

# HALYs AND QALYs AND DALYs, OH MY: Similarities and Differences in Summary Measures of Population Health

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■ **Abstract** Health-adjusted life years (HALYs) are population health measures permitting morbidity and mortality to be simultaneously described within a single number. They are useful for overall estimates of burden of disease, comparisons of the relative impact of specific illnesses and conditions on communities, and in economic analyses. Quality-adjusted life years (QALYs) and disability-adjusted life years (DALYs) are types of HALYs whose original purposes were at variance. Their growing importance and the varied uptake of the methodology by different U.S. and international entities makes it useful to understand their differences as well as their similarities. A brief history of both measures is presented and methods for calculating them are reviewed. Methodological and ethical issues that have been raised in association with HALYs more generally are presented. Finally, we raise concerns about the practice of using different types of HALYs within different decision-making contexts and urge action that builds and clarifies this useful measurement field.

## INTRODUCTION

Health has long been evaluated by mortality-based indicators, both in the United States and internationally. Life expectancy, all-cause and disease-specific mortality, and infant mortality are compared by region, by nation, and across nations. Death rates and life expectancies are disaggregated and presented by sociodemographic and ethnic descriptors in efforts to evaluate population health and, at times, to monitor the impact of health interventions. Although mortality-based rates are useful in a cursory way, they provide insufficient information with which

to make any but the most basic judgments about the health of a population or the comparative impact of an intervention. The contribution of chronic disease, injury, and disability to population health goes unrecorded.

As commitment to monitoring health and rational allocation of health resources has grown in the United States and internationally, so too have the methods that researchers and policymakers use to evaluate health and medical outcomes in individuals and in populations. Health-adjusted life years (HALYs) are summary measures of population health that allow the combined impact of death and morbidity to be considered simultaneously. This feature makes HALYs useful for comparisons across a range of illnesses, interventions, and populations. A 1998 Institute of Medicine report (15) found these measures to be “increasingly relevant to both public health and medical decision makers” and of late, HALYs have gained higher visibility in policy circles, both domestically and internationally.

An umbrella term for a family of measures, HALYs includes disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs). The morbidity or quality of life component of HALYs is referred to as health-related quality of life (HRQL) (22), and is captured on a scale of 0 to 1.0, representing the extremes of death and full health. The HRQL associated with different conditions of health and disease is multiplied by life expectancy, and then, depending on the underlying methodology, produces an estimate of DALYs or QALYs associated with different levels of health. Health-adjusted life expectancy (HALE), a related type of summary measure of population health, estimates the average time in years that a person at a given age can expect to live in the equivalent of full health. Life tables, such as those created by the US census, are combined with cross-sectional age-specific HRQL data. Note that in HALE the contribution of any specific disease or condition to decrements in health is not presented. Rather, HALE seeks to provide an overarching view of the morbidity and mortality burden of a population.

Although both QALYs and DALYs interweave estimates of morbidity and mortality, their original purposes are somewhat at variance and their methods of calculation differ. This paper provides an overview of their origins and their key features. Our intention is to better familiarize public health professionals with the differences and, importantly, the similarities between these tools. In addition, we flag methodological and ethical issues that have been raised in association with HALYs generally so that readers may more critically examine study and report findings. We conclude with a discussion of the implications of the use of the different types of HALYs within decision-making settings and explore approaches that could help build the field.

## HEALTH-ADJUSTING LIFE YEARS: A BRIEF HISTORY OF QALYs AND DALYs

### QALYs

Following on early work to develop a descriptive measure combining time lived with functional capacity (34, 52, 54), QALYs were developed in the late 1960s

by economists, operations researchers, and psychologists, primarily for use in cost-effectiveness analysis (CEA) (13, 29, 43). In this setting, they represented an important breakthrough in conceptualizing the health outcome (denominator) in a cost-effectiveness (CE) ratio. A CE ratio describes the incremental price of obtaining a unit of health effect from a health intervention—be it preventive or curative, population-based, or clinical—when compared with an alternative intervention. When the denominator of the CE ratio is computed using QALYs, the cost-effectiveness analysis is referred to as cost-utility analyses (CUA).

Cost-utility analysis is appropriate in situations where quality of life is “the” or “an” important outcome of health care, and when it is necessary to have a common unit of measurement to compare between types of interventions and programs (55). Cost-utility analyses of medical interventions have been conducted for over 30 years; Klarman and coauthors published a CUA of chronic renal disease in 1968 (29). Quality-adjusted life years are routinely used in assessments of medical care, technology, and public health interventions; these studies have proliferated over the past two decades (9).

Given a specific budget constraint, QALYs are maximized by increasing the “utility” of individuals and aggregates of individuals. Utility can be understood as the value, or preference, that people have for health outcomes along a continuum anchored with death (0) and perfect health (1.0) (for a fuller discussion, see Reference 55). The original formulation of QALYs was drawn from the theoretical underpinnings of welfare economics and expected utility theory (46). In welfare economics, a social utility function is the aggregate of individuals’ utilities, and economists hold that maximizing the social utility function is the primary goal for resource allocation. Quality-adjusted life years are often seen as inexorably linked with utilitarianism, a social theory that dictates that policies designed to improve social welfare should do the greatest good for the greatest number of people. We return to this when we explore ethical concerns that have been raised more generally about HALYs.

## DALYs

In 1993, a World Bank and World Health Organization collaboration resulted in the publication of a volume that sought to quantify the global burden of premature death, disease, and injury and to make recommendations that would improve health, particularly in developing nations (66). The Global Burden of Disease (GBD) study, an ongoing effort that has continued to evolve from the initial World Bank effort, had three major objectives, “to facilitate the inclusion of nonfatal health outcomes in debates on international health policy, to decouple epidemiological assessment from advocacy so that estimates of the mortality or disability from a condition are developed as objectively as possible, and . . . to quantify the burden of disease using a measure that could be used for cost-effectiveness analysis” (35).

Disability-adjusted life years (DALYs) were developed to quantify the burden of disease and disability in populations, as well as to set priorities for resource allocation. Disability-adjusted life years measure the gap between a population’s

health and a hypothetical ideal for health achievement. Internationally, a number of countries have either completed or are conducting national burden of disease studies that use DALYs as their metric (36). A recent U.S. study has used DALYs to look at the burden of disease in Los Angeles County, demonstrating significant differences in rankings by ethnicity, gender, and area of residence (6).

As we discuss in greater detail below, the aspects of health that are valued as well as the populations from whom values are gathered differ between QALYs and DALYs. Life expectancy is also handled in divergent ways within the two frameworks. Finally, DALYs, in their original formulation, place different value weights on populations based on their age structure so that DALYs in the very young and the very old are discounted compared to other age groups.

## CALCULATING QALYs AND DALYs: METHODS AND IMPLICATIONS

There are three general steps in calculating a HALY: (a) describing health, i.e., as a health state or as a disease/condition; (b) developing values or weights for the health state or condition, which are called HRQL weights here; and (c) combining values for different health states or conditions with estimates of life expectancy. Each of these steps includes methodological choices that affect the estimates that are obtained.

### Describing Health: QALYs

Traditional QALYs are built using HRQL weights that are attached to individual experiences of health. These HRQL weights are not linked to any particular disease, condition, or disability. Rather, HRQL weights are based on the values of individuals for either their own health state (patient weights) or the health states of others that are described to them (community weights). The health states that are valued are comprised of component “attributes,” “dimensions,” or “domains” for which there exists general consensus on their centrality to health.<sup>1</sup> To create QALYs, health states—which are often, but not necessarily associated with a particular disease or condition—are first described along their component domains.

Measuring health status in a standardized way requires a conceptualization of the thorny issue of what exactly constitutes “health.” The universe of health states that individuals experience is immense, and the challenge of any health status measure is to capture the complexity of these states in a manageable way that is resonant with shared views of health across ages, cultures, and gender. A number of descriptive systems that include all or some of key domains such as physical, psychological, and social/role function, health perceptions, and symptoms, have

<sup>1</sup>These terms are used in describing generic elements of health status and largely represent differences in vocabulary rather than in concept.

been developed over the past 30 years with the intention of filling this requirement. Descriptive health status measures that have been used to create QALYs include the Health Utilities Index (HUI) (8, 56), the Quality of Well-Being Scale (QWB) (28), the EQ-5D (EuroQoL) (12), and the Health and Activity Limitation Index (HALex) (11).

Because the domains or health attributes described are particular to each instrument, not surprisingly, each portrays a different picture of health status. Much controversy has swirled around the validity of these measures; investigators are appropriately concerned with the question of whether these systems are measuring what they intend to measure. Given an absence of a benchmark of health, determining criterion validity—comparing the results achieved to an accepted gold standard—is impossible. Researchers therefore rely on other forms of validity, such as convergent validity—an indication that results achieved using the same method for similar individuals are compatible—and content validity—an indication of the extent to which a measure is consistent with an intended domain of content.

Although different conceptualizations of health, together with differing techniques for valuing the states (described briefly in the next section) result in variations in HRQL scores when they are attached to specific disease entities (27, 37, 39), overall correlations among the instruments have been shown to be quite reasonable (18, 20). A number of reviews of these instruments are available to the interested reader who wishes to gain a fuller understanding of the structure of each of the systems (22, 32, 38, 44).

## Describing Health: DALYs

In contrast to QALY methods, DALY architects chose to attach estimates of HRQL to specific diseases, rather than to health states. In part this was done for pragmatic reasons, given the difficulties of collecting comparable primary data from the vast numbers of countries for which a global burden of disease is calculated. In addition, DALY developers have voiced concerns about self-assessments of health, viewing them as potentially misleading, especially for purposes of cross-cultural comparisons. World Health Organization researchers give as an example the aboriginal population in Australia, whose mortality experience is greater than the rest of Australians, but who are less likely to rate their health as either “poor” or “fair” (35). When objective tests of health are viewed as a type of criterion validity, use of self-assessment data across-countries is found wanting by the WHO.<sup>2</sup>

Given these concerns, Murray and colleagues have relied on secondary data and expert opinion to identify and describe disease, placing different conditions along a continuum of disability (35, 36). Rather than creating a classification scheme of generic health states as is done with all other HRQL measures, DALYs use the

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<sup>2</sup>Self-assessment is distinguished here from “self-report.” In point of fact, disease prevalence rates, which are used to build DALYs estimates, in many countries are based on self-report.

conceptualization of nonfatal health outcomes drawn from the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) (35, 67), focusing on disability, or the impact of a disease or condition on the performance of an individual. Descriptions of the specific ICIDH disabilities are generated by health professionals; values for the undesirability of specific diseases and conditions are based on their descriptions, as we describe later.

Disability states in DALYs do not take account of comorbid conditions. For aging populations in industrialized nations, comorbidities are the norm rather than the exception, and someone with angina is quite likely to have coincident illnesses such as diabetes and hypertension. There is no provision in DALY weights to simultaneously consider all of these illnesses within the same individual (or population). A corollary to this occurs at the level of intervention evaluation. A therapy that creates unwanted side effects cannot be captured within the DALY framework. For example, if treatment of arthritis with nonsteroidal antiinflammatory medications resulted in peptic ulcers, there is no method within the DALY lexicon to describe the accompanying alteration in HRQL that accompanies abatement of arthritic symptoms and simultaneous onset of the symptoms that accompany peptic ulcer disease. Because the QALY family of measures is grounded in domains of health, rather than descriptions of specific diseases and disability, it is at least theoretically possible to describe, and therefore value, combinations of illness.

## Generating Values for Health and Disease

Once an illness, condition, or disability is described, its desirability (or lack of such) must be valued in a manner that allows it to be combined with units of life expectancy. Although this process differs somewhat for valuation of HRQL in QALY as compared to DALY calculations, generation of the values share certain common requirements.

First, by convention, each measure is anchored on a 0 to 1.0 scale of health. Quality-adjusted life years are a measure of health expectancy (a “good” to be maximized); DALYs are a measure of a health gap (a “bad” to be minimized). Consequently, the scale for each measure is reversed from the other—a valuation of 1 represents full health on the QALY scale and full disability (death) on the DALY scale; 0 represents the lowest possible health state (death) on the QALY scale and no disability or full health on the DALY scale.

Second, the health scales in each system are created so that they have interval scale properties, i.e., changes of equal amount anywhere on a scale of 0 to 1.0 can be interpreted as equivalent to one another. This means that an improvement in health (using the QALY orientation) from 0.4 to 0.6 would be numerically equivalent to an improvement from 0.7 to 0.9. This requirement occurs because years of life and HRQL must be combined into a single metric such that more QALYs (or fewer DALYs) can be influenced equivalently by changes in life expectancy and health status.

Third, HRQL weights must reflect preferences that people have for different states of health or disease. Dimensions of health that can be affected at different levels must ultimately be summarized into scores representing the relative trade-offs in desirability between these different components of health, or impacts of disease. Health-related quality of life weights used in QALYs are assigned to health states based on how people make trade-offs between different dimensions of health. Disability-adjusted life years do this by assigning a disability weight (which can be seen as a preference) to a specific disease or health condition.

### Generating Values: QALYs

Preferences, or values for HRQL for use in QALYs, are generated by a number of techniques. The most commonly used methods include standard gamble, time trade-off, and rating or visual analogue scales. Standard gamble and time trade-off methods ask respondents to value health states by making explicit what they would be willing to sacrifice (in terms of time or risk of death) in order to return from the health state being described (or experienced) to perfect health. These techniques are preferred by many economists, who hold that eliciting preferences in this manner is consistent with utility theory, a model for how people make decisions under conditions of uncertainty (60). The theoretical foundations of CUA lie, at least in part, in expected utility theory (19). The Health Utility Index (HUI), developed in Canada and applied both in clinical (14) and population health settings (63), was scaled using the time trade-off method to assess preferences.

In rating scales or visual analogue scales, respondents must designate a point on a scale, or "feeling thermometer," that corresponds to the strength of their preference for a given health state. Many investigators believe that the cognitive burden to respondents is less with these scales, since they are familiar to most people from a variety of everyday experiences where they are asked to fill out questionnaires or respond to queries regarding their strength of preference. Both the Quality of Well-Being (QWB) scale and the EuroQol EQ-5D (in part) use rating scales in assessment of values. Fuller descriptions of these methods together with discussions of their advantages and limitations are covered elsewhere (22, 38, 44, 55).

The different methods employed by the varied valuation techniques give rise to inconsistencies in values for like health states or illnesses (27, 42, 48, 59). These variations arise for a number of reasons, including the differential sensitivity of the measures to particular domains of health that are affected by illness, the differences in how individuals comprehend and implement the weighting tasks, and scaling properties particular to the technique that is used.

Another potential source of variation in HRQL scores for health states and illnesses arises from the elicitation of values from different groups of people. Values can be elicited from people with experience of the illness/condition (patient preferences), a representative population sample who would be affected by resource allocation decisions (community preferences), study investigators,

and experts—generally health professionals who have good understanding of the symptoms associated with the disease entities under investigation. Although some evidence suggests that values for health states are fairly consistent across groups in general (3, 4, 12, 31), health professional experts have been found to provide lower values than others in ranking illnesses (35). In addition, the literature suggests that patients often adapt to their illness and value their health states higher than those who do not have experience with the disease (10, 51, 53).

The Panel on Cost Effectiveness in Health and Medicine (PCEHM), an expert group appointed by the Department of Health and Human Services to improve standardization of cost-effectiveness methodology in the health care arena, recommended that any CEA designed to inform resource allocation decisions use a societal perspective that incorporates the costs and the effects of the intervention to all members of society. As an extension of that recommendation, the Panel found that “the best articulation of society’s preferences . . . would be gathered from a representative sample of informed members of the community”<sup>3</sup> (23).

## Generating Values: DALYs

In DALYs, values for diseases and other nonfatal health outcomes were obtained through an iterative, deliberative process that attempted to reconcile differences in the preferences of health professional expert groups with respect to the desirability of different conditions and injuries. Framers of the DALY argue for using experts for valuation on the grounds of feasibility and efficiency (convenience samples of WHO and affiliated health workers were used rather than gathering community data in multiple locations), as well as on a methodologic basis. Concerns that potential variation of community health perceptions across cultures could inhibit cross-national comparisons, uncertainty of how to handle adaptation by people with disabilities,<sup>4</sup> and the cognitive burden of preference weighting techniques on respondents, all influenced DALY developers who utilize a single technique for value elicitation (35).

The DALY valuation exercise was built upon a person trade-off (PTO) method (40, 45) that explicitly addresses trade-offs between life and HRQL for people with different diseases. Champions of the PTO method have argued that this technique

<sup>3</sup>Relying on a community perspective is not without controversy. Advocates for people with disabilities posit that individuals with specific conditions should be the ones to value that particular health state, since health professionals and community members both tend to rate disability states more negatively than individuals who have actually experienced them. Depending on the intervention in question (e.g., prevention or treatment of disability versus treatment of someone who is disabled for a condition unrelated to their disability), this difference could make an intervention look better or worse as a societal investment.

<sup>4</sup>WHO researchers refer to this as the “happy slave” phenomenon, implying that some people with disabilities become more satisfied with their quality of life over time simply because of the way in which they have coped, despite the underlying functional disability remaining unchanged.



is better than standardly applied QALY techniques to embed the notion of resource allocation within the measurement of population health.

DALY architects used the person trade-off method on a series of 22 “indicator” health conditions selected to represent different dimensions of disability and non-fatal health outcomes. Some of the indicator conditions create limitations that are predominantly physical (e.g., blindness and deafness); others have more significant cognitive and psychological impact (e.g., Down syndrome, unipolar major depression.) Pain, along a continuum ranging from sore throat to severe migraine, is a feature of some of the illnesses. Conditions affecting sexual and reproductive function were also evaluated (35).

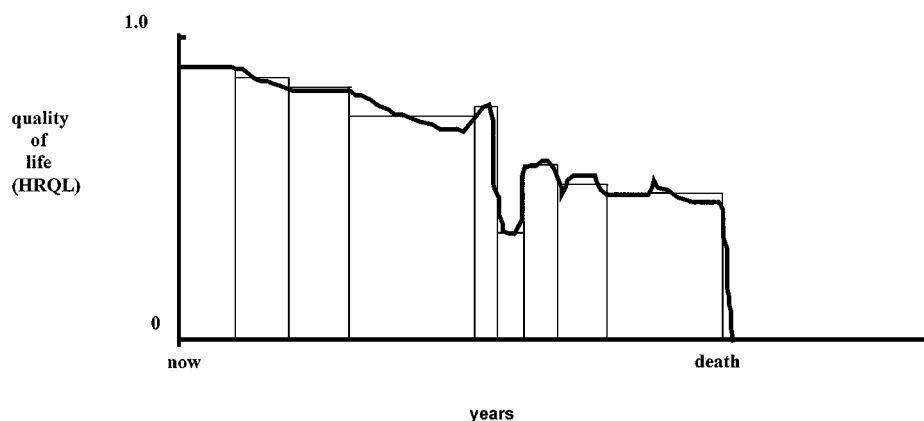
Health experts were first asked to establish “equality” in life extension between healthy people and people with the indicator conditions. For example, informants were asked whether they would prefer to purchase an intervention that provided one year of health for 1000 fully healthy people, or 2000 people with angina. Next, they were asked to consider what trade-off they would make between raising the quality of life for people with angina to a state of full health versus extending by one year the life of individuals who were already healthy. Although both of these PTO exercises yield weights, they typically differed from one another and needed to be made internally consistent to arrive at a final score.

Deliberation is integral to the DALY weighting process. It is promulgated on the basis that individuals should be faced with the policy implications of their choices. In valuing nonfatal outcomes, it has been used to reconcile individual discrepancies regarding weights, as well as to align a larger group in generating a consensus set of values. For the Global Burden of Disease project, nine expert groups participated in the weighting process. Good correlations between the ordinal rankings as well as the cardinal values of the indicator conditions are reported by WHO<sup>5</sup> (35). Based on these results, DALY investigators created seven disability classes that lie along the spectrum from full health to death. Included within disability class 5, for example, are conditions such as unipolar major depression, blindness, and paraplegia, which ranged in severity from 0.619 to 0.671. Once preference scores for a set of index conditions were established, weights for hundreds of other conditions were mapped by extrapolation (35).

## Combining Values for Health with Life Expectancy

In a general sense, HALYs are created by multiplying values for health states or conditions by life expectancy. Because QALYs emerge from a clinical tradition, life expectancy is handled in a more heterogenous fashion than in DALYs, which are expressly designed to look at disease burden from a population perspective with an average life expectancy. The clinical tradition is accustomed to measuring the effectiveness (in life extension and symptom relief) of specific

<sup>5</sup>Some participants have, however, described difficulties with creating consistency across the two exercises and felt “led” in order to harmonize the results of the PTO exercises (2).



**Figure 1** The life path of changing health-related quality of life (HRQL) for an individual from “now” to that person’s death is shown by the irregular line. After a steady decline for some years followed by a brief improvement, the person suffers a major event from which he or she briefly recovers some HRQL, but this recovery is followed by fluctuating HRQL until a precipitous decline and death. The area under this curve is the QALYs accumulated by the person over this portion of his or her lifetime. The area is approximated by summing the areas of the rectangles as described in the text.

interventions on groups of individuals. Much of the life-expectancy information drawn on for QALY calculations relies on data from observational studies and clinical trials, as well as standard population life tables.

## Combining—QALYs

The calculation of QALYs is explained with reference to Figure 1. The irregular line graphs the HRQL life path of a hypothetical individual over time from “now” forward. Ideally, we compute QALYs attained between “now” and the individual’s death by determining the area under this shaded line—i.e., the product of instantaneous HRQL times a small time increment summed over the individual’s remaining lifetime. Of course, we have no way of knowing the individual’s HRQL at each possible point in time. Alternatively, we suppose that this individual’s HRQL has been measured at various times (centered in each vertical rectangle but not marked on the graph, to preserve clarity), using a standardized instrument [such as the Health Utilities Index or the EuroQol (57)]. The standardized HRQL instrument is used to classify the individual’s health state at each point in time on a system of health attributes (e.g., degree of mobility, mental status, social functioning, sensory capabilities, etc.), and the scoring function associated with the instrument is used to assign an HRQL to each state. We approximate the area under the curve by computing areas of the rectangles, which are drawn assuming

the measured HRQL is constant between measurement intervals. The area of each rectangle is the product of an HRQL weight and the time for which the individual is assumed to experience that HRQL level. The result of summing the areas of the rectangles is an approximation of the QALYs attained by the individual from “now” onward. The more points at which HRQL is measured, the better the approximation.

For example, consider the “normal” life path of health for a white non-Hispanic American woman, with a life expectancy of 79 years. She might spend the first 40 years of her life in excellent health, with HRQL valued at 0.95,<sup>6</sup> experience a little nonspecific wear and tear that decreases her HRQL to 0.9 from age 40 to age 60, have the onset of other constellations of symptoms decreasing her HRQL to 0.8 from age 60 to age 70, and then at age 70, experience further declines that decrease her HRQL to 0.70 for a final 12 years of her life. That path would provide her with 72.4 QALYs  $\{[40] (0.95) + [20] (0.9) + [10] (0.8) + [12] (0.7)\}$ . Although she actually lived 82 life years, 3 years more than her life expectancy at birth, she accumulates 72.4 QALYs. Note that decrements in her HRQL could be associated with onset of specific illnesses (for example, hypertension or allergies) or might simply be associated with loss of vigor, onset of ill-defined symptoms, less ability to function in her role. No specific “diagnosis” is required in order for her HRQL to decrease. If at age 60, the drop from 0.9 to 0.8 was averted through successful replacement of an arthritic hip, maintaining her HRQL at 0.9 until age 70, when she developed symptoms associated with diabetes and dropped to 0.7, she would have a life path that yielded an additional 1.0 QALYs, for a total of 73.4. Alternatively, if she had a bad outcome from her hip replacement, her HRQL might have dropped to 0.7 at age 60 and persisted there until age 82, losing a total of 1.0 QALYs. Had she died at 60 as a result of her surgery, her life path sum of QALYs would have been 56.<sup>7</sup>

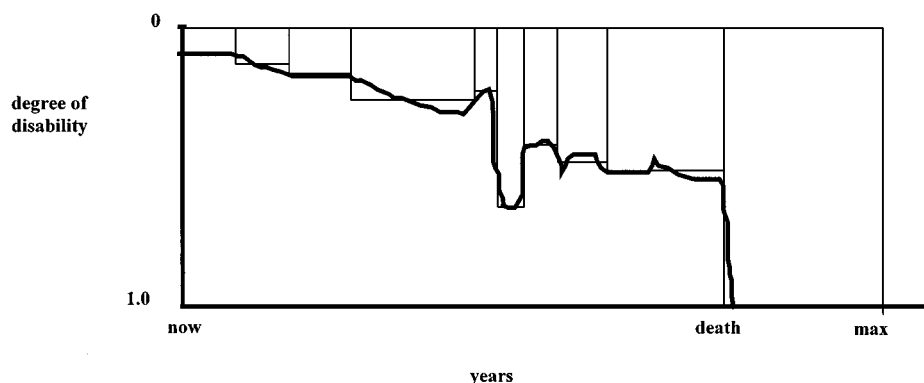
Although our example has computed QALYs retrospectively, looking back over the life path of the described individual, individual decision problems are usually projected forward in time using a mathematical model of the anticipated life path based on observations from clinical trials, observational cohorts, and population epidemiology. In a population, cross-sectional surveys using HRQL instruments can be used along with stationary population actuarial techniques to compute the average QALYs expected to be attained by an individual (49, 64).

Note that QALYs might also be calculated to look at specific segments of life, for example, the QALYs gained or lost following successful (or unsuccessful)

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<sup>6</sup>Many investigators believe that it is inappropriate to assume that people have “perfect” health, so that even at younger ages when people are presumably at their healthiest, a score of 1.0 is viewed as inaccurate (see 18a).

<sup>7</sup>For simplicity, QALY modelers frequently omit adjusting for gradations of HRQL during different segments of a life path—once a diminution in health has occurred it is frequently handled as persisting throughout the remaining years of life.



**Figure 2** The same life path as in Figure 1 is shown by the irregular line. Added to the graph is a point, “max,” which is the ideal sex-specific life expectancy for humans as determined by the WHO researchers. To compute DALYs, the area lost from the ideal lifetime, living to the maximum life expectancy in full health, is computed approximately by summing the areas of the rectangles.

chemotherapy for cancer. And they might be calculated to look more closely at subpopulations. For example, low-income women have lower life expectancy and poorer HRQL, in general, than do more affluent women.

## Combining—DALYs

The computation of DALYs, in principle, proceeds in the same fashion as QALYs, but as shown in Figure 2, the area being computed is that above the life path and extending out to the ideal life expectancy, to approximate the total area lost from the “ideal” life path of living in perfect health for the entire ideal life expectancy. As DALYs measure health gaps, specific ideal life expectancies are used for males and females from which to calculate the gaps. DALYs take as their standard a life-expectancy at birth of 82.5 years for women, and 80 years for men; these numbers are chosen to represent the average life expectancy of the Japanese, who at present have the longest overall life expectancy in the world. Note that these imply age-specific life expectancies that are greater than average life expectancies when considering individuals who have lived to a given age (e.g., a male at age 50 is assumed to have a life expectancy of 30.99 years, since he has avoided mortality hazards affecting men in their first 50 years). World Health Organization investigators have selected these life expectancies for universal application (i.e., regardless of sociodemographic characteristics) on equity grounds, arguing that all nations should be able to obtain the survival results of the most successful. In Figure 2, this point is denoted “max.”

In practice, the DALY weighting system for disability adjustments is tied to diseases and not to generic, descriptive dimensions of health. Disability weights

have been assigned to typical time courses of health in cohorts of persons after onset of a particular disease. Population burden due to a particular disease is computed using these weights, data about the incidence of the disease in the particular population, and average age of onset. Total population disease burden is computed by summing attributable DALYs across diseases.

If DALYs were used to describe the life course of the woman above, the first decrement that would be recorded would be for osteoarthritis, at age 60. Until that time she would be considered to be “fully” healthy, with disability weighted at 0. With the onset of osteoarthritis, a disability decrement of 0.158 (untreated), or 0.108 (treated), would be tallied. This level of decrement would be counted as if it lasted for her life expectancy (ideally 24.83 years in a woman who has attained an age of 60 years), resulting in a loss of (24.83) (0.158) DALYs (treated) or (24.83) (0.108) DALYs (untreated). The added decrement in her health resulting from the onset of diabetes would be incorporated by adding the full weight of the decrement coming from the diabetes scores (ranging from .012 to 0.078) and decreases in actual life expectancy (i.e., the loss of life years relative to the ideal) due to diabetes and its complications, to the decrement already extant for osteoarthritis. If she suffered death as a complication of hip replacement surgery at age 60, she would be denoted as losing 22.5 DALYs.

In our example as presented, we do not make two added adjustments to DALY computation that are made by WHO researchers. The first of these is an age-weighting that is applied similarly to an HRQL weighting. Building this weighting into the DALY formula gives greater value to years lived in young adulthood and less to years lived at the beginning and end of the life span. The WHO researchers present age weights as consistent with community values and reflective of the reliance of the old and the young on support by the middle-age groups (35). In response to some astringent critiques that hold age-weighting to be unethical and discriminatory (1, 5), DALY researchers have countered that age-weighting does not discriminate between individuals but simply differentiates between differently productive periods of life for a cohort. DALY researchers also report that sensitivity analyses have shown that age-weighting makes little difference in ranking conditions by burden of disease (35). The final adjustment to the DALY formula is to discount time in the future at a discount rate of 3%. To simplify our comparisons here we have omitted this further adjustment.

Although QALY measures in principle could incorporate weighting schemes that value time lived at different ages differently, this approach has not been adopted in QALY-based CEAs (62); instead, life years are valued equally across individuals. When age-weighting is used (as with DALYs), it appears that age is essentially counted “against” older people twice—once because of the greater incidence of functional impairment among older people (making saving their life years less “valuable” overall) and again because of embedded judgments about the intrinsic worth of a year of life at older ages. When QALYs are used in cost-effectiveness analyses, they are regularly discounted to present value in a similar manner to DALYs.

## ETHICAL CHALLENGES TO HALYs

Both QALYs and DALYs are designed to support a resource allocation framework that is largely utilitarian in its orientation. In that capacity, the goal of each of the measures is to accurately represent outcomes that can be generated most efficiently per dollar spent so that the total “good” for a population is maximized. Although an efficiency-oriented approach maximizes overall health, however it is defined, the practical and distributional implications of such an approach can be problematic to individuals and to particular subgroups who fare less well in the HALY calculus.

Several critiques of QALYs and DALYs highlight the ways in which these measures can be used counter to “societal values” (1, 2, 25, 33, 58). Methodological problems that bear on ethical issues remain contentious. We have previously flagged concerns about the sources of values (patients versus health experts versus community members) and, in the case of DALYs, the use of differential age-based weights. Additional objections that are primarily ethical in nature can be grouped into three broad categories (the first two of which are distributional concerns): QALYs and DALYs fail to give priority to those who are worst off (e.g., on the basis of ill health or low social class); they discriminate against people with limited treatment potential (e.g., those with preexisting disability or illness); and they fail to account for qualitative differences in outcomes (e.g., life saving versus health improving) because of the way in which morbid and mortal outcomes are aggregated.

In the first instance, critics argue that HALYs, as currently calculated, discriminate against those members of society who are already at health or social disadvantage. These potential consequences strike many as unfair (25, 26, 30, 47); indeed, this orientation does not adequately reflect the concern that people often have for those who are least well off (5, 7). Detractors from the HALY approach suggest that absent incorporating a socially sanctioned and empirically valid “equity weight,” distributional effects of resource allocation based solely on HALYs will always be unjust and those most in need by reason of health or social disadvantage will remain most in need (1, 33).

Related to this concern is the problem that certain groups of individuals—older persons and people with extensive disabling conditions refractory to significant amelioration—are comparatively bad investments. This is the case because older people have a finite number of years that can be gained, and because some illnesses can only improve a small amount. Limitations on either type of improvement yield fewer HALYs. With respect to age in particular, there is considerable debate about its pertinence as a criterion for priority setting (1, 25), although some have argued that social values and empirical findings support giving priority to younger persons who have not had the opportunity to achieve their “fair innings” (61). Countering concerns of systematic bias against those with lessened capacity to benefit is the argument put forward by the PCEHM that cost-effectiveness studies primarily evaluate the comparative economic efficiency of interventions and do not disaggregate people into subgroups based on age or comorbid status (23, 50). However,

others have pointed out that some interventions are targeted to diseases that are heavily concentrated in the elderly or in subpopulations whose life expectancy is markedly decreased (e.g., persons with cystic fibrosis), and when compared with interventions that are beneficial to a younger population, the aged or chronically ill will always come up short (33).

A third major concern is one of “aggregation”; i.e., how values for health states and diseases are combined across individuals, as well as along the spectrum of alive to dead. Critics of HALYs say that failure to treat life-saving interventions as conceptually distinct from health-improving interventions is at odds with how society views life and death medical decisions (24, 33). Similarly, some question whether minor benefits accruing to many should be viewed as equivalent to more significant benefits accruing to few (7).

In response to the dilemmas detailed above, two general approaches have been suggested. The first argues for changes in how measures are constructed. The desire to “build a better machine” for CEA stems from the view that policymakers often take economic pronouncements at face value, and it is therefore incumbent upon researchers to incorporate societal values into the ratio. This would be possible because although welfare economics seeks to maximize a social utility function (an aggregate of individual utilities), it does not prescribe how individual utilities should be aggregated. Different types of people could therefore receive different weights in counting HALYs (for a fuller discussion see References 23, p. 32; 62). Techniques attempting to better reflect social judgments about equity have been proposed (41, 58). These techniques are in early stages of development, and they have not yet been fully justified on a theoretical basis, nor implemented in real-world situations. Concerns about how to factor in the complexity of many social judgments into a single moral calculus have been raised (7).

The second approach, favored by the PCEHM, is that cost-effectiveness studies be seen as only one of multiple inputs to decision making (23). Consideration of distributional issues for those with greater needs, of allocation priorities for illnesses that are rare or expensive, and of the balance between health status improvement and life saving, need to remain part of the political and clinical decision-making process in which HALYs may be one factor, instead of entering as distortions in the HALY calculations. Economic efficiency, the PCEHM argues, should never be the sole criterion for resource allocation. If QALYs or DALYs were to lead policymakers to make decisions based solely on economics, they would be being used inappropriately.

## CONCLUSIONS

As initially conceived, DALYs were primarily intended to document information about the comparative health of populations. Accuracy and responsiveness to more nuanced changes in health status at the individual level were less important than accumulating a database that could provide reliable data with respect to the descriptive epidemiology of fatal and nonfatal health outcomes. At their start, QALYs focused on the evaluation of medical interventions. Developers of HRQL measures

placed a greater emphasis on issues such as measure responsiveness, sensitivity and reliability (16, 17, 44), paying less attention to generating overall models of disease distribution, severity, and mortality.

Although not without detractors, DALYs and QALYs have proved serviceable for their initially intended uses. As each measure extends across the chasm that separates population health and medical care, however, inevitable differences will be seen in the outputs of their estimates of disease burden. And different outputs may imply different priorities. One study that compared HALYs for five common medical conditions, using DALY- and QALY-associated HRQL weights, but keeping life-expectancy calculations identical, found differences in disease-burden estimates as well as changes in rank order of the illnesses (21).<sup>8</sup> As Murray points out, once a measure is used it influences policy, permeates the thinking of decision makers, and becomes normative (35). More than one normative measure at play in the same fields may contribute to significant confusion.

Important objectives for any health care system are to maximize the aggregate health of its populace and to minimize disparities within subgroups. Although social factors and social policies have a dominant influence on the overall health of populations, public health and clinical interventions are the tools that are available to health professionals. Understanding gaps in health achievement and maximizing effectiveness in intervention implementation require measures that can reliably capture the duration of life and its quality. Summary measures of population health such as HALYs offer the possibility of more rational allocation of health-related interventions at both clinical and population levels.

In a perfect measurement world, HALYs would be used at the macro level to track population health and monitor population-based interventions (e.g., health education, environmental protection, health-related legislative actions) and at the micro (clinical) level to assess the effectiveness of preventive, palliative, and curative therapies. Statistics Canada has taken an approach to monitoring and policy development that relies on use of the Health Utility Index (57) in both clinical and population settings. They have reasoned that a common metric, employed in clinical trials and in population health monitoring, will build a rich and coherent evidence base. Reliable information about the effectiveness and efficiency of different interventions will be available to inform clinical as well as population health-based decision making (65).

The United States has taken a more laissez-faire attitude toward its summary measures. Many investigators believe that the science of these measures, particularly in the area of describing and valuing health, is not fully developed and selection of one particular system now would result in premature closure of an

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<sup>8</sup>For example, in the case of asthma, the DALY system records a decrement of 0.06 for asthma, whereas the QALY-linked Quality of Well-Being Scale measures a 0.32 loss from full health. Similar inconsistencies can be seen in QALY-associated HRQL measures, but in the DALY/QALY comparison they are compounded by the different methods used in calculating life expectancy within the two systems.



important area of research. Others believe that failure to select a standard measure hinders rational policy development; they argue that the perfect measure will be hard to find. In the meantime, federal funding supports some studies that use DALYs and others that use QALYs. No investigations are currently under way to systematically compare outcomes/burden of disease inferred using the DALY approach to inferences based on QALYs computed with any of the many available HRQL measurement instruments. A careful consideration of the outputs of the two methods simultaneously could provide a better understanding of convergence or divergence in estimates. Convergence would bolster confidence in their validity; divergence would point the way to a better understanding of the performance characteristics of each of the methods and encourage more focused research. Either outcome would advance us toward resolution in this key measurement arena.

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## LITERATURE CITED

1. Anand S, Hanson K. 1997. Disability-adjusted life years: a critical review. *J. Health Econ.* 16(6):685–702
2. Arnesen T, Nord E. 1999. The value of DALY life: problems with ethics and validity of disability adjusted life years. *BMJ* 319(7222):1423–25. Erratum. 2000. *BMJ* 320(7246):1398
3. Balaban DJ, Sagi PC, Goldfarb NI, Nettler S. 1986. Weights for scoring the quality of well-being instrument among rheumatoid arthritics: a comparison to the general population weights. *Med. Care* 24:973–80
4. Boyle MH, Torrance GW. 1984. Developing multiattribute health indexes. *Med. Care* 22:1045–57
5. Brock D. 1998. Ethical issues in the development of summary measures of population health status. See Ref. 15, pp. 73–91
6. The burden of disease in Los Angeles County. A study of the patterns of morbidity and mortality in the county population. (<http://www.hsph.harvard.edu/org/organizations/bdu/papers/usbody/index.html>) The link on this is “US Patterns of Mortality by County and Race: 1965–1994” by CJL Murray, CM Michaud, M McKenna, J Marks
7. Daniels N. 1998. Distributive justice and the use of summary measures of population health status. See Ref. 15, pp. 58–71
8. Drummond MF, Stoddart GL, Torrance GW. 1987. *Methods for the Economic Evaluation of Health Care Programmes*. New York: Oxford Univ. Press
9. Elixhauser A, Halpern M, Schmier J, Luce BR. 1998. Health care CBA and CEA from 1991 to 1996: an updated bibliography. *Med. Care* 36(5 Suppl.):MS1–9, MS18–147
10. Epstein AM, Hall JA, Tognetti J, Son LH, Conant L. 1989. Using proxies to evaluate quality of life. *Med. Care* 27:S91–98
11. Erickson P, Wilson RW, Shannon I. 1995. *Years of Healthy Life*. Stat. Note No. 7. Hyattsville, MD: Natl. Cent. Health Stat.
12. EuroQol Group. 1990. EuroQol: a new facility for the measurement of health-related quality of life. *Health Policy* 16:199
13. Fanshel S, Bush JW. 1970. A health status index and its application to health-services outcomes. *Oper. Res.* 18:1021–66
14. Feeny DH, Furlong W, Barr RD, et al. 1992. A comprehensive multi-attribute

- system for classifying the health status of survivors of childhood cancer. *J. Clin. Oncol.* 10:923–26
15. Field JM, Gold MR, eds. 1998. *Summarizing Population Health: Directions for the Development and Application of Population Metrics*. Inst. Med., Washington, DC: Natl. Acad. Press
  16. Froberg DG, Kane RL. 1989. Methodology for measuring health-state preferences I. Measurement strategies. *J. Clin. Epidemiol.* 42:345–54
  17. Froberg DG, Kane RL. 1989. Methodology for measuring health-state preferences II. Scaling Methods. *J. Clin. Epidemiol.* 42:459–71
  18. Fryback DG, Dasbach EJ, Klein R, Klein BEK, Dorn N, et al. 1993. The Beaver Dam Health Outcomes Study: initial catalog of health-state quality factors. *Med. Decis. Mak.* 13:89–102
  - 18a. Fryback DG, Lawrence WF. 1997. Dollars may not buy as many QALYs as we think: a problem with defining quality-of-life adjustments. *Med. Decis. Mak.* 17:276–84
  19. Garber AM, Weinstein MC, Torrance GW, Kamlet MS. 1996. Theoretical foundations of cost-effectiveness analysis. See Ref. 23, pp. 25–53
  20. Gold MR, Franks P, McCoy KI, Fryback DG. 1998. Toward consistency in cost-utility analyses. Using national measures to create condition-specific values. *Med. Care* 36(6):778–92
  21. Gold MR, Muennig P. 2002. Measure-dependent variation in burden of disease estimates: implications for policy. *Med. Care*. 40:In press
  22. Gold MR, Patrick DL, Torrance GW. 1996. Identifying and valuing outcomes. See Ref. 23, pp. 82–134
  23. Gold MR, Siegel JE, Russell LB, Weinstein MC. 1996. *Cost-effectiveness in Health and Medicine*. New York: Oxford Univ. Press. 425 pp.
  24. Hadorn DC. 1991. Setting health care priorities in Oregon. Cost-effectiveness meets the rule of rescue. *JAMA* 265:2218–25
  25. Harris J. 1987. QALYfying the value of life. *J. Med. Ethics* 13(3):117–23
  26. Harris J. 1988. Life: quality, value and justice. *Health Policy* 10(3):259–66
  27. Hornberger JC, Redelmeier DA, Peterson J. 1992. Variability among methods to assess patients' well-being and consequent effect on a cost-effectiveness analysis. *J. Clin. Epidemiol.* 5:505–12
  28. Kaplan RM, Anderson JP. 1988. A general health policy model: update and applications. *Health Serv. Res.* 23:203–35
  29. Klarman HE, Francis JO, Rosenthal GD. 1968. Cost-effectiveness analysis applied to the treatment of chronic renal disease. *Med. Care* 6:48–54
  30. Koch T. 2000. Life quality vs the 'quality of life': assumptions underlying prospective quality of life instruments in health care planning. *Soc. Sci. Med.* 51(3):419–27
  31. Llewellyn-Thomas HA, Sutherland JH, Tibshirani R, Ciampi A, Till JE, Boyd NF. 1984. Describing health states: methodologic issues in obtaining values for health states. *Med. Care* 22:543–52
  32. McDowell I, Newell P. 1996. *Measuring Health: A Guide to Rating Scales and Questionnaires*. New York: Oxford Univ. Press
  33. Menzel P, Gold MR, Nord E, Pinto-Prades JL, Richardson J, Ubel P. 1999. Toward a broader view of values in cost-effectiveness analysis of health. *Hastings Cent. Rep.* 29(3):7–15
  34. Moriyama I. 1968. Problems in the measurement of health status. In *Indicators of Social Change*, ed. E Sheldon, WE Moore, pp. 573–600. New York: Russell Sage Found.
  35. Murray CJL, Lopez AD. 1996. *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020*. Global Burden of Disease and Injury Series, Vol.

1. Cambridge, MA: Harvard Sch. Public Health/WHO/World Bank. 990 pp.
36. Murray CJ, Lopez AD. 2000. Progress and directions in refining the global burden of disease approach: a response to Williams. *Health Econ.* 9(1):69–82
37. Nease RF, Kneeland GT, O'Connor W, Sumner W, Lumpkins C, et al. 1995. Variation in patient utilities for outcomes of the management of chronic stable angina: implications for clinical practice guidelines. *JAMA* 273:1185–90
38. Neumann PJ, Goldie SJ, Weinstein MC. 2000. Preference-based measures in economic evaluation in health care. *Annu. Rev. Public Health* 21:587–611
39. Nord E. 1992. Methods for quality adjustment of life years. *Soc. Sci. Med.* 34(5):559–69
40. Nord E. 1995. The person trade-off approach to valuing health care programs. *Med. Decis. Mak.* 15(3):201–8
41. Nord E, Pinto JL, Richardson J, Menzel P, Ubel P. 1999. Incorporating societal concerns for fairness in numerical valuations of health programmes. *Health Econ.* 8:25–39
42. O'Leary JF, Faircloth DL, Jankowski MK, Weeks JC. 1995. Comparison of time trade-off utilities and rating scale values of cancer patients and their relatives: evidence for a possible plateau relationship. *Med. Decis. Mak.* 15:132–37
43. Packer A. 1968. Applying cost-effectiveness concepts to the community health system. *Oper. Res.* 16:227–53
44. Patrick DL, Erickson P. 1993. *Health Status and Health Policy: Allocating Resources to Health Care*. New York: Oxford Univ. Press
45. Patrick DL, Bush JW, Chen MM. 1973. Methods for measuring levels of well-being for a health-status index. *Health Serv. Res.* 8(3):228–45
46. Pliskin JS, Shepard DS, Weinstein MC. 1980. Utility functions for life years and health status. *Oper. Res.* 28:206–24
47. Rawles J. 1989. Castigating QALYs. *J. Med. Ethics* 15(3):143–47
48. Read JL, Quinn RG, Berwick DM, Fineberg HV, Weinstein MC. 1984. Preferences for health outcomes: comparisons of assessment methods. *Med. Decis. Mak.* 4:315–29
49. Rosenberg MA, Fryback DG, Lawrence WF. 1999. Computing population-based estimates of health-adjusted life expectancy. *Med. Decis. Mak.* 19:90–97
50. Russell LB, Gold MR, Siegel JE, Daniels N, Weinstein MC. 1996. The role of cost-effectiveness analysis in health and medicine. *JAMA* 276:1172–77
51. Sackett DL, Torrance GW. 1978. The utility of different health states as perceived by the general public. *J. Chronic Dis.* 31:697–70
52. Sanders B. 1964. Measuring community health levels. *Am. J. Public Health* 54(7):1063–70
53. Slevin ML, Stubbs L, Plant HJ, Wilson P, Gregory WM, et al. 1990. Attitude to chemotherapy: comparing views of patients with cancer with those of doctors, nurses, and general public. *BMJ* 300:1458–60
54. Sullivan D. 1966. *Conceptual Problems in Developing an Index of Health*. Washington, DC: U.S. Dep. HEW
55. Torrance GW. 1986. Measurement of health state utilities for economic appraisal. A review. *J. Health Econ.* 5:1–30
56. Torrance GW, Boyle MH, Horwood SP. 1982. Application of multi-attribute utility theory to measure social preferences of health states. *Oper. Res.* 30:1043–69
57. Torrance GW, Furlong W, Feeny D, Boyle M. 1995. Multi-attribute preference functions. Health Utilities Index. *Pharmacoeconomics* 7:503–20
58. Ubel PA, Nord E, Gold MR, Menzel P, Pinto-Prades JL, Richardson J. 2000. Improving value measurement in cost-effectiveness analysis. *Med. Care* 38(9):892–901
59. Van Wijck EE, Bosch JL, Hunink JM.

1998. Time-trade-off values and standard gamble utilities assessed during telephone interviews versus face-to-face interviews. *Med. Decis. Mak.* 18:400–5
60. Von-Neumann J, Morgenstern O. 1944. *Theory of Games and Economic Behavior*. Princeton, NJ: Princeton Univ. Press
61. Williams A. 1996. QALYS and ethics: a health economist's perspective. *Soc. Sci. Med.* 43(12):1795–804
62. Williams A. 1999. Calculating the global burden of disease: time for a strategic reappraisal? *Health Econ.* 8:1–8
63. Wolfson M. 1994. POHEM—a framework for understanding and modeling the health of human populations. *World Health Stat. Q.* 47(3):157–76
64. Wolfson MC. 1996. Health-adjusted life expectancy. *Health Rep.* 8:41–46
65. Wolfson MC. 1999. Measuring health—visions and practicalities. *Stat. J. U. N. ECE* 16:1–17
66. World Bank. World Dev. Rep. 1993. *Investing in Health*. New York: Oxford Univ. Press/World Bank
67. World Health Organ. 1980. International Classification of Impairments, Disability and Handicap. Geneva: WHO



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