 8

A Comparison of the Age-Specific Death Rates, the Age-Adjusted Rates, and the Mortality Index for White Males in Rhode Island and in Utah, 1940

Age Group	Age-Specific Rates Per 100,000		Per Cent Difference, Rhode Island-Utah
	Rhode Island	Utah	
Under 1	5300.7	5489.9	— 3.4
1– 4	250.7	299.0	— 16.2
5–14	104.8	153.7	— 31.8
15–24	93.6	245.4	— 61.9
25–34	193.5	384.6	— 49.7
35–44	410.2	617.2	— 33.5
45–54	1114.3	1189.0	— 6.3
55–64	3101.1	2464.4	+ 25.8
65–74	6307.0	4585.1	+ 37.6
75–84	12112.5	11230.1	+ 7.9
85 and over	23600.0	22304.8	+ 5.8
Crude Rate	11.9	10.0	+ 19.0
Age-Adjusted Rate			
U. S. 1940	11.9	11.4	+ 3.5
Mortality Index	95.95	113.37	— 15.4

It will be seen that both the crude rate and the age-adjusted rate are higher for Rhode Island than for Utah, while the Mortality Index shows Rhode Island in much more favorable light than it does Utah. A review of the age-specific rates shows that the rates for Rhode Island were considerably lower than those for Utah from the beginning of life to age 55, but that after age 55 the rates are relatively higher for Rhode Island than for Utah. The age-adjusted rate is influenced by these later increases to nullify the favorable situation of Rhode Island during the relatively large portion of the age scale. The Mortality Index, on the other hand, although taking the increasing rates at the older ages into account, does not assign to them such great weights as to hide the rather favorable position which the state of Rhode Island enjoys as compared to Utah in the very important productive periods of life.

DISCUSSION

The possible merits of the Mortality Index presented here, and its potential use for mortality comparisons, depend on a clarification of the purpose of age adjustment and the needs which it was devised to meet. Presumably the adjustment procedure was introduced to render groups more comparable so that their relative mortalities could be more easily evaluated. The question arises as to what is meant by evaluating comparative mortalities of two groups. In practice, the age-adjusted rates for the two groups are determined, and the ratio of the two obtained. This ratio is presented with the implication that the mortality of A is p per cent higher or lower than that of B. It would be difficult, however, if not impossible, to spell out even in a remote fashion what this p per cent higher mortality really means. Since the age-specific rates are the bricks with which the age-adjusted rate is constructed, it is assumed that the purpose of the latter is to present in summary form the information present in the set of age-specific rates, in order that it may be compared with a similar figure obtained in the same manner from another set. When so stated, the purpose becomes clearer, and the methods for accomplishing it may be more easily evaluated.

Thus, it is evident that a summarization which is based on absolute number of deaths and where comparison is made of absolute differences between rates will inevitably lead to confusion. For the results of the comparison will auto-

matically be interpreted as differences in risk, while the summarization is affected by the relative risks only to a minor degree, compared with the absolute number of deaths, which controls it. Moreover, the comparison of two index numbers thus constructed will convey an impression which is far different from that derived from a detailed comparison of two sets of age-specific rates as it is usually performed.

This does not mean that there are no occasions when the age-specific rates are compared in terms of absolute differences in rates and in absolute number of deaths. The construction of life table functions is such an example. However, when the desired information relates to an evaluation of the relative risks of death, the resultant comparison will be devoid of meaning unless the summarization is that of *proportionate* and not *absolute* differences in the individual age-specific rates.

The Mortality Index presented here is the only one which is constructed on this principle. It therefore has the property that a difference of p per cent between two values of the index conveys the information that Group A has a higher mortality than Group B equivalent to age-specific rates which are higher by p per cent all along the age scale. Moreover, this figure of p per cent presents the composite effects of the relative age-specific rates of the two groups in *both directions,* each weighted by the length of the period in the age scale in which it was present. In other words, in arriving at this p per cent, proportionate credit was given to A for each period of the life span where its rate was lower than that of B, as was given to the latter for each period where its rate was lower than that of A.

It should be noted that the mechanism provided by this index lends itself also to modifications which allow for different evaluations of relative mortalities at different ages if this is desired. All that is necessary is to multiply these weights by another set which assigns different relative values for the different ages. For example, if it is found desirable to weight reductions in infant mortality k times as heavily as similar proportionate reductions at any other age of life, all that is necessary to do is to multiply the weight for under 1 year by k and adjust the weights accordingly. The difference is that in this case the control of the index is in our hands and it can be definitely stated what the relative evaluations are; whereas present methods of age adjustment leave the control of the relative weighting to an arbitrary and accidental distribution of a certain population at a given point of time.

It is obvious that a great number of questions arise relating to the possible adoption of the Mortality Index for place-to-place and time-to-time comparisons. A great many experimentations and trials would be required before its practical utility could be evaluated. A number of problems can easily be anticipated. For example, the values of the index bear no relationship to the numbers in the population experiencing the different rates. Whether or not it is in general desirable that such a relationship exist, it is obvious that in certain cases a limit must at least be set for the proportion of persons experiencing the rate before any changes in it be given equal weights with changes in other rates. In fact, the problem has already been encountered in the construction of the present weights, in that it was found that adjustments were necessary for the age group 85 years and over. Even more difficult situations will no doubt be encountered if indices are constructed for factors other than age. For example, in adjustment for race it will be necessary to face the problem whether it is justifiable to assign equal weighting to changes in the rates for different races in light of the great numerical superiority of the white race.

Another problem relates to the stability of the index—namely, whether weights determined from age-specific rates in one period differ much from those for another period, and if so, which are the more desirable. This could be answered only by extensive experimentation and testing. However, on general grounds it appears that the weights have considerable stability because it is not the level of the age-specific rates but rather their mutual numerical relationship which determines the weights. Since it may be anticipated that future reductions in mortality will not vary by age as much as they have in the past, it is likely that an index constructed with the schedule of mortality for 1950 will serve satisfactorily for a long period of time.

Another serious consideration relates to the reliability of the different age-specific rates along the age scale. In the present discussion the problem was not dealt with. It was assumed throughout that the rates for each age group are based on sufficiently large numbers so that, for example, a reduction at age 20, from a rate of 2 to 1, is real. This question needs to be investigated in terms of the standard error for the index. It should, however, be noted that the problem is not confined to the present Mortality Index but needs to be dealt with also in all other methods of adjustment.

A number of other disadvantages may be quoted for the index. For example, different sets of weights need to be constructed for different causes of death. The weights derived from one cause cannot be used for derivation of indices for a different cause. For each cause of death the index must be derived from its own age-specific rate schedule. This does not seem to be a great disadvantage, however, because there are rarely occasions in which adjusted rates for one cause are compared with those for another.

The Mortality Index is inferior to the age-adjusted rate in terms of simplicity of explanation. It is relatively easy to explain the age-adjusted rate because it is put in terms of another population group, which is easily comprehensible. This handicap, however, may not be as great as first appears, for the frame of reference adopted for the index will assist in comprehension. If, for example, the age-specific rates for 1950, when they become available, are used in the construction of the weights, the value of the index for that year will be 100, and the values of the index for all other groups will provide automatic comparisons to the mortality of the country in mid-century. The situation will be much like that of the cost of living index, which has now become generally accepted and is even incorporated in contracts between employers and employees. There is little reason to suppose that it will be more difficult for the country to grasp the meaning of a release by the National Office of Vital Statistics that the Mortality Index for this year is a certain percentage lower than it was last year. It is likely that in a short time boards of health and county commissioners will learn the meaning of such an index as unions and employers learned to understand the cost of living index.

SUMMARY

The age-adjusted rate as presently employed is an inadequate measure for comparing group mortalities. It lacks specificity and sensitivity and evaluates differently equal proportionate changes when they occur in different ages. It puts relatively heavy premiums and penalties on minor proportionate changes in the older ages. The relative difference between two age-adjusted rates is determined to only a minor degree by the differences in the two sets of age-specific rates. Neither is the age composition of the standard population a major contributing factor. The largest share of

the difference between the two adjusted rates results from the level of the rate at which the changes occur.

A mortality index has been constructed which summarizes more adequately a set of age-specific rates. It is built on the principle that equal proportionate changes affect the index equally, no matter at which point in the age scale the changes occur. It is both specific and sensitive in the sense that when the value for one group is p per cent higher than that for another, it indicates that the difference in mortality between the two groups is equivalent to p per cent higher rates for one group over another along the entire age scale. The summarization provided by the index is such that each change between the two sets of age-specific rates has been weighted by the length of time in the life span in which it operated and was evaluated equally.

It is suggested that this mortality index be tested carefully in its practical application. It appears to possess sufficient merit to recommend it for experimentation and trial.

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The Clark Health Insurance Report

On May 28, Senator Herbert H. Lehman, as chairman of the Senate Subcommittee on Health, presented to the Senate a report on Health Insurance Plans in the United States. Authorized in Senate Resolutions of both the 81st and 82nd Congresses directing further study of health problems, the report was made under the supervision of Dean A. Clark, M.D., as consulting director.

Among its findings are that half the people in the United States have no form of medical care insurance protection and that less than three per cent have comprehensive medical care insurance, including hospital, surgical, and relatively complete medical care insurance.

The report is in three parts, the second being an appendix of seven statements submitted to the Subcommittee by various organizations to be used in preparation of the report. Part III, much briefer than the other two, is a summary of activities of local, state, and federal governments in the field of health. Copies may be secured from the Government Printing Office or from your own Senator.