

Reprinted from

JOURNAL OF HEALTH ECONOMICS

Journal of Health Economics 16 (1997) 685–702

Disability-adjusted life years: a critical review ¹

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Received 1 October 1995; accepted 1 December 1996

Abstract

The disability-adjusted life year (DALY) has emerged in the international health policy lexicon as a new measure of the 'burden of disease'. We argue that the conceptual and technical basis for DALYs is flawed, and its assumptions and value judgements are open to serious question. In particular, the implications of age-weighting and discounting are found to be unacceptable. Moreover, the proponents of DALYs do not distinguish between the exercises of measuring the burden of disease and of allocating resources. But the appropriate information sets for the two exercises are quite different. Allocating resources by aggregate DALY-minimization is shown to be inequitable. © 1997 Elsevier Science B.V.

JEL classification: I12; D63; O2

Keywords: DALYs; Equity; Burden of disease; Cost-effectiveness; Discounting; Age-weighting

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¹ Anand's research was supported by the John D. and Catherine T. MacArthur Foundation, and by the Institute of Economics and Statistics, Oxford. We are extremely grateful to Ramesh Govindaraj, who was involved in the early stages of this project and provided valuable substantive and editorial comments. For helpful comments or discussion, we are also very grateful to Lincoln Chen, Roger Crisp, William Hsiao, Jonathan Levin, Michael Lockwood, Sanjay Reddy, Michael Reich, Dan Robinson, Amartya Sen and Devinder Sivia.

1. Introduction

The disability-adjusted life year (DALY) has emerged in the international health policy lexicon as a new measure of the 'burden of disease'. The conceptual framework for DALYs is described and justified in a recent paper, "Quantifying the burden of disease: the technical basis for disability-adjusted life years" (Murray, 1994). Developed as an input into the World Bank's *World Development Report 1993: Investing in Health*, DALYs are being used as a tool for policy-making in a wide range of countries (Bobadilla and Cowley, 1995). According to some, the DALY concept has "the potential to revolutionize the way in which we measure the impact of disease, how we choose interventions, and how we track the success or failure of our intervention" (Foegen, 1994, p. 1705).

DALYs combine "time lived with a disability and the time lost due to premature mortality" (Murray, 1994, p. 441). Years lost from premature mortality are estimated with respect to a standard expectation of life at each age. Years lived with disability are translated into an equivalent time loss by using a set of weights which reflect reduction in functional capacity, with higher weights corresponding to a greater reduction. In both cases, time spent in the state is adjusted using a set of "value choices" (Murray, 1994, p. 430) which weight time lived at different ages and at different time periods differently (through age-weighting and discounting, respectively). By definition, DALYs are a 'bad' which should be minimized.²

DALYs are claimed by Murray to be superior to measures that ignore time lived with disabilities and consider mortality alone in assessing disease burden, such as potential years of life lost (PYLL). Further, DALYs are considered to be an 'advance' over other composite indicators, such as quality-adjusted life years (QALYs), because the value choices incorporated in the DALY are made explicit: "The black box of the decision-maker's relative values is then opened for public scrutiny and influence" (p. 430). The present paper constitutes a response to Murray's invitation to debate the specific values which have been adopted in the construction of the DALY.

The proponents of DALYs use the metric for at least two separate exercises: (1) the 'positive' exercise of measuring the burden of disease; and (2) the 'normative' exercise of resource allocation. The burden of disease is simply measured as the sum of DALYs attributable to premature mortality or morbidity. For resource allocation, Murray suggests that DALYs be used "in conjunction with the literature on cost-effectiveness of health interventions" so as to facilitate "using estimates of the burden of disease in determining health resource alloca-

² The terminology of disability-adjusted life years can be misleading: more of a 'life-year' (even 'adjusted') should be a 'good', which should be maximized and not minimized. The World Bank and Murray himself are victim to this terminological confusion (for example, see World Bank, 1993, p. 213 and Murray, 1994, p. 440).

tions" (p. 442). In using DALYs for this purpose, the object is to minimize aggregate DALYs subject to a given budget.

Murray (1994, p. 429) states: "[T]he intended use of an indicator of the burden of disease is critical to its design. At least four objectives are important.

- to aid in setting health service (both curative and preventive) priorities;
- to aid in setting health research priorities;
- to aid in identifying disadvantaged groups and targeting of health interventions;
- to provide a comparable measure of output for intervention, programme and sector evaluation and planning.

Not everyone appreciates the ethical dimension of health status indicators.... Nevertheless, the first two objectives listed for measuring the burden of disease could influence the allocation of resources *among individuals*, clearly establishing an ethical dimension to the construction of an indicator of the burden of disease" (emphasis added).

The attractions of applying a universal formula, not only to measure the burden of ill-health but also to decide how much money should be spent in controlling which disease, and how much money should be spent in doing research on different diseases, are clear enough. However, we argue in this paper that the conceptual and technical basis for disability-adjusted life years is flawed, and that the assumptions and value judgements underlying it are open to serious question. Our concerns relate to the use of DALYs for both quantifying the global burden of disease and allocating resources on the basis of DALYs prevented. We shall argue that the appropriate information sets for the two exercises are quite different.

The 'burden' of disease as defined by Murray is a measure of ill-health which reflects functional limitation and premature mortality, and is adjusted for age, sex and time of illness. This notion would seem to be closer to the aggregate quantity of ill-health than to the 'burden' as commonly understood. Although this may appear to be a semantic quibble, it has substantive implications. If the goal were measurement of the actual 'burden' of illness, more information would be needed about the circumstances of individuals who experience ill-health (e.g. the support provided through public services, private incomes, family and friends) and not just their age and sex. Moreover, if the object of public sector resource allocation were to minimize *this* 'burden' of illness, such considerations would clearly be relevant. Even if the object were simply to measure the quantity of illness (an exercise that has some independent value) we argue in this paper that age-weighting and discounting are inappropriate procedures.

This highlights a more general problem with the DALY information set. By 'information set' we mean the set of variables that is used to quantify an individual's contribution to the burden of disease,³ or that may be used for resource allocation—depending on the exercise at hand. In the DALY framework

³ Henceforth we use the term 'burden of disease' in Murray's narrow sense of quantity of ill-health.

the information set used for both these separate exercises is the same, and consists of age, sex, disability status, and time period. A principle is enunciated of "treating like health outcomes as like" along these dimensions (p. 431). However, it is not at all obvious that one would wish to treat those who are *unlike* along some of these dimensions *differently*. We will argue that, in measuring an individual's contribution to the burden of disease, age and time period are irrelevant distinctions to make.

For the exercise of resource allocation, in contrast to that of measuring the quantity of ill-health, a further issue concerns the treatment of those who are *different* along dimensions *not* included in the DALY information set. Here the DALY framework fails to make relevant distinctions between those who are unlike along dimensions that are surely important for resource allocation, such as income and socio-economic status.

Finally, the *use* of variables that are included in the information set can differ depending on whether the purpose is measuring the burden of disease or allocating resources. In the DALY framework, a person with a pre-existing disability, such as a physical handicap, contributes less to the disease burden (for an illness independent of her disability) than an able-bodied person. On a cost-effectiveness basis she will receive lower priority, yet her claim on public resources should be greater precisely on account of her pre-existing disability. In general, we show that if the existing DALY information set is used in conjunction with the criterion of aggregate DALY-minimization, the implications for resource allocation will be inequitable.

Our paper is structured as follows. Section 2 considers the implications of using DALYs as a measure of disease burden, and assesses each of Murray's "value choices" in the order in which he presents them. Section 3 turns to the problems of resource allocation in the health sector based on the DALY framework. Section 4 is in conclusion.

2. Measuring the burden of disease: implications of the DALY framework

2.1. What is the burden?

The DALY approach measures the burden of illness through reduction in "human function" (Murray, 1994, p. 438). The "multiple dimensions of human function" are mapped onto a unidimensional scale between 0 (perfect health) and 1 (death) along which six discrete disability classes are distinguished. Human function is represented by ability to perform certain activities of daily living, such as learning, working, feeding and clothing oneself. The space in which ill-health is assessed is limitation in these activities rather than, for example, that of pain or

suffering which would be the relevant categories in a utility-based framework.⁴ Another space for assessment might be reduction in well-being, a notion that is broader than utility and is captured by general ‘capability to function’—including physical functioning.⁵ Of course, there will be utility or well-being consequences associated with reduction in human function, but these are not the basis for the DALY metric.

An often-cited advantage of DALYs, and similar composite indicators such as QALYs, is that they allow fatal and non-fatal health outcomes to be combined into a single indicator. A necessary condition for a finite scale which has perfect health (or quality of life) at one end and death at the other is that the values of all health states, including death, be bounded. In the DALY scale death differs from disability merely by reducing human function to nought. While having an indicator that combines states of imperfect health with death is clearly convenient, there is an obvious information loss in reducing death to simply another health state. Some will argue that the two events are incommensurable, and that a lexical priority attaches to life over death. At any rate, this suggests that information about mortality and morbidity should be presented separately—even if trade-offs were conceded between the two events.

DALYs attempt to measure the burden of disease in a somewhat narrow sense. As discussed in Section 1, they represent the quantity of ill-health experienced by individuals through functional limitation and premature death. The burden that is measured does not reflect individuals’ differential ability to cope with their functional limitation. Moreover, burdens which fall on family, friends, and society at large (e.g. the economic cost of illness) are not included. Only in the use of unequal age-weights does there appear to be an attempt to capture the indirect health burden of illness. We return to the rationale for and ethical implications of unequal age-weighting in Section 2.3.

DALYs use standardized maximum life expectancies (80 years for men and 82.5 years for women) which are considerably higher than the levels of life expectancy currently achieved in developing countries. Using these standardized life expectancies either in measuring the global burden of disease or in cost-effectiveness analysis implicitly assumes that health interventions alone are capable of achieving an increase in life expectancy to these higher levels. It is clear that many non-health circumstances will also need to change for life expectancy to rise to the level used in the DALY calculations. These interventions would have to

⁴ A framework based on limitation in physical (or mental) activities would also tend to emphasize the importance of conditions such as locomotor disability and chronic degenerative disease relative to those which do not result in (or extend beyond) reduction in human function (e.g. depression or psycho-social stress).

⁵ The terminology of ‘functioning’ was initially proposed by Sen (1985), and is broader than that associated with health alone.

address the socio-economic determinants of health. They would include raising incomes, increasing female education, improving water supply and sanitation conditions, improving workplace safety, and reducing accidents and violence. Hence the burden that is measured by DALYs is the *burden of disease and underdevelopment*, and not that of disease alone.

2.2. Standard expectation of life and gender gap

To calculate the DALYs from morbidity and premature mortality, a standard expectation of life at birth of 82.5 years is chosen for women and of 80 years for men. This gap is considerably smaller than the observed gender gap in life expectancy in low mortality populations, for example, Japan which has a gender gap of some 6 years. However, the gender gap of 2.5 years is argued to correspond purely to the "biological difference in survival potential between males and females" (Murray, 1994, p. 434), factoring out the effects on life expectancy of males' greater exposure to social and other risk factors. It is, nonetheless, an arbitrary choice.⁶

The assumed gender gap in life expectancy may have important implications for the estimation of the disease burden of women relative to that of men. World Bank (1993, p. 28) estimates that "[F]emales have about a 10 percent lower disease burden per 1,000 population than males for the world as a whole". The smaller the gender gap, *ceteris paribus*, the smaller will be the female contribution to the burden of disease relative to the male contribution. If the true biological gap happens to be greater than 2.5 years, then the calculations in Murray et al. (1994) and World Bank (1993) will understate the burden of disease of females relative to that of males.

While DALYs take account of higher female life expectancy in calculating years lost to premature mortality, the valuation of these years can be sharply reduced by age-weighting and discounting. As an illustration Table 1 shows the estimate of time lost, and of its value, from the death of a female and a male infant, respectively. The female advantage in years lost of 3% is reduced by age-weighting to 1.5%, and is further reduced by discounting to 0.3% for the calculation of DALYs.

⁶ The literature on the 'biological-genetic' difference between the sexes acknowledges there to be significant disagreement regarding the relative contributions of biological factors and environmental or social ones (Waldron, 1983, Holden, 1987, Collins, 1992). Murray's attempt (Murray, 1994, p. 434) to isolate the contribution of biological factors in longevity is based on the observation of narrowing gender gaps among higher income quintiles in urban Canada, and a gender difference in the highest income quintile of 4-5 years. This gap is then projected "forward", without explanation, to the assumed gap of 2.5 years.

Table 1
The value of time lost from an infant death

	Years lost	Age-weighted years lost ^a	DALYs, i.e. age-weighted and discounted (at 3% per annum) years lost ^a
Female	82.5	85.42	32.45
Male	80	84.14	32.34
Gap	2.5	1.28	0.11
Gap, relative to male (%)	3	1.5	0.3

^aThe age-weighting function used in Murray (1994) is $f(x) = 0.16243 xe^{-0.04x}$.

2.3. Age-weighting and the value of time lived at different ages

Age-weighting assigns a different value to time lived at different ages. Thus in the construction of a DALY, a year lived at age 2 counts for only 20% of a year lived at age 25 where the age-weighting function is at a maximum, while that lived at age 70 counts for 46% of the maximum. In a human capital framework, age-weighting might be justified in terms of the differential productivity of an individual at different stages of his life cycle. This approach allows one to impute a money value to life and to disability according to the respective (discounted) income streams foregone. Although it provides a consistent justification for age-weighting (and for discounting), valuing people's lives in terms of a money metric, through their instrumental worth in production, is hard to defend ethically. Murray (1994) himself explicitly rejects the human capital approach, arguing that it "inadequately reflects human welfare" (p. 435).⁷ What, then, is the basis for assigning different relative values to years of life lost at different ages?

Murray (1994) views "unequal age weights as an attempt to capture different social roles at different ages", arguing that "[H]igher weights for a year of time at a particular age does not mean that the time lived at that age is per se more important to the individual, but that because of social roles the social value of that time may be greater" (p. 435). He claims that "social roles vary with age" because the "young, and often the elderly, depend on the rest of society for physical, emotional and financial support" (p. 434). How "different roles and changing levels of dependency with age" (p. 434) are supposed to affect the burden of illness to the individual is far from clear to us. We take it that unequal

⁷ He also seems to suggest an "apparent inconsistency in the application of the human capital concept"—"even though it would only be logically consistent" to "...weight time by other human attributes that correlate with productivity such as income, education, geographical location or even, in some economies, ethnicity" (p. 435). There is no inconsistency here, apparent or real, and if the human capital approach is adopted time should indeed be weighted according to productivity.

age weights do not constitute a differential *intrinsic* valuation of years lived at different ages. Rather, there appears to be an *instrumental* justification for valuing the time of people in middle age-groups more highly than that of the young or elderly. Presumably ill-health among the middle age-groups also has an indirect effect on the health of the young and elderly because the latter depend on the former for care.⁸

However, if age-weighting is supposed to reflect an instrumental valuation of people's time, even if solely in terms of its health impact, then a host of other instrumentalities with health impacts will need to be incorporated. From the viewpoint of preventing ill-health the 'social value' of time will clearly differ for different occupation groups in the population. For example, doctors' and nurses' time could be argued to be more valuable than that of other professions. More indirectly, the time of people who have a greater capacity to contribute, through taxation, to the size of the health budget should be valued more highly. However, a person's occupation or tax bracket are not part of the information set used to calculate DALYs, and nor are other (for example, social and economic) factors which directly and indirectly influence individuals' health.

Murray (1994) apparently believes that "[U]nequal age weights [also] has broad intuitive appeal", and goes on to state that "informal polling of tuberculosis programme managers by the author in an annual training course has revealed that everyone polled believes that the time lived in the middle age groups should be weighted as more important than the extremes" (p. 435). But what precise question were his group of programme managers asked? Did it concern an intrinsic valuation of time lived at different ages or an instrumental valuation? How do we know that it is not reflecting their view of income levels and productivity through the life cycle? Were they made aware of the implications of age-weighting for resource allocation? It is not obvious to us that the author has properly solicited from his programme managers their value judgements concerning age-weighting per se.

It is also not at all clear that the programme managers were provided with (adequate) information about *other* adjustments made in the DALY formula to life years lived. It is possible, for instance, that they had in mind different functional capacities at different ages, in other words, a higher level of functioning in the middle age-groups compared with either end. But reduction in 'human function'

⁸ Note that for the purpose of measuring the burden of disease, higher weights placed on the middle age-groups according to this instrumental justification will lead to double-counting. Any consequential health effects should already have been recorded when the burden of disease is measured. On the other hand, for the purpose of resource allocation, avoiding ill-health for a mother will also avoid the consequential ill-health of her child. In this case, allocating resources to the mother will generate health benefits in excess of those that accrue to her alone. Hence for the purpose of resource allocation, age-weighting might be justified by Murray in a way that it cannot be for measuring the burden of disease.

will be captured separately and independently through Murray's disability weights (see our Section 2.4). Even if function and age were correlated (and followed the shape of the age-weighting function), applying age weights on top of disability weights would amount to penalizing reduced functional capacity twice over.

Murray (1994, p. 436) posits an age-weighting function of the form $Cxe^{-\beta x}$ where x is age, $\beta = 0.04$, and the normalization constant $C = 0.16243$. Without discounting (q.v. Section 2.5), the sum of age-weighted time lived beyond age a , $V(a)$, is given as

$$V(a) = \int_a^{a+L(a)} Cxe^{-\beta x} dx$$

where $L(a)$ is interpreted differently in the case of morbidity and premature mortality. In the former, $L(a)$ is the duration of an illness occurring at age a ; in the latter, $L(a)$ is the expectation of life at age a (i.e. the expected years lost from premature mortality).⁹ By differentiation with respect to a , it can be shown that

$$V'(a) = Ce^{-\beta a} \{ [a + L(a)]e^{-\beta L(a)} [1 + L'(a)] - a \}.$$

In the case of an illness of constant duration, $L(a)$ will be constant and $L'(a) = 0$.¹⁰ In this case, $V'(a) > 0$ whenever $a < L/(e^{\beta L} - 1)$. In other words, the value of time lost from an illness of constant duration will be increasing in the early years of a person's life (from age 0) to some maximum. This leads to the inevitable conclusion within the cost-effectiveness framework that, given a choice between treating two persons with the same illness and the same cost of treatment, more DALYs will be prevented if the older person of age $L/(e^{\beta L} - 1)$ is treated rather than an infant. With the given value of $\beta = 0.04$ and an illness lasting 1 year, i.e. $L = 1$, maximum DALYs are prevented at age 24.5. These implications of

⁹ Note that the expression $V(a)$ corresponds to the age-weighted value of the expected time lost at age a , which assumes that everyone at age a will live exactly $L(a)$ more years. However, the expected loss is the expected value of age-weighted time lost—which will differ from the above.

¹⁰ In discussing the loss from premature mortality rather than from illness of constant duration, the *World Development Report 1993: Investing in Health* (World Bank, 1993, p. 213) asserts that "[I]n the absence of discounting, [therefore,] the greatest loss of DALYs [sic] from premature death occurs from infant deaths". This is not correct because the mean age at death, $a + L(a)$, where $L(a)$ is the expectation of life at age a , is not constant. According to the Model Life Table West Level 26 that is used, mean age at death $a + L(a)$ increases with a , while life expectancy $L(a)$ decreases with a (see Murray, 1994, Table 1, p. 435). In other words, we have $-1 < L'(a) < 0$. Applying the formula for $V'(a)$ in the text to value the time lost from death at age $a = 0$ we have

$$V'(0) = CL(0)e^{-\beta L(0)} [1 + L'(0)] \\ > 0 \text{ because } 1 + L'(a) > 0 \text{ for the entire age range.}$$

This shows that the greatest number of DALYs from premature death arises *not* from infant deaths (at age $a = 0$) but from death at a higher age. Indeed, undiscounted but age-weighted DALYs will continue to *increase* until age a^* given as the solution of

$$[a^* + L(a^*)]e^{-\beta L(a^*)} [1 + L'(a^*)] = a^*.$$

age-weighting are thoroughly unacceptable, and we can see no reason for valuing time lived at different ages differently. A principle of universalism of life claims (Anand and Sen, 1994) would argue strongly for a common intrinsic valuation of human life, regardless of the age at (or time period in) which it is lived.

2.4. Disability weights

In the DALY framework, the effects of illness are captured through six disability classes which assign increasing weights associated with the extent of loss of physical functioning. Murray (1994, p. 439) states that "weights for the six classes have been chosen by a group of independent experts".¹¹ As in the case of age weights, the meaning attached to the different weighting of health states depends in an important way on the precise question that was asked of these experts. Their responses would also depend on understanding the use to which such estimates would be put.

In Murray's formulation, DALYs suffered by individual i are a function of both his life expectancy L_i (at age a) and his disability weight D_i . Between the values of $D_i = 0$ which represents perfect health and $D_i = 1$ which represents death, six discrete disability categories are defined (Murray, 1994, p. 438). The weights D_i may be referred to as 'uncompensated' disability weights.

A more appropriate measure of burden must take account of the way in which individual and social resources can compensate for the level of disability experienced. The individual's actual loss of functioning will depend on both his uncompensated disability state and the factors which affect his capacity to cope with that disability (given his circumstances). 'Compensated' disability weights would depend inter alia on the individual's income (for example, whether he can employ somebody to prepare his meals and provide other assistance with his activities of daily living), and on the provision of local services to facilitate his daily activities. The latter might include designated parking, transport services for the disabled, etc. Compensated disability weights would come closer to reflecting the true burden of disability as experienced by the individual. The DALY approach does not distinguish between the quantity of ill-health and the 'burden' associated with it.

A final question about the construction of disability weights relates to the manipulations necessary to restrict the maximum disability weight for an individual to 1. In particular, although DALYs are aggregated across individuals, problems caused by co-morbidity (an individual experiencing multiple illnesses)

¹¹ No information is reported which would allow an assessment of the statistical or scientific basis for selecting the weights and, thus, of their validity. This same criticism applies to the choice of the age-weighting function, the estimate of disability duration associated with each disease, and other parameters.

are not adequately dealt with in the framework, and can lead to an overestimation of the total disease burden.¹²

As they stand Murray's disability categories do not distinguish functionings associated with illness and those associated with age (but no illness). For example, the most severe disability class (Class 6) involves disability states in which an individual "needs assistance with activities of daily living such as eating, personal hygiene or toilet use" (Murray, 1994, Table 2, p. 438). Infants are not capable of feeding themselves: does this imply they are disabled? Do they by virtue of the functional limitations of their stage of development contribute to the burden of disease?¹³ If disability weights are to be usable and consistent, they should be defined so as to avoid confounding age with disability.

2.5. Time preference and the discounting of future life

In the DALY formula, future years of life lived are valued less than present years. With the recommended 3% discount rate,¹⁴ this implies that one life saved today will be worth more than five lives saved in 55 years. Discounting future lives in this way would justify many forms of environmental degradation today which benefit the present generation at the expense of future generations. For example, the benefit today of economic activities which emit greenhouse gases at present rates could well outweigh the harm done to future generations from global warming if future lives are valued at only *one-fifth* of present lives.

We can see no justification for an estimation of the time lost to illness or death which depends on when the illness or the calculation occurs. Suppose a person experiences an illness today and another person, identical in all respects, experiences an illness of exactly the same description next year. Discounting amounts to concluding that the quantity of the (same) illness is lower in the latter case. This does not accord with intuition or even with common use of language.

As in the case of age-weighting, a logically consistent defence of discounting could be provided if the human capital approach to valuing life were adopted. Life would then be reducible to a monetary value, and discounting it justified because of the opportunity cost of money. But Murray (1994) eschews this framework yet invokes economic cost-benefit arguments to defend "social time preference" (p. 440).

¹² Because of the disease- and not individual-specific estimation of the disease burden, an individual can turn out to have a cumulative disability weight greater than 1. While states worse than death might be possible in some evaluation spaces (pain, suffering, etc.), in the DALY space of physical functioning this is impossible.

¹³ See Section 2.3 above on the confounding of age and disability.

¹⁴ In choosing a discount rate of 3%, Murray (1994, p. 440) argues that: "This is consistent with the long-term yield on investments. There is also a precedent in the World Bank Disease Control Priorities Study that used a 3 percent rate". Below we argue that the yield on investments has little to do with discounting health outcomes.

Because life cannot be reduced to money, the usual arguments for discounting money do not apply to discounting DALYs. Yet Murray (1994) fails to distinguish between discounting DALYs (or utility) and discounting money (or consumption). Hence the usual cost-benefit reasons presented by him for discounting future consumption (money) (e.g. by appeal to the marginal utility of consumption falling with expected future growth of consumption) are irrelevant to discounting utility or DALYs. Moreover, it is difficult to see how pure time preference in the discounting of future utility or future DALYs can be justified.¹⁵

The only defensible argument for treating future periods differently rests on the possibility that the world might end. A construction which could accommodate uncertainty is the minimization of expected (in the statistical sense) undiscounted DALYs.¹⁶ Under this objective function lives in each period are weighted by the probability that the world will exist in that period.¹⁷ Note that a 3% discount rate implies a 50% chance that the world will end in 23.4 years. Even a 1% discount rate implies there is a 50% chance that the world will end in 69.7 years. How many people would be willing to take an odds-on chance that the world will end within their, or their children's, lifetime? We reckon that the discount rate implied by the probability of the world ending within the planning horizon for DALY

¹⁵ See Anand and Sen (1994, Appendix A.2) for a critique of pure time preference, i.e. the discounting of future utility or well-being itself. Even if individuals themselves should happen to have a positive rate of pure time preference, there is no reason for a government to use pure time discounting in social decision-making. Social decision-making need not necessarily be "welfarist" (Sen, 1979); indeed the DALY approach itself is not obviously consistent with individuals' health behaviour—individuals do not minimize DALYs. In the case of pure time discounting, for example, Harrod (1948, pp. 37-40) argued that "On the assumption...that a government is capable of planning what is best for its subjects, it will pay no attention to pure time preference, a polite expression for rapacity and the conquest of reason by passion".

In rejecting pure time discounting, Pigou (1932, pp. 29-30) noted that "there is wide agreement that the State should protect the interests of the future *in some degree* against the effects of our irrational discounting and of our preference for ourselves over our descendents. The whole movement for 'conservation' in the United States is based on this conviction. It is the clear duty of Government, which is the trustee for unborn generations as well as for its present citizens, to watch over, and, if need be, by legislative enactment, to defend, the exhaustible natural resources of the country from rash and reckless spoliation."

A similar argument against pure time discounting applies in the context of health-sector planning: since future generations are not here to represent their preferences, the government should act as trustee in protecting their interests—in particular, the value of the life years they will live.

¹⁶ Of course, strong assumptions would be needed to justify this extension of the DALY-minimization criterion to conditions of uncertainty. Moreover, if the probability of the world ending can be represented by a Poisson process, the minimization of expected undiscounted DALYs will be functionally equivalent to as-if-discounting of future lives. But note that this is not the same as *valuing* future lives less than present lives.

¹⁷ Incidentally, if planet Earth were to be struck by a comet, such as Shoemaker-Levy 9, the burden of illness would immediately vanish: there would be *no* people with any illness.

calculations is infinitesimally small. For any practical purpose, the assumption of a zero discount rate is likely to command more assent than even a very small one.

It appears to us that Murray's positive arguments in support of discounting are based largely on attempts to avoid some awkward implications of the use of undiscounted DALYs for cost-effectiveness analysis. The first of these states that "if health benefits are not discounted, then we may conclude that 100% of resources should be invested in any disease eradication plans with finite costs as this will eliminate infinite streams of [undiscounted] DALYs which will outweigh all other health investments that do not result in eradication" (p. 440). Quite apart from whether it is necessary to invest 100% of resources to eradicate diseases, we fail to see how this statement provides an argument for discounting DALYs. In the burden of disease framework it would seem a desirable outcome to eradicate a disease, for precisely the author's goal of minimizing aggregate ill-health.

Murray also invokes the so-called "time paradox", arguing that if health benefits are not discounted then "one will always choose to put off investing in a health project until the future" because "...the budget could be invested and yield a positive return" (p. 440). Whether or not any "time paradox" arises,¹⁸ if Murray's concern is that, without discounting, present health outcomes will be sacrificed in favour of future health outcomes (leading to an undesirable inequality between generations) then this concern for equity should be incorporated directly in a temporally neutral way. One way of making the criterion sensitive to inequality is to express it as a strictly convex, additive function of undiscounted DALYs

$$B = \sum_{i,t} (\Delta_{it})^\alpha$$

where Δ_{it} is the DALYs suffered by individual i at time t , and $\alpha > 1$. The size of the parameter α will capture the extent of aversion to inter-generational (and inter-individual) inequality.¹⁹ With α large enough, it will no longer be cost-effective to defer all expenditure to the future: it will be worth preventing some DALYs now if fewer DALYs arise in the future.

¹⁸ In fact, the "time paradox" is by no means inevitable. Murray assumes that it will arise as long as the return to investment of the health budget elsewhere is greater than the increase in the cost per DALY averted of an intervention. For if the health budget is invested elsewhere with a return which exceeds the increase in the cost of the intervention, then it will pay to postpone health spending. Note that this argument rests critically on the further assumption that the stream of DALYs in the future will be the same with or without the current health spending. However, failure to invest in health today can significantly increase DALYs in the future—for example, through failure to immunize against communicable diseases or to provide nutritional supplementation. The cost of eliminating these additional DALYs may turn out to be larger than the return to deferring health spending (where the 'return' includes any reduction through improved technology in the cost of preventing DALYs). Hence, one will not "always choose to put off investing in a health project until the future".

¹⁹ When $\alpha = 1$ there is no concern for inequality and the criterion reduces to aggregate DALY-minimization.

Finally, discounting at 3% in the Murray-World Development Report 1993 framework implies that we should save the life of a 20-year-old person rather than an infant: more age-weighted and discounted DALYs are prevented in the former case. But does this accord with general intuition? It is the non-monotonic feature of Figs. 4 and 5 in Murray (1994, p. 436 and p. 441, respectively) and Box Fig. 1.3 in World Bank (1993, p. 26) which jars with our basic intuitions. Discounting, which in itself is totally indefensible in the context of lives and life years, can be shown to compound the problems inherent in age-weighting. Together they comprise the most unappealing features of the DALY formula.

2.6. Sensitivity

Much is made in Murray et al. (1994) of the extensive sensitivity analysis undertaken on the global burden calculations to the various assumptions concerning unequal age weights, discount rate, and disability-class weights. Two points are relevant here. First, even though changing these parameters may result in small changes to the overall estimates, this does not constitute evidence that the approach is *correct*. Insensitivity to parameter changes can hardly validate a formula! This paper has raised various concerns about the ethical underpinnings of the DALY approach. These concerns are little affected by any lack of sensitivity of the overall calculations to particular assumptions.

Secondly, although the overall burden of disease calculation may not be very sensitive to changing crucial parameter values, this in no way indicates that the calculation for individual diseases is not highly sensitive to the underlying assumptions. Evidence from a recent study of the burden of trachomatous visual impairment (Evans and Ranson, 1995) suggests that at the level of specific diseases the calculations are indeed highly sensitive to several of the assumptions in the DALY framework, including the discount rate. It is possible that individual diseases are sensitive in compensating directions, resulting in relative lack of overall sensitivity.

2.7. Whose values?

There appear to be at least four distinct agents whose values are incorporated in the DALY-minimization exercise. First, there is a social planner who specifies the exercise (minimizing the burden of ill-health) and who determines the DALY function used to measure it. Secondly, there are a number of other agents whose values are incorporated into the DALY through the parameters of this function: for age-weighting, TB (tuberculosis) programme managers (perhaps *qua* individuals); for disability weights, "a group of independent experts"; for the discount rate, the authors of the World Bank Disease Control Priorities Study (Jamison et al., 1993). It is entirely arbitrary to appeal to different agents' values for the different parameters without prior justification or reasoning. Furthermore, it has to be asked why the social planner's objective is to minimize DALYs if individuals themselves have different objectives. And if compelling reasons can be provided for the

social planner to override individual preferences and minimize DALYs, why should the social planner rely on individual values for choosing DALY parameters?

Even if it could be argued that individual values should be incorporated in the choice of parameters, a precondition for doing so is that everyone should agree on the form of the DALY function—i.e. share a common definition of ill-health. Otherwise, the responses to questions asked in determining parameter values (for example, disability weights or age-weights) will depend on the individual's own conception of ill-health and on his understanding of the purpose for which the estimate is intended. When these differ among individuals the responses provided cannot be compared, let alone averaged.

3. Resource allocation based on the DALY framework

3.1. *General limitations of cost-effectiveness analysis*

There are problems with restricting the framework of health sector analysis and resource allocation to health interventions alone. Many health sector interventions have non-health sector returns, and many non-health sector interventions have health sector returns. Practical examples are easy to construct. For instance, the provision of clean water could, apart from reducing morbidity due to diarrhoeal diseases, also lead to significant economic benefits by reducing the time spent by women in fetching water from distant sources. Evaluating this intervention solely from the health perspective will ignore potentially large non-health sector gains. A non-health sector intervention such as female education, which has been shown to be important in reducing infant mortality and increasing contraceptive use, will reduce DALYs. If mothers' education, or improving water supply and sanitation conditions, generate a bigger 'bang-for-a-buck' than health interventions, then the health budget should be redirected to the ministry of education, or of public utilities. A committed DALY-minimizer should in principle be willing to give over his entire health budget to other ministries! Otherwise, his restricted cost-effectiveness exercise can lead to a seriously suboptimal allocation of resources in the improvement of health outcomes.²⁰

²⁰ It is interesting to note the implications of a simple formulaic approach to allocating health-sector resources, such as DALY-minimization. The most cost-effective way to allocate the health budget may be to invest it in a rigorous family planning programme so as to reduce the number of people who can contribute to DALYs. There would be no DALYs if there were no people—a misanthropic implication of the DALY approach! The reverse applies to the metric of QALYs, where a year lived in a state of perfect health receives a weight of unity while death has a weight of zero. In contrast to DALYs, the criterion of maximizing aggregate QALYs may carry with it the implication of *increasing* population size. The elimination of family planning services could in this case both save costs and increase total QALYs.

Another weakness of cost-effectiveness analysis is that the framework of minimizing DALYs subject to a health budget constraint can be used neither to defend a given budget nor to argue for a different (e.g., larger) one. The cost-effectiveness expert has no basis for commenting on whether the given budget is appropriate. He must remain equally content with a budget which is a half or a tenth the size of his existing budget, since it cannot be compared with 'effectiveness' elsewhere.

3.2. *Implications of aggregate DALY-minimization*

Using the DALY framework for resource allocation may lead to consequences that are at odds with principles of equity. This arises from both the information set that is used in calculating DALYs and the criterion itself, i.e. aggregate DALY-minimization. Broadening the information set to take account of equity will require a substantial re-examination of the DALY-minimization criterion.²¹

The DALYs prevented by an intervention which extends the life of a disabled person will be less than those prevented for an able-bodied person. For example, a treatment which enables a person in a wheelchair to live another year (without altering the person's existing disability) prevents fewer DALYs than the same treatment given to a perfectly healthy person. This is because, given his existing disability (weighted, say, at a value of $\frac{1}{2}$), he is permanently suffering half a DALY each year. Extending his life by a year thus only averts half a DALY (assuming an age weight of unity and no discounting), whereas extending the life of a perfectly able-bodied person averts a whole DALY.²² From an ethical point of view it could be forcefully argued that priority should be given to the disadvantaged person rather than to the perfectly healthy person—exactly the opposite of what is implied in using the DALY formula for resource allocation (Anand, 1993).²³ Similarly, as discussed in Section 2, the age-weighting and discounting schemes of the DALY approach will have implications for resource allocation. They imply preferential treatment of young adults compared with infants or the elderly, and of present generations over future ones.

4. Conclusion

Whether the purpose to which DALYs are put is measurement of disease burden or resource allocation in the health sector, our contention in this paper has

²¹ If the priorities resulting from resource allocation based on the DALY framework happen to identify those diseases which, for example, disproportionately affect the poor, this will be by accident and not by design. There is no built-in concern for equity in the DALY-minimization exercise.

²² See Sen (1973); also Lockwood (1988).

²³ For example, such an argument can be made by applying Rawls' Difference Principle in the space of capabilities.

been that the conceptual and technical basis for the metric is flawed. Many of the principles underlying it are at best unclear, and at worst unjustified. Whilst recognizing the value of attempting to quantify, by cause, the "global burden of disease", the DALY framework needs to be modified fundamentally even for this limited purpose. More importantly, the purposes of measuring the quantity of ill-health and of allocating resources must be sharply distinguished—because the information sets appropriate to the two exercises, and the use that is made of some common variables, will be quite different.

Murray (1994, p. 431) propounds the principle of "treating like health outcomes as like". In measuring the disease burden, this principle implies that two people of the same sex, disability status, age, and time period (the variables in his information set) are treated similarly. The appeal of any principle of treating like health outcomes as like must rest on how exactly it characterizes 'likeness'. The dimensions used to define likeness will depend on the purpose at hand. In quantifying ill-health, it could indeed be plausibly argued that people of the same sex and disability status, *independent of other characteristics*, should be treated similarly. However, in resource allocation (or even in measuring the 'true' burden of disease), it is not equitable to treat *similarly* people of the same sex and disability status who *differ* in critical characteristics such as wealth or access to publicly-provided services. By being blind to variables other than those included in the DALY information set, the principle lacks cutting power and cannot possibly provide a "plausible treatment of equity" (p. 431).

At best the principle of treating like health outcomes as like will be innocuous: obviously we would wish to treat those of the same sex, disability status, age, and time period lived, *ceteris paribus*, similarly. Likewise, *ceteris paribus*, we would also wish to treat similarly those who have the same colour of eyes or hair! However, the principle does not invoke a *ceteris paribus* clause in characterizing 'likeness' along dimensions outside the restricted DALY information set. Hence at worst, by failing to distinguish relevant differences between individuals (for example, in their socio-economic circumstances) the principle ceases to be acceptable.

The principle itself is silent about the treatment of people who are *unlike* along the dimensions that it uses to define likeness. But the DALY framework, through age-weighting and discounting, values life years lived by people of different ages and generations differently. In measuring the burden of disease or in allocating resources, we see no reason why a life year lived by a young or old person should be valued less than that lived by a person in the middle age-groups, or why a life year lived by someone in the next generation should count for less than that by a person in this generation.

Finally, resource allocation that is based on the criterion of aggregate DALY-minimization can lead to perverse outcomes. Using the DALY information set the criterion implies that, all other things equal, for a given illness episode fewer resources should be allocated to a disabled person compared with an able-bodied

one, or to a young or elderly person compared with one in the middle age-groups. This is a consequence of using the particular disability status and age-weighting schemes incorporated in the DALY formula.

In our view, equity must play a central role in public-sector resource allocation. This requires giving priority to the claims of the disadvantaged—for example, the poor and the disabled. As we have shown in this paper, the DALY approach either ignores equity or runs directly counter to it.

References

- Anand, S., 1993. Inequality between and within nations. Center for Population and Development Studies, Harvard University, Cambridge, MA (mimeo.).
- Anand, S., Sen, A.K., 1994. Sustainable human development: concepts and priorities. Center for Population and Development Studies Working Paper No. 94.04, Harvard University, Cambridge, MA (World Development, forthcoming).
- Bobadilla, J.-L., Cowley, P., 1995. Designing and implementing packages of essential health services. *Journal of International Development* 7, 543–554.
- Collins, J.R., 1992. Explaining the gender gap – why do women live longer than men? Unpublished Long Essay for the Honours Degree in Human Sciences, University of Oxford.
- Evans, T.G., Ranson, M.K., 1995. The global burden of trachomatous visual impairment: II. assessing burden. *International Ophthalmology* 19, 271–280.
- Foege, W., 1994. Preventive medicine and public health. *Journal of the American Medical Association* 271, 1704–1705.
- Harrod, R.F., 1948. *Towards a Dynamic Economics*. Macmillan, London.
- Holden, C., 1987. Why do women live longer than men?. *Science* 238, 158–160.
- Jamison, D.T., Mosley, W.H., Measham, A.R., Bobadilla, J.-L., 1993. *Disease Control Priorities in Developing Countries*. Oxford University Press, Oxford.
- Lockwood, M., 1988. Quality of life and resource allocation. In: Bell, J.M., Mendus, S. (Eds.), *Philosophy and Medical Welfare*. Cambridge University Press, Cambridge, pp. 33–55.
- Murray, C.J.L., 1994. Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bulletin of the World Health Organization* 72, 429–445.
- Murray, C.J.L., Lopez, A.D., Jamison, D.T., 1994. Global burden of disease in 1990: summary results, sensitivity analysis and future directions. *Bulletin of the World Health Organization* 72, 495–509.
- Pigou, A.C., 1932. *The Economics of Welfare*, 4th ed. Macmillan, London.
- Sen, A.K., 1973. *On Economic Inequality*. Clarendon Press, Oxford.
- Sen, A.K., 1979. Personal utilities and public judgements: or what's wrong with welfare economics?. *Economic Journal* 89, 537–558.
- Sen, A.K., 1985. *Commodities and Capabilities*. North-Holland, Amsterdam.
- Waldron, I., 1983. The role of genetic and biological factors in sex differences in mortality. In: Lopez, A.D., Ruzicka, L.T. (Eds.), *Sex Differentials in Mortality: Trends, Determinants and Consequences*. Australian National University, Department of Demography, Canberra, pp. 141–164.
- World Bank, 1993. *World Development Report 1993: Investing in Health*. Oxford University Press, New York.