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MEASURING AND EXPLAINING THE CHANGE IN LIFE EXPECTANCIES

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Abstract—A set of new indices for interpreting change in life expectancies, as well as a technique for explaining change in life expectancies by change in mortality at each age group are presented in the paper. The indices, as well as the new technique for explaining the differences in life expectancies, have been tested and examples using United States life tables are presented. The technique for explaining life expectancy differentials can be used for analyzing change in mortality or mortality differentials by sex, ethnicity, region, or any other subpopulations. The technique can be applied to life expectancies at birth or temporary life expectancies between any desirable ages.

It is well known that an analysis of the general level of mortality of a population based on crude death rates is affected by changes in the population age structure. Consequently, although crude death rates are easy to understand, they are not recommended for determining the pace of mortality change. The problem is partially solved by using standardized crude death rates (standardized by age structure), but the selection of the standard age structure could have some effect on the results. Furthermore, standardized crude death rates would approach a limit (since humans have to die) and therefore problems in interpreting the change would arise.

Life expectancies at birth have frequently been used for analyzing change in mortality. Nevertheless, the measurement and interpretation of life expectancy changes are affected by a problem of relative magnitude. The possible future change of a life expectancy depends on the already achieved level of life expectancy. For instance, a country with a current life expectancy at birth of 75 years for both sexes is not likely to have an increase of 10 or even 5 additional years during a decade; however, there have been populations with life expectancies at birth of about 40 years which did experience increases of over 10 years in life expectancy at birth during a decade. This characteristic of life expectancies (not only at birth but for any age) leads to the problem of how to interpret their change, since it appears easier to achieve a change of 10 years of life expectancies at birth at a level of 40 years of life, than a change of five years at a level of 75 years of life during a similar period of time. Undoubtedly, the possible change in life expectancies is restricted by the limits of the human life span.

In addition to the effect of biological limit on the problem of interpreting a life expectancy change, there is also a technical problem due to unreliable information. Many countries with incomplete death registration systems often report levels of mortality at older ages (usually over 65 years) which are unacceptable or which contain random fluctuations (because of small populations), reflecting information problems rather than mortality variations. (Corona, et al, 1981; Hong Kong, 1978; Stolnitz, 1955). The problem is usually solved by using smoothing techniques or by disregarding the reported information and estimating the mortality of old ages by using models or mathematical functions. (Arriaga, 1968; Balmford, no date; Barral and Somoza, 1953; Caffin, no date; Hong Kong, 1978; Medica, 1964; U.S. Bureau of the Census, 1921 and 1964; and others). Since mortality at older ages may not represent actuality and its level affects life expectancies at younger ages, life expectancy changes could be affected by the assumptions or corrections made on mortality at old ages. These two aspects—the biological limit and errors in old ages—make it cumbersome to compare life expectancies for the purpose of determining the pace of mortality change in a population.

Another aspect of mortality analysis is to estimate and/or to understand the contribution of mortality change at each age group to the total change in life expectancy (the decomposition of the change). A change in life expectancy (at any age) does not necessarily mean that mortality rates change in the same magnitude, or even in the same direction at all ages. Usually, most age groups will register a decline in mortality and hence will contribute to increased life expectancy; but for some age groups, mortality may have even increased and would have a counteracting effect on the increase in life expectancy. This would be the case for some developed countries where, although males have increased their life expectancies at birth, some young adult age groups have experienced an increase in mortality (Caselli and Egidi, 1981; Dutton, 1979). Among developing countries, Argentina, Brazil, Chile, and Honduras (Arriaga, 1981) can also be given as examples. Also, it would be useful to explain or decompose differences in two life expectancies pertaining to two populations (male-female, urban-rural, states, ethnic groups, etc.) in relation to the mortality differential at each age. In comparing two different populations, the cross-over of mortality at different ages is not an unexpected phenomena.

This article describes first, some indices that could help in measuring and understanding change in life expectancies; and second, illustrates how a change in life expectancy can be decomposed to show the contribution of each age group to the total change. The term "life expectancy" is used in its general sense to refer to any age or to temporary life expectancies.

THE USE OF TEMPORARY LIFE EXPECTANCIES IN THE MEASUREMENT OF MORTALITY CHANGE

As indicated above, published life table mortality at old ages, mainly in countries with unreliable statistics, may not represent the actual mortality of those ages but instead a simplistic assumption based on a model life table or a mathematical function. Therefore, a comparative analysis of mortality trends should avoid, if possible, the use of the assumed mortality at those ages where reported statistics are grossly deficient. Also, the effect of the limit of the human life span on the possible change in life expectancies should be taken into account when interpreting the observed change in life expectancies.

Both problems can be avoided by the use of temporary life expectancies (life expectancies between two specific ages) and indices based on the comparison of temporary life expectancies. The temporary life expectancy from age x to $x + i$ is the average number of years that a group of persons alive at exact age x will live from age x to $x + i$ years. In symbols,

$$_{i}e_{x} = \frac{T_x - T_{x+i}}{l_x} \tag{1}$$

If $x = 0$ and $i = 65$, then the temporary life expectancy would be from birth to age 65. As far as possible, the old age limit should be the oldest age with reliable information; otherwise actual changes of mortality at older ages will not be included. However, while the absolute change of temporary life expectancies will give the increase or decrease of years of life between two particular ages, it should not be used for analyzing the pace of mortality change. As has been suggested (Arriaga, 1971), the pace of mortality change during a period of time should be treated as a relative measure, i.e., the observed change in temporary life expectancies in relation to the possible maximum change. In symbols,

$$ {}_iRC_x^{\,n} = \frac{{}_ie_x^{\,t+n} - {}_ie_x^{\,t}}{i - {}_ie_x^{\,t}}. \qquad (2)$$

However, this index does not permit a comparison of the change when periods of time are different (Arriaga, 1971). In this case, an annual change of the *RC* index should be used and it can be estimated as:

$$ {}_iARC_x^{\,n} = [1 - (1 - {}_iRC_x^{\,n})^{1/n}]\ .100 \qquad (3)$$

The index of relative change can be interpreted as the percent change in mortality rates. When calculating the percent change in two mortality rates, the numerator is the reduction in deaths per thousand population during a period of time and the denominator is the maximum possible reduction in deaths (the mortality rate at the beginning of the period). That is, the percent change in two mortality rates measures the observed reduction in deaths in relation to the total possible reduction. The index of relative change is similar. The increase in the number of life years during a period of time (the numerator) is also a reduction in life years *lost* because of deaths and the possible increase in the number of life years (the denominator) is also the maximum reduction of the life years *lost* between two particular ages.

Examples

The concept of relative change in temporary life expectancies refers to the years of life expectancy increase between two ages as a proportion of the maximum possible increase. For example, Table 1 presents mortality trends for white females in the United States from 1901 to 1978 and different trends of the

Table 1.—Levels and Changes of Life Expectancies at Birth and Temporary Life Expectancies from Birth to Age 80 Years for White Females in the United States for Selected years, 1901–1978

	Life Expectancy at Birth			Temporary Life Expectancy, Birth to Age 80		
		Annual Average				
Year	Level	Years Added	Percentage Change	Level	Annual Average Years Added	Index of Annual Relative Change[a]
1901	51.08			50.24		
		.282	.54		.281	.98
1910	53.62			52.76		
		.491	.89		.460	1.83
1920	58.53			57.36		
		.412	.68		.400	1.93
1930	62.65			61.36		
		.464	.71		.423	2.54
1940	67.29			65.59		
		.474	.68		.393	3.14
1950	72.03			69.52		
		.216	.30		.169	1.74
1960	74.19			71.21		
		.130	.17		.062	.73
1970	75.49			71.83		
		.288	.38		.155	2.03
1978	77.79			73.07		

SOURCE: Calculated from U.S. Department of Commerce, 1936 and 1946; U.S. Department of Health, Education and Welfare, 1954, 1964 and 1975; and U.S. Department of Health and Human Services, 1980.

[a]See formula (3).

pace of mortality change when measured using life expectancies at birth or using temporary life expectancies between birth and age 80 years.

The change in life expectancies at birth, the average number of years added to life expectancies, or the annual percentage change indicates that mortality declined fastest during the 1910–1920 decade, followed by the 1930–1940 decade. If instead, the change in mortality is measured by using temporary life expectancies, the absolute change shows a very similar trend, as does the absolute change in the life expectancies at birth. However, when the annual average relative change index (formula 3) is estimated, the situation is different and the greatest relative improvement in mortality seems to have occurred during the 1940s. Furthermore, the mortality change during the 1970s seems more significant than the one observed from 1901 to 1930. The trend in the annual relative change of temporary life expectancies seems to follow what has been recently suggested concerning the trend of mortality decline in the United States since 1940, measured by age-specific mortality rates (Crimmins, 1981). In other words, it seems that while the change in life expectancies (absolute or percentage) does not follow the pattern of most age specific mortality rates, the annual index of relative change does.

DECOMPOSITION OF THE LIFE EXPECTANCY DIFFERENCE

Scholars have focused their interest on measuring the impact of eradicating a particular cause of death on the life expectancy (Chiang, 1968; Schwartz and Lazar, 1963; Spiegelman, 1968). For this purpose, multidecrement life tables were used for determining the change that life expectancy at birth would have if a particular cause of death (or group of causes) were eliminated. These tables explain the impact of eradicating a cause of death on life expectancy without determining the effect of changing mortality on life expectancy at each age as does the technique presented in this paper. Scholars also have been interested in measuring the variance of life expectancies (Chiang, 1968; Irving, 1949; Keyfitz, 1971; Wilson, 1938) in order to determine the impact that errors in mortality levels at each age will have on life expectancy. Since the magnitude of an error could be assumed to be a change of mortality, these authors among others, were also dealing with the subject of this article. In their analyses, they developed an approximation formula for detecting the impact of changes in mortality rates at a given age on the life expectancy (in the discrete and continuous field). Since their interest was to estimate the variance of the life expectancies, no further attempt was made to explain the different impact that change in mortality at a particular age has on life expectancy, nor did they examine the possibility of explaining the 100 percent life expectancy change as a function of mortality change by age (since they derived an approximation formula). Nevertheless, they were pioneers in explaining the impact of changing mortality on life expectancy in certain age groups.

This section explains how to estimate the contribution of a change in mortality at each age group to the total change in life expectancy at birth, or any other age, as well as temporary life expectancies. The formula development will also apply to analyzing and/or decomposing the difference in any two life expectancies according to the difference in mortality at each particular age group. Whether the mortality difference is due to a historical change in mortality, a sex mortality differential, or mortality levels of any population or subpopulation, does not have any impact on the deductions of the formulae. For facilitating the explanation, it is assumed that mortality has changed in a population during a period of time (although time will not affect the results), and hence the change in life expectancy being analyzed.

When comparing abridged life tables with different levels of mortality, it is observed in most cases that mortality differs in all age groups by different magnitudes. Because of this fact, it is not a simple task to decompose the difference in life expectancies into the change in mortality at each particular age group. There is always an interaction effect that must be distinguished from the exclusive impact that the change in mortality in each age group (independent of other ages) has on the observed change in life expectancy. In a schematic way:

Effects of mortality change by age groups on life expectancies:

1. Effects due to the exclusive change of mortality in each particular age group:
   (a) Direct effect
   (b) Indirect effect
2. Effect of the interaction between the exclusive effect of each age group and the overall effect.

The *direct effect* on life expectancy is due to the change in life years *within* a particular age group as a consequence of the mortality change in that age group (see Figure 1). The *indirect effect* consists of the number of life years added to a given life expectancy because the mortality change within (and only within) a specific age group will produce a change in the number of survivors at the end of the age interval. The difference in survivors (between those surviving before and after the mortality change) will be added to or subtracted from "years lived" (if the difference is positive or negative, respectively) as they pass through successive ages, assuming that mortality has not changed and remains at the same level. Both direct and indirect effects are generated because mortality has changed *only* within the age group under study (it is assumed that mortality has not changed in other ages). Consequently, the addition of these two effects gives the total or exclusive effect that a

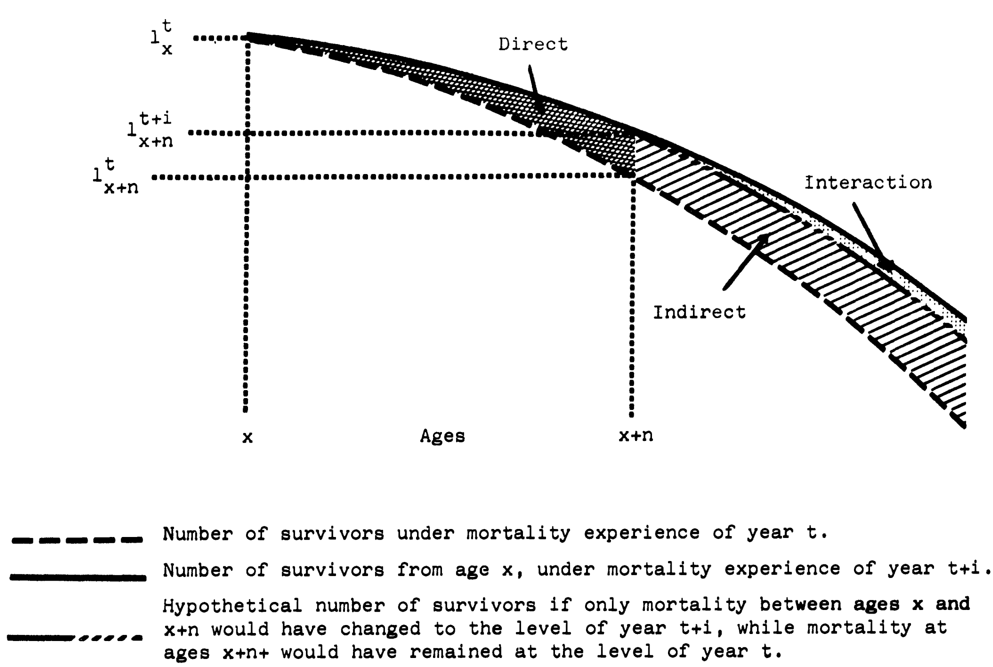


Figure 1.—Direct and Indirect Effects of a Change in Mortality at Ages x and x+n, and Interactions as a Consequence of Changing Mortality at Older Ages, on the Number of Survivors

change in mortality of a specific age group (and only that age group) produces in the life expectancy. Nevertheless, it is useful to analyze these two effects separately because of their different meaning.

Both previous effects take into account only the mortality change at each age group, independent of the change in other ages. Since mortality changes simultaneously in all ages, a small part of the life expectancy change is due to the fact that the difference in the number of survivors at the end of the age interval (those responsible for the indirect effect) will not experience an unchanged mortality. The difference in mortality levels (unchanged and actual) applied to the difference in survivors (at the end of the group age interval) produces the *interaction effect* (see Figure 1). This is the effect of the overall mortality change on life expectancy that cannot be explained by or assigned to particular age groups. Each of these different effects can be calculated as follows.

Direct Effect.

To estimate the direct effect that a mortality change in an age group x, $x + i$ has on the life expectancy at age a (at birth or any other age), age x should be equal to or greater than age a. Once mortality has changed in the age group x to $x + i$, the cohort living through ages x to $x + i$ will live (on the average) a different number of years than before (greater or smaller). The difference in the number of years lived will be given by the difference in two temporary life expectancies between ages x and $x + i$ years $({}_ie/x_x{}^{t+n} - {}_ie_x{}^t)$, times the number of survivors at exact age x years, l_x. To evaluate this change in years lived on the life expectancy at age a, the product of survivors at age x and the difference in temporary life expectancies has to be divided by the number of persons alive at exact age a, l_a. Using life table symbols, the direct effect $({}_iDE_x)$ of the change in mortality at ages x to $x + i$ on life expectancy at age a is:

$$
{}_iDE_x = \frac{l_x{}^t}{l_a{}^t}\,({}_ie_x{}^{t+n} - {}_ie_x{}^t)
$$

$$
= \frac{l_x{}^t}{l_a{}^t}\left(\frac{T_x{}^{t+n} - T_{x+i}^{t+n}}{l_x{}^{t+n}} - \frac{T_x{}^t - T_{x+i}^t}{l_x{}^t}\right) \tag{4}
$$

Where l and T are the life table functions, x is the initial age of the age interval i being considered, a is the age at which the life expectancy is calculated (if life expectancy at birth, $a = 0$); ${}_ie_x$ is the temporary life expectancy for the age interval, and t is the initial year of the observation period of n years.

INDIRECT EFFECT (IE)

This effect is called indirect because although it is due to the change in mortality within an age group x to $x + i$ years, it is produced at ages older than $x + i$ years under the condition that after age $x + i$ mortality *has not* changed. If mortality changes between ages x to $x + i$ years, the result is a change in the number of survivors at age $x + i$ in relation to the number of survivors at the same age before the change of mortality. The change (or difference) in the number of survivors (CS) at age $x + i$ is:

$$
{}_iCS_x = l_x{}^t\,\frac{l_{x+i}^{T+n}}{l_x{}^{t+n}} - l_{x+i}^{t} \tag{5}
$$

The additional (or reduced) number of survivors will continue living (or will not live any more) after age $x + i$ as many years as the rest of the population. Hence they will contribute with additional (or reduced) years of life to the life expectancy at age a. The number of years that each additional survivor will live (or will not live) after age $x + i$ will be the life expectancy at the same age $x + i$ before the change of mortality (e_{x+i}^t). Finally, since these additional (or reduced) years of life have to be shared by those survivors at age a, (at which life expectancy change is being analyzed) it has to be divided by l_a. Thus, the indirect effect (IE) is:

$$ {}_iIE_x = \frac{{}_iCS_x}{l_a^{\,t}}\, e_{x+i}^{t} $$

$$ = \frac{T_{x+i}^{\,t}}{l_a^{\,t}} \left(\frac{l_x^{\,t} l_{x+i}^{t+n}}{l_{x+i}^{t} l_x^{\,t+n}} - 1 \right) \qquad (6) $$

The addition of the direct and indirect effects gives the total or exclusive effect that a change in mortality in an age group will have on the total change in life expectancy.

Interaction.

There is another effect which cannot be allocated to any particular age group alone, but to the change in mortality at all ages. The additional survivors at age $x + i$ (CS, formula 5) resulting because mortality changed within ages x to $x + i$ years will be exposed to new levels of mortality after age $x + i$ years. This creates an interaction effect which is defined as a difference between two components: (a) The one resulting from the years of life to be added because the additional survivors (CS) at age $x + i$ will continue living under the *new* mortality level after mortality changed; and (b) the indirect effect (IE) mentioned above (formula 6). The difference in these two components (interaction) gives the contribution that the additional survivors at age $x + i$ years (because mortality changed in ages x to $x + i$ years) will make to the total change in life expectancy because mortality also changed after age $x + i$ years.

Each of the additional survivors at age $x + i$ (CS) will live on the average after age $x + i$ a number of years equal to the life expectancy at that age, under the new level of mortality. Hence the product of the life expectancy at age $x + i$ after the change in mortality (year $t + n$) times the additional survivors (CS), and divided by the l_a survivors at age a (at which the analysis is being evaluated) gives the component mentioned above in (a). In symbols, calling this component (OE):

$$ {}_iOE_x = \frac{{}_iCS_x}{l_a^{\,t}}\, e_{x+i}^{t+n} $$

$$ = \frac{T_{x+i}^{\,t+n}}{l_a^{\,t}} \left(\frac{l_x^{\,t}}{l_x^{\,t+n}} - \frac{l_{x+i}^{t}}{l_{x+1}^{t}} \right) \qquad (7) $$

The interaction (I) as defined here is the difference between the component OE and the indirect effect IE. In symbols:

$$ {}_iI_x = {}_iOE_x - {}_iIE_x \qquad (8) $$

Finally, the effect that mortality change in the open-ended age group produces on the total change in life expectancy at age a will be only the direct effect. Since this is the *last* age group, the indirect effect and interaction do not exist. The formula for calculating the direct effect for the open-ended age group differs from the direct effect formula (4) for other age groups. The difference is the life expectancies used for its calculation; they are not temporary life expectancies, but a life expectancy at age x. In symbols,

$$ DE_{x+} = \frac{l_x^t}{l_a^t} \left(e_x^{\,t+n} - e_x^t \right) $$

$$ = \frac{l_x^t}{l_a^t} \left(\frac{T_x^{\,t+n}}{l_x^{\,t+n}} - \frac{T_x^{\,t}}{l_x^t} \right) \qquad (9) $$

DECOMPOSITION OF TEMPORARY LIFE EXPECTANCY CHANGES

The analysis of mortality may exclude some age groups, e.g. the oldest because of the data problems discussed earlier, or may only be directed toward some segments of life such as school age years, labor force ages, or childbearing years. In this case, the decomposition is made for the total change of two temporary life expectancies. Such change can also be decomposed by the contribution made by mortality change in each age group. The formula is practically the same as for life expectancies. The only difference is that since the analysis is limited to a segment of life, temporary life expectancies should be used in the formulae. If the analysis is directed at an age span between ages a and $a + j$ (for a temporary life expectancy ${}_je_a$) then the *direct effect*, as in the previous case for life expectancies, would be:

$$ {}_iTDE_x = \frac{l_x^t}{l_a^t}\left({}_ie_x^{t+n} - {}_ie_x^t\right) \qquad (10)$$

The *indirect effect* would be:

$$ {}_iITE_x = \frac{1}{l_a^t} \cdot {}_iCS_x \cdot {}_ue_{x+i}^t \qquad (11)$$

where ${}_ue_{x+i}$ is the temporary life expectancy from age $x + i$ to age $a + j$, and $u = a + j - x - i$. In symbols,

$$ {}_ue_{x+i}^t = \frac{T_{x+i}^t - T_{a+j}^t}{l_{x+i}^t} \qquad (12)$$

The other effect necessary for determining the interaction is:

$$ {}_iTOE_x = \frac{1}{l_a^t} \cdot {}_iCS_x \cdot {}_ue_{x+i}^{t+n} \qquad (13)$$

and therefore, the interaction is:

$$ {}_iTI_x = {}_iTOE_x - {}_iTIE_x$$

$$ = \frac{1}{l_a^t} \cdot {}_iCS_x \left({}_ue_{x+i}^{t+n} - {}_ue_{x+i}^t\right) \qquad (14)$$

Because temporary life expectancies are calculated between two specific ages, the analysis of the difference of two temporary life expectancies does not have an open-ended age group but a specific oldest age group. As in the analysis of life expectancies at age a, the oldest age group has only a direct effect. The direct effect of the oldest age group in the analysis of difference of temporary life expectancies is calculated with the same formula (10) as the direct effect for any age group. The total effect of mortality change by age on the life expectancy is additive by age. For instance, the addition of the total effect on ages 15–19 and 20–29 is the same as the total effect of ages 15–29. However, the direct and indirect effects as well as interactions do not have such properties independently. The addition of direct effects of two consecutive age groups (15–19 and 20–29) is smaller than the direct effect for both age groups combined (15–29), while the indirect effect and interaction will have the opposite result.

DISCUSSION AND EXAMPLES

The procedure for decomposition of the difference between two life expectancies such as in comparing and explaining historical mortality changes, can also be used for analyzing differences in mortality levels among subpopulations at the same point in time. The first case consists of calculating the contribution that the mortality change at each age group makes to the total change in life expectancy. The second case decomposes the total life expectancy difference of two subpopulations by the contribution to such difference of the mortality differential at each age group.

Table 2 presents a comparison of the change in temporary life expectancies from birth to age 80 years for white females during three periods: 1920–1930, 1940–1950, and 1970–1978. Life expectancies are shown in Table 3. The fastest pace of mortality decline occurred during the 1940–1950 period (see Table 1). In the other two time periods, the pace of mortality decline was similar. At the beginning of the century, change in mortality at the young ages made the largest contribution to the change in temporary life expectancies while changes at the oldest ages, 45–79 years, contributed only five percent of the total change. The mortality situation changed substantially during this century, and during 1970–1978, the decline in mortality at the oldest ages, 45–79 years, had the largest impact on the increase in temporary life expectancy. The direct effect alone makes this trend more notable since it is related to the reduction of deaths within each age group. The change in mortality

Table 2.—Contribution of the Mortality Change at Each Age Group to the Total Change in Temporary Life Expectancy from Birth to Age 80 Years for White Females in the United States for Selected Periods, 1920–1978

Age	Exclusive Age Contribution: Direct (1)	Exclusive Age Contribution: Indirect (2)	Exclusive Age Contribution: Subtotal (1) + (2) (3)	Interaction (4)	Total (3) + (4) (5)	Percent of Total (6)
			1920-1930			
0-14	.386	1.589	1.975	.071	2.046	51.2
15-44	.659	1.066	1.725	.012	1.737	43.4
45-79	.217	0.000	.217	0.000	.217	5.4
All Ages	1.262	2.655	3.916	.083	3.999	100.0
			1940-1950			
0-14	.290	1.206	1.496	.056	1.552	39.4
15-44	.349	.722	1.071	.039	1.110	28.2
45-79	1.274	0.000	1.274	0.000	1.274	32.4
All Ages	1.913	1.928	3.840	.095	3.935	100.0
			1970-1978			
0-14	.080	.341	.421	.005	.426	34.4
15-44	.048	.174	.222	.004	.225	18.2
45-79	.586	0.000	.586	0.000	.586	47.3
All Ages	.713	.515	1.228	.009	1.237	100.0

SOURCE: See footnote to Table 1.

NOTE: Figures may not add to totals due to rounding.

during the 1920s produced the largest "savings" of life in ages 15–44. Nevertheless, when we add the direct and indirect effects, the mortality change under age 15 has the largest impact on temporary life expectancy from birth to age 80 years. This was due not only to the reduction of deaths up to age 15, but also because the additional survivors at age 15 will remain living from age 15 up to extinction. The situation from 1970 to 1978 was different. Most of the "savings" of life occurred between ages 45 and 80. The impact of the direct effect on these oldest ages was even greater than the total effect on the younger age groups. The different age grouping should not be overlooked. If a similar age grouping is made, for instance five-year age groups, the youngest age group, 0–4 years, still makes the largest contribution to the total change in temporary life expectancy during the period 1970 to

Table 3.—Temporary Life Expectancies from Birth to Age 80 Years, White Females in the United States, for Selected Periods 1920–1978

Period	Life Expectancies
1920	57.36
1930	61.36
1940	65.59
1950	69.53
1970	71.83
1978	73.07

Table 4.—Contribution of the Mortality Racial Differential at Each Age Group to the Total Racial Differential in Temporary Life Expectancy Between Ages 15 and 65 Years for White and Black Males in the United States, 1910 and 1978

Age	Exclusive Age Contribution: Direct (1)	Exclusive Age Contribution: Indirect (2)	Exclusive Age Contribution: Subtotal (3)	Interaction (4)	Total (3) + (4) (5)	Percent of Total (6)
			1910			
15-24	.299	1.676	1.975	.329	2.303	32.3
25-34	.315	1.354	1.670	.243	1.913	26.9
35-44	.345	1.009	1.354	.154	1.508	21.2
45-54	.377	.606	.984	.058	1.042	14.6
55-64	.358	0.000	.358	0.000	.358	5.0
Total 15-64	1.694	4.646	6.339	.785	7.124	100.0
			1978			
15-24	.005	.134	.139	.010	.148	5.8
25-34	.095	.525	.620	.038	.659	25.6
35-44	.165	.613	.778	.038	.816	31.7
45-54	.217	.415	.632	.018	.650	25.2
55-64	.302	0.000	.302	0.000	.302	11.7
Total 15-64	.784	1.687	2.471	.104	2.575	100.0

SOURCE: See footnote to Table 1.

NOTE: Figures may not add to totals due to rounding.

1978, followed by the 65–69 year age group.

Table 4 compares the difference in average number of years lived by whites and blacks in economically active ages in the United States in 1910 and 1978 (for 1978, data refer to white and nonwhite males). Since the analysis is focused on economically active ages, temporary life expectancies from ages 15–65 years are used (Table 5) and their difference is decomposed by the mortality differential in each 10-year age group.

Table 5.—Temporary Life Expectancies for White and Black Males Aged 15–64 Years, in the United States, 1910 and 1978

Race	Year: 1910	Year: 1978
White	41.20	46.45
Black	34.07	43.87
Difference	7.12	2.58

The information presented in Table 4 can be analyzed in two dimensions: First, the race differential in each of the years; and second, the changing differentials during the 1910 to 1978 period. More than 50 percent of the total difference in life expectancy (seven years) in the economically active ages (15–65 years) between whites and blacks in 1910 was due to the youngest ages (15–34 years). In relative terms, the mortality differential between the two population groups in older ages had a rather small impact on explaining the total differential of life in economically active ages, although in 1978 oldest ages contributed more than youngest ages.

The total contribution of the mortality differential in each age group to the total life expectancy differential in economically active ages between whites and blacks also shows remarkable aspects. In 1910 the mortality differential at ages 15–24 contributed more than two years to the total racial differential in ages 15–64, while in 1978 the same age group contributed only 15–hundredths of a life year. However, the direct effect indicates that while in 1910 the higher mortality of blacks over whites in each group was producing a similar impact on years of life within each age group, the situation changed in 1978 (Table 4, Col. 1). In recent years the direct effect (and hence the mortality differential) has been significantly reduced in young adult ages. In 1978, the mortality differential at ages 35–44 made the largest total contribution to the change in life expectancy between ages 15–64. This is due not only to the difference in years lived between ages 35–44, but to the effect (indirect) of the difference of survivors at age 45 (because

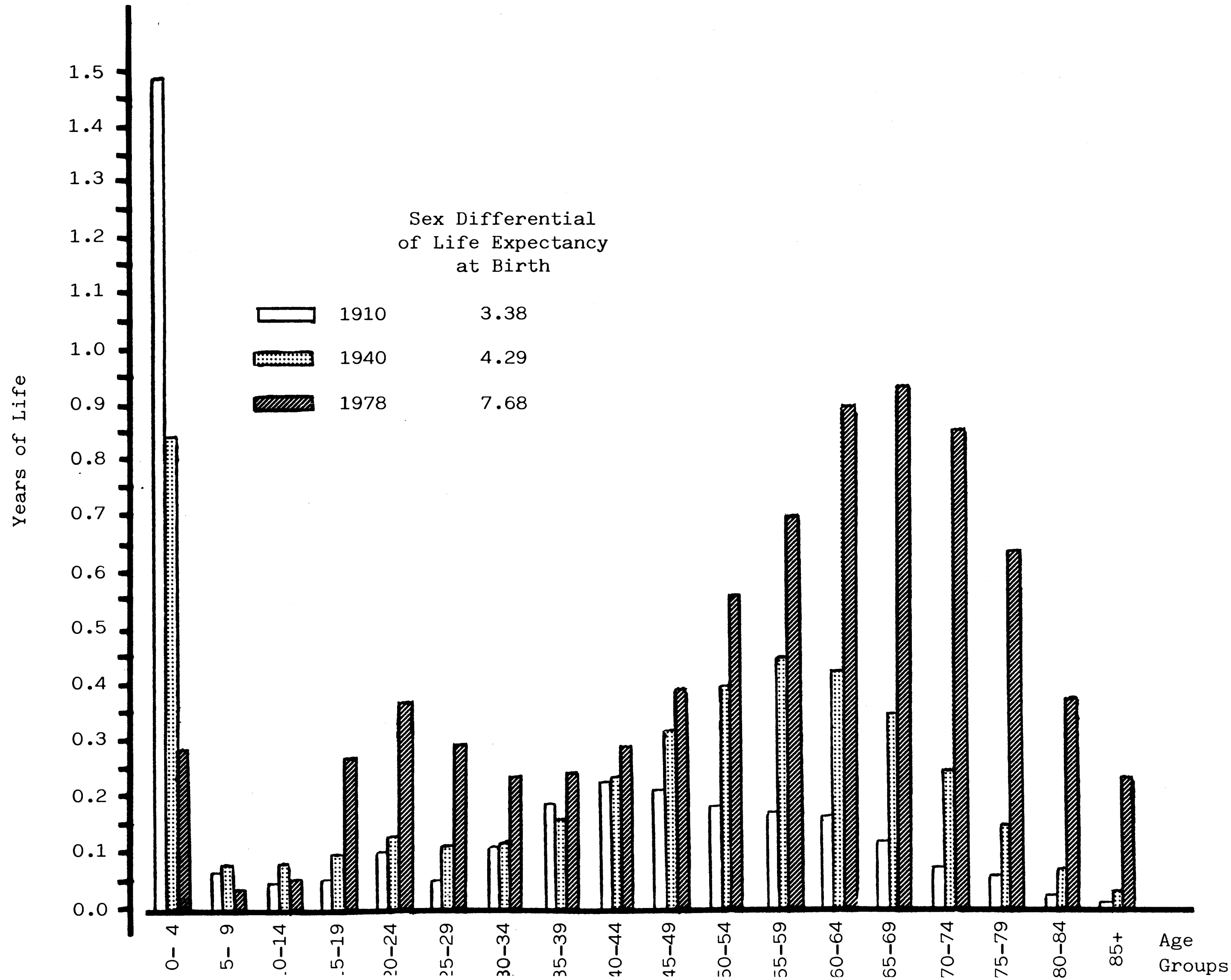
Table 6.—Contribution of the Mortality Sex Differential at Each Age Group to the Total Sex Differential in Life Expectancy at Birth for the United States, 1910, 1940 and 1978

	Exclusive Age Contribution					
Age	Direct (1)	Indirect (2)	Subtotal (3)	Inter-action (4)	Total (3) + (4) (5)	Percent of Total (6)
			1910			
0-14	.357	1.191	1.548	.056	1.605	47.5
15-29	.035	.170	.205	.010	.215	6.4
30-44	.103	.400	.503	.027	.530	15.7
45-59	.192	.355	.547	.024	.571	16.9
60-74	.208	.142	.350	.010	.359	10.6
75+	.097	0.000	.097	0.000	.097	2.9
All Ages	.993	2.257	3.250	.127	3.377	100.0
			1940			
0-14	.192	.767	.959	.053	1.012	23.6
15-29	.051	.277	.328	.024	.352	8.2
30-44	.087	.376	.463	.043	.506	11.8
45-59	.321	.742	1.063	.096	1.159	27.0
60-74	.530	.424	.959	.047	1.006	23.5
75+	.252	0.000	.252	0.000	.252	5.9
All Ages	1.432	2.592	4.024	.263	4.287	100.0
			1978			
0-14	.059	.291	.351	.039	.389	5.1
15-29	.118	.705	.823	.111	.934	12.2
30-44	.123	.531	.654	.113	.767	10.0
45-59	.354	1.005	1.359	.296	1.655	21.5
60-74	1.044	1.240	2.283	.399	2.682	34.9
75+	1.256	0.000	1.256	0.000	1.256	16.3
All Ages	2.954	3.773	6.726	.958	7.685	100.0

SOURCE: See footnote to Table 1.

NOTE: Figures may not add to totals due to rounding.

Figure 2.—Contribution of the Mortality Sex Differential at Each Age Group to the Total Sex Differential in Life Expectancy at Birth, in the United States, 1910, 1940 and 1978



of the different mortality between ages 35 and 44 years) who will continue living (most of them) from age 45–65 (Table 4, Col. 2). The changing mortality differentials between whites and blacks in each age group during the 68-year period reduced the contribution of all age groups to the differential in life expectancy between ages 15 and 64 years. Since the reduction was larger in younger than older ages, the percentage distribution of the age contribution to the black-white difference in life expectancy between ages 15–64 changed (See Table 4, Col. 6.)

Finally, the total U.S. sex mortality differentials in life expectancy at birth in 1910, 1940, and 1978 are decomposed by age in Figure 2 and Table 6. The contribution of the male-female mortality differential at each age group to the sex differential in life expectancy at birth has changed significantly over time. At the beginning of the century, the sex differential in mortality at youngest ages (0–4 years) contributed the most to the total sex differential in life expectancy at birth—almost 1.5 years (Figure 2). Among the other age groups, ages 40–44 were the second largest contributors with almost a quarter of a year. In 1940, the mortality differential at ages 0–4 years still made the largest contribution to the total sex differential of life expectancy at birth, but only with 0.84 years. On the other hand, the contribution of mortality differential at the adult ages started to become significant, and at ages 45–65 years already contributed almost two years of life to the sex differential in life expectancy at birth (Figure 2).

Table 7.—Life Expectancy at Birth, by Sex, in the United States, 1910, 1940 and 1978

Sex	Year		
	1910	1940	1978
Male	49.86	61.60	69.50
Female	53.24	65.89	77.18
Difference	3.38	4.29	7.68

The trends continued up to 1978, producing a completely different situation from that of 1910. The sex differential in mortality at ages 0–4 years contributed less than one-third of a year to the sex differential in life expectancy. Even the contribution of the age group 20–24 years was greater than the one pertaining to the youngest ages (Figure 2). The astonishing finding was that the sex differential in mortality at ages 45–74 years (Table 6) contributed more than four years of life to the total sex difference in life expectancy at birth. The impact of the mortality sex differential at ages 45–74 years in 1978 was larger than the total sex differential in life expectancy at birth in 1940 or 1910 (Table 7).

CONCLUSION

This article presents a set of tools for analyzing mortality change and differentials. The indices presented here for measuring the pace of mortality change by using temporary life expectancies, as well as the decomposition of a difference in life expectancies, should be considered as a complement to other procedures for analyzing mortality change. The indices and procedures suggested in this article should not replace other frequently used indices and procedures, but complement them by offering another perspective on mortality differential research. The article does not attempt to interpret change in mortality differentials nor try to explain the factors affecting change or differentials. These objectives could be the subject of other research.

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