A Single Index of Mortality and Morbidity

DANIEL F. SULLIVAN

A CONTINUING interest of the National Center for Health Statistics is the development and evaluation of new health indices suited to diverse specific purposes. No one index can reflect all aspects of health, but there is considerable agreement that an index which measures some aspects of nonfatal illness as well as mortality would be desirable. A rationale for using both mortality and disability rates as the components of such an index has already been published (*1*).

One technique for combining mortality and morbidity rates into a single index was devised and reported by Chiang in conjunction with his development of mathematical models of illness frequency, illness duration, and mortality (*2*). Moriyama has discussed criteria desired in an index of health and, in view of these, reviewed some approaches proposed in the literature (*3*). A description and evaluation of disability concepts and measures being considered as the basis of the morbidity component of a mortality-morbidity index appeared in a recent report (*4*).

Another technique for merging death rates with illness rates, and some illustrative results are described in this paper. A primary objective of these studies is development of a summary measure which reflects changes over time in the health status of the nation's population. Too little is known as yet about these techniques, and in some cases about the data they employ, to permit thorough evaluation of alternative approaches to the construction of such indices. Results of studies of such measures are presented as they become available by the Center to stimulate consideration of the issues and, possibly, to stimulate further studies by those in a position to conduct related research.

Some preliminary index values based upon the techniques presented in this paper have already been published for fiscal years 1958–66 (*5*). The estimates in this article are also preliminary. Although they relate to only a single year, they provide previously unpublished information on whites and other persons and on sex differences. These estimates are considered more accurate than earlier computations of such values.

Results

The two related indices described in this paper are based upon a life table model. They are (*a*) the expectation of life free of disability and (*b*) the expectation of disability. Either of these measures can be calculated using various definitions of disability, and values of each index based on two alternative definitions of disability will be presented and compared.

The techniques employ a relatively simple modification of the conventional life table model

Mr. Sullivan is a statistician with the Office of Health Statistics Analysis, National Center for Health Statistics, Health Services and Mental Health Administration. Tearsheet requests to Mr. Daniel F. Sullivan, National Center for Health Statistics, Parklawn Bldg., 5600 Fishers Lane, Rockville, Md. 20852.

to compute the expected duration of certain defined conditions of interest among the living population. Somewhat similar methods have been employed to compute expected values for conditions such as labor force participation and school enrollment (*6, 7*). In those applications current mortality rates, summarized in the life table values, were combined with survey-based rates for events among the living population to produce potentially valuable measures not otherwise obtainable. Calculation of a summary measure of health status in a somewhat similar fashion was once suggested in a paper by Sanders, but the more elaborate health measures which his proposal required have not yet been developed (*8*).

The expectations of life and of disability presented in this paper are hypothetical values derived from a period life table. They are the values which would occur if a birth cohort of fixed size experienced, age for age throughout life, the recent age-specific mortality and disability rates used in these life table calculations. Since the age-specific rates may change considerably over the lifespan of any real birth cohort, expectations based on a period life table may not reflect accurately the life experience of infants born in any specific period. Hence, these measures are intended primarily as an index for comparing the mortality-morbidity experience of different population groups and should not be construed as projections or forecasts. Methods of computing these measures are described in a subsequent section.

The modified life tables provide values of the expectation of life which omit time lost to disability. In one version of these tables, disability was defined broadly as institutional confinement for health care, prolonged incapacitation that does not include institutional care, and short-term episodes of restriction on a person's usual activities (table 1). An alternative version eliminates only the lifetime duration of periods of bed disability (table 2). Bed disability in this paper includes any periods spent in hospitals or other institutions for health care and also days of noninstitutional illness involving confinement to bed for more than half the daylight hours. Whichever definition is used, elimination of disability periods has a substantial effect on the expectation of life. Possibly more striking is the average amount of time lost to disability among members of the hypothetical life table population.

Although the conventional expectation of life in the United States now exceeds 70 years, the expected duration of disability-free life is not quite 65 years (table 1). The difference between these two figures is the expectation of disability, approximately 5 years. Illness of the aged contributes heavily, as the expectation of more than 3 years of disability at age 65 indicates, but it is not the sole determinant. Younger age groups account for the difference of 2 years between expectation of disability at birth and that at age 65.

Using a less comprehensive definition of disability and discounting only the lifetime duration of days of bed disability changes the magnitude of these figures, but the results are still noteworthy. Expectation of life free of bed disability is about 68 years at birth, and the expectation of bed disability is approximately 2 years (table 2). Again the relatively large cumula-

Table 1. Expectations of life and approximate expectations of life free of disability and of disability, for whites and other persons by sex at birth and at age 65, civilian resident population, United States, mid-1960's

Color and sex	Expectation		
	Life (1965 U.S. abridged life tables)	Life free of disability	Disability
	Years at birth		
All persons	70.2	64.9	5.3
Male	66.8	61.6	5.2
Female	73.7	68.4	5.3
White	71.0	65.8	5.2
Male	67.6	62.5	5.1
Female	74.7	69.4	5.3
All other persons	64.1	58.2	5.9
Male	61.1	55.1	6.0
Female	67.4	61.4	6.0
	Years at age 65		
All persons	14.6	11.3	3.3
Male	12.9	9.4	3.5
Female	16.2	13.1	3.1
White	14.6	11.5	3.1
Male	12.9	9.5	3.4
Female	16.3	13.3	3.0
All other persons	14.0	9.3	4.7
Male	12.6	7.5	5.1
Female	15.5	11.2	4.3

Table 2. Expectations of life and approximate expectations of life free of bed disability and of bed disability, for whites and other persons by sex at birth and at age 65, civilian resident population, United States, mid-1960's

Color and sex	Expectation		
	Life (1965 U.S. abridged life tables)	Life free of bed disability	Bed disability
	Years at birth		
All persons	70.2	68.2	2.0
Male	66.8	65.2	1.6
Female	73.7	71.4	2.3
White	71.0	69.1	1.9
Male	67.6	66.1	1.5
Female	74.7	72.4	2.3
All other persons	64.1	62.3	1.8
Male	61.1	59.5	1.6
Female	67.4	65.2	2.2
	Years at age 65		
All persons	14.6	13.5	1.1
Male	12.9	12.1	.8
Female	16.2	14.9	1.3
White	14.6	13.6	1.0
Male	12.9	12.1	.8
Female	16.3	15.0	1.3
All other persons	14.0	13.0	1.0
Male	12.6	11.7	.9
Female	15.5	14.3	1.2

tive impact of bed disability among younger persons can be detected by comparing the expectation of 2 years of bed disability at birth with the corresponding expectation of just over 1 year at age 65.

Although persons who survive to age 65 have a further life expectancy of almost 15 years, their prospects are somewhat dimmed by the fact that this 15 years can include more than 3 years of disability and more than a year of bed disability.

Sex differentials. Sex differentials in the expectation of life free of disability and the expectation of life free of bed disability are determined primarily by the large and well-known sex differences that exist in conventional life expectancies. Using any one of these three measures, the expectations for males are much shorter than those for females, both at birth and at age 65 (tables 1, 2; fig. 1). Both white and other males face unfavorable prospects when compared with their female counterparts in terms of these life expectancies.

When the expectations of disability and of bed disability are considered, however, most of the sex differentials favor males (tables 1, 2; fig. 2). Within both white and other groups, males have lower expectations of bed disability than females at birth and at age 65. White males also have lower expectations of all forms of disability at birth than do white females. Expectations of disability are equal at birth for all other males and females. Of the data given in this paper, only the expectations of disability at age 65 are consistently favorable for females.

These sex differentials need to be interpreted with considerable caution. In the surveys which produced the data underlying these estimates, different definitions were used to determine the existence of chronic disability among men and among women. The nature of these differences and their possible consequences have been discussed extensively elsewhere (*4, 9*). In this paper, it seems sufficient to note the existence of these differences and to point out that they would affect the expectations of disability but not the expectations of bed disability. Expectations of bed disability favor males both at birth and at age 65. Pregnancy accounts for some but not all of the excess bed disability among females at younger ages. Consequently, it seems reasonable to conclude that bed disability, at least, imposes a heavier burden upon women throughout life.

Whites compared with other persons. Differences between whites and other persons in the expectations of life free of disability and expectations of life free of bed disability are also largely a result of differences in conventional life expectancies. For each of these measures, expectations at birth for persons other than white are substantially less than for whites, and similar differences are observed among both males and females (tables 1, 2).

At 65, differences between whites and other groups are numerically much smaller for each of these expectancies, although still favorable to whites. The difference is slightly more than one-half year for the expectation of life and for the expectation of life free of bed disability. It is more than 2 years, however, for the expectation of life free of disability.

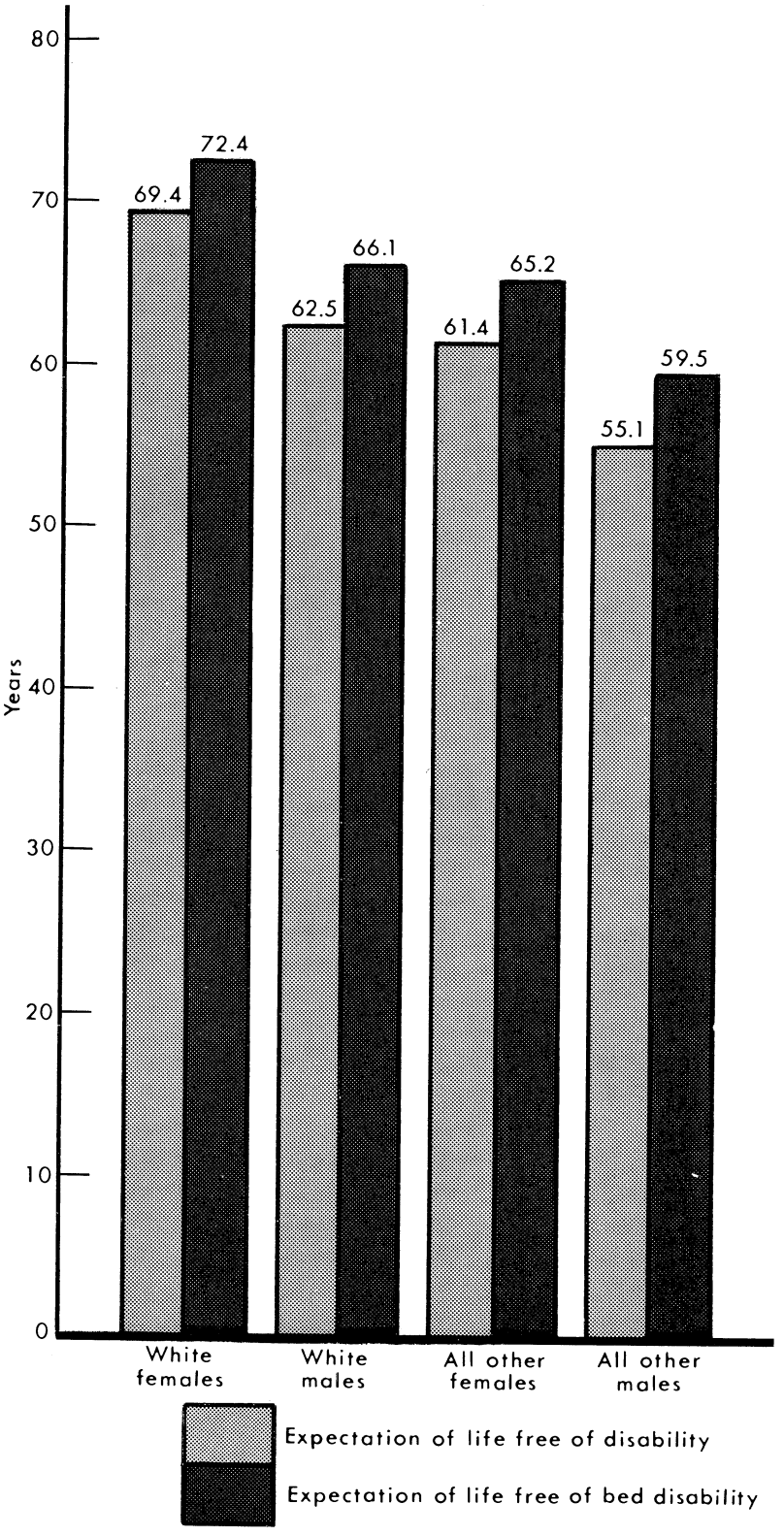
Differences between whites and other persons in the expectation of disability and the expectation of

bed disability correspond to these differences in life expectancies. Differences between whites and others in the expectation of bed disability, either at birth or at age 65, are only negligible. Consequently differences in the expectation of life free of bed disability are almost equal to differences in the conventional expectation of life.

There are noticeable differences in the expectation of disability between whites and other persons, however. At birth, whites have an expectation of disability of about one-half year shorter than the remainder of the population. This differential widens to more than 1½ years at age 65. At birth, the difference in expectation of disability (0.7 years) is a relatively small component of the difference in expectation of life free of disability (7.6 years). At age 65, however, the difference in expectation of disability (1.6 years) is the dominant component of the difference in expectation of life free of disability (2.2 years) and results in a difference between whites and other persons much larger than that shown by conventional life expectancies.

Thus, not only is the expectation of life shorter for persons who are not white, but the expected duration of disability of all types is greater—both absolutely and also proportionately in relation to length of life. When bed disability alone is considered, however, no substantial differentials between whites and other persons in expected duration are observed. Examination of the disability data underlying these measures confirms that the differences between whites and other persons in expectation of disability are primarily a result of differences in the prevalence of long-term disability that is neither bed disability nor insti-

Figure 1. Approximate expectations of life free of disability and of life free of bed disability for whites and other persons by sex, United States, mid-1960's



tutional care. These episodes represent the experience of persons unable to carry on activities such as work, housework, or school attendance.

Methods

Data required to compute these indices are a current abridged life table and a set of current age-specific rates for disability days applicable to the population group of interest.

Computation of the indices. Computation of the expectation of life free of disability is illustrated in table 3. Computations begin with the stationary population of the life table (L_x column). These figures can be interpreted as the number of life-years lived in successive age intervals among a cohort of births who experience during life the age-specific mortality rates observed during the current year. Within each age interval the number of life-years lived is multiplied by the average fraction of the year persons of that age group are free of disability. This factor (l_x) is calculated from current disability rates by the formula:

$$l_x = 1 - \frac{w_x}{365}$$

where w_x is the number of days of disability per person per year in the interval beginning at age x.

The result of these calculations is the set of $L_x\dagger$, interpreted as life-years free of disability in the given age interval. Values of $T_x\dagger$, and $\mathring{e}_x\dagger$ are then calculated in the conventional manner (*10*). (The dagger symbol, †, is used in this paper to distinguish these weighted life table values from the corresponding values denoted by the conventional notation.)

When expectation of life free of disability, $\mathring{e}_x\dagger$, has been obtained for a given age x, the corresponding expectation of disability can be calculated as:

$$\mathring{e}_x - \mathring{e}_x\dagger$$

where $\mathring{e}_x$ is the conventional expectation of life. This expectation of disability can be interpreted as the number of years of disability a member of the life table cohort would experience if current age-specific rates of mortality and disability prevailed throughout the cohort's lifetime.

Measurement of disability. The disability rates (w_x) called for in the aforementioned general formula may be based upon any operational definition of disability for which adequate data are available. One could use, for example, any one of several disability variables measured by the National Health Interview Survey such as restricted-activity days, bed-disability days, or hospital days (*11*). In practice, choice is usually limited by the availability of data and the need to use a measure which is meaningful and technically adequate for the objectives in view.

In this paper results are presented and contrasted using two alternative definitions of disability. These definitions were selected because they are applicable to most members of the population and should provide comprehensive measures of the impact of disease and injury among the living. The disability data used were obtained almost exclusively from surveys conducted by the National Center for Health Statistics.

The disability measures used are based upon the concept of the total volume of disability, which is defined and discussed in greater detail in a forthcoming paper (*4*). This concept was developed to incorporate into a single figure the duration of all disability—both long term and short term—experienced by members of a population during a given year. The total volume of disability estimates used were calculated as the

Table 3. Computation of the approximate expectation of life free of disability ($\mathring{e}_x\dagger$) for white males, civilian resident population, United States, mid-1960's

Age group	Exact initial age x	1965 abridged life table values [1]		Disability weighting factor	Life table values, weighted for disability [3]		
		l_x	L_x	l_x [2]	$L_x\dagger$	$T_x\dagger$	$\mathring{e}_x\dagger$
Under 15	0	100,000	1,457,411	0.967	1,409,316	6,252,782	62.5
15–44	15	96,767	2,830,657	.964	2,728,753	4,843,466	50.1
45–64	45	90,639	1,623,962	.915	1,485,925	2,114,713	23.3
65–74	65	65,901	532,960	.802	427,434	628,788	9.5
75 and over	75	39,665	318,095	.633	201,354	201,354	5.1

[1] Reference 10.

[2] For each age group, the weighting factor is

$$l_x = 1 - \frac{w_x}{365}$$

where w_x is the total number of disability days per person per year in the designated age group.

[3] The dagger symbol, †, is used in this paper to distinguish weighted life table values from the corresponding values denoted by conventional notation.

sum of three component estimates:

1. Days of health care in long-term institutions, obtained by allocating 365 days of disability per resident to the estimated annual average number of residents in institutions providing such care.

2. Days unable to carry on major activity among members of the civilian noninstitutional population. These data were obtained by allocating 365 days of disability each to the estimated annual average number of persons having a chronic condition and also reported as usually unable to carry on appropriate activities such as work, housework, or school.

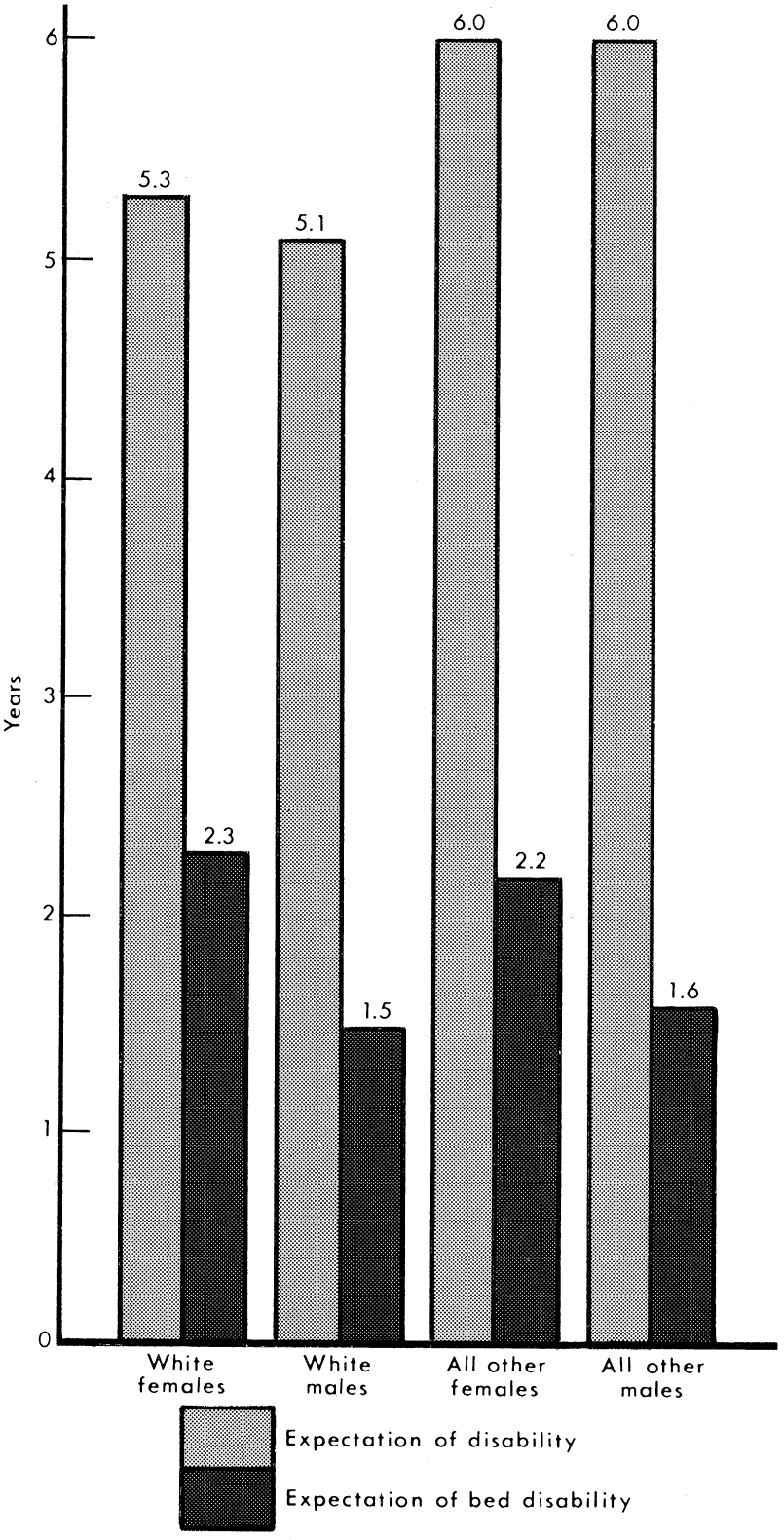
3. Days of restricted activity (not elsewhere included), derived from annual estimates for members of the civilian noninstitutional population not included in the categories previously mentioned. A day of restricted activity is one when the person cuts down on his usual activities because of illness or injury.

Bed disability measures are based upon a less comprehensive concept of disability. All days of bed disability are included in the total volume of disability, but days of disability are not necessarily days of bed disability. Computationally, the volume of bed disability is the sum of two component estimates:

1. Days of health care in long-term institutions. These are obtained as previously described.

2. Days of bed disability among the civilian noninstitutional population. These include all reported days of care in general service short-stay hospitals, whether or not the person is actually confined to bed on the day in question. Days of disability outside of hospitals and institutions are counted as days of bed disability only when

Figure 2. Approximate expectations of disability and of bed disability for whites and other persons by sex, United States, mid-1960's



the person is reported as confined to bed for more than half the daylight hours.

Total volume of disability estimates, upon which expectations of disability are based, include but greatly exceed the corresponding estimates of bed disability. Thus, the approximate lifetime expectation of disability is 5.3 years at birth while the corresponding expectation of bed disability is only 2.0 years (tables 1, 2). The 5.3 year figure is so much larger because the underlying estimates of the total volume of days of disability include two large categories not counted in estimating the volume of bed disability days. These two categories are (*a*) days unable to carry on major activity excluding days of bed disability and (*b*) days of restricted activity excluding days of bed disability.

Estimates of the components of these disability measures were derived from data collected by the survey programs of the National Center for Health Statistics, supplemented by certain data from the U.S. Census of 1960. Since it was not possible to derive each component for the same year, the illustrative data shown are labeled mid-1960's to indicate they are synthetic estimates based on data for several different years. Nevertheless, it is felt that the results are reasonably accurate approximations applicable to the United States in mid-decade. Definitions of terms used in this paper, and a complete account of procedures used to estimate the total volume of disability are soon to be published (*4*).

Discussion

The objective of this mortality-morbidity index is to measure change over time in the health status of the nation as a whole. Reasons for using mortality and disability rates as components of a single index which may serve this purpose have been discussed elsewhere (*1*). If such a combination of rates for death and disability is desired, the techniques described have certain advantages.

Use of the life table model provides one solution to the problem of the relative weights to assign deaths and episodes of disability when attempting to measure both phenomena by a single index. The model is a familiar conceptual tool, conventionally used in weighting diverse schedules of mortality rates for comparison with each other. Its elaboration to permit comparison of disability rates as well may meet with fewer objections than would any other arbitrary equation of a death to some specific duration of disability.

The data in this paper only permit comparisons of whites and other persons and of sex, but the observed differences in expectation of disability are sizable enough to indicate the measure is sensitive to differentials in disability experience of a magnitude likely to occur in present-day populations. Since even fractional differences in this measure represent differences of months in the cumulative average experience of disability in the groups compared, the measure would seem to be a meaningful reflection of the impact of disease and injury among the living.

Although observed differences in the expectation of disability are fairly large in absolute terms, they make a relatively small contribution to differences cited here in expectation of life free of disability at birth. This fact may make it appear that mortality dominates comparisons based on the index. Where large differences in conventional expectations of life exist, as they do between the sexes and between whites and other persons in this country, they obviously will be a principal component of differences in expectations of life free of disability. But the disability rates also enter into computation of expectation of life free of disability and may widen or narrow the gap between populations for which the index is computed. In the event two populations approached equality in conventional expectation of life, they might still differ substantially in expectation of disability and this difference would be reflected in their expectations of life free of disability.

In this sense, the disability component emerges as a more prominent component in comparisons as mortality differences diminish. This tendency to enhance the role of disability in comparisons of health status between populations with similar mortality levels seems reasonably analogous to the relative weight frequently assigned to risks of death and disability when one is assessing the importance of a health problem (*1*).

A principal, and probably enduring, disadvantage of these indices is the heavy demands they make upon available data. Both conventional life tables and data on disability must be available for a population in order to calculate these measures. At the national level the required data can be obtained only for the total population and a few major population categories. Lack of data is likely to preclude application of the indices to States or local areas for the foreseeable future.

In addition to their data requirements, there are other problematical aspects of these measures. Problems in interpreting sex dif-

ferences in disability resulting from the criteria of disability used have already been mentioned. Further studies are also needed to determine the sensitivity of the disability measures to changes over time. These problems and other limitations on the indices have been discussed more extensively in reference 4.

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SULLIVAN, DANIEL F. (National Center for Health Statistics): *A single index of mortality and morbidity. HSMHA Health Reports, Vol. 86, April 1971, pp. 347–354.*

The National Center for Health Statistics is considering several techniques for combining mortality and morbidity rates into a single index, which might provide a more adequate measure of changes over time in the nation's health status. A technique which weights life table values according to disability time experienced at each age level and produces measures of expectation of life free of disability and expectation of disability is described. Results are presented using two alternative measures of disability time experienced by a population during a year. The two measures are (*a*) the total volume of disability, which encompasses all forms of long-term and short-term disability, and (*b*) bed disability, which includes only periods of institutional confinement and noninstitutional disability involving bed confinement.

Expectation of disability-free lifetime was about 65 years in the United States in the mid-1960's, compared with a conventional life expectancy of about 70 years. The expected lifetime duration of all forms of disability was approximately 5 years, 2 years of which reflected disability before age 65, and 3 years was disability experienced by persons older than 65. Differences between males and females in expectation of disability are not great, but differences between whites and other persons are substantial and favorable to whites.

Expectation of life free of bed disability was about 68 years, and expectation of bed disability was approximately 2 years. Of the 2 years expected bed disability, persons 65 and over account for over 1 year. Differences between males and females in expectation of bed disability are noticeable and favorable to males. Differences between whites and other persons, however, are not substantial.