DALYs: the age-weights on balance

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In studies for the 1993 World development report: investing in health *Murray et al. developed the disability-adjusted life year (DALY). This article examines one particular aspect of the DALY methodology: the weighting of life years by age. For the quantitative implementation of this notion Murray proposed a general equation to weight life years by age, which specifies that the years lived between the ages of 9 and 54 years have a weight greater than unity, and for the years outside this range less than unity. The age-weighted life years are used to calculate the "expected years of life lost" (EYLL). Comparison of age-weighted and unweighted age-specific life expectancies shows that the age range which becomes more important due to weighting is not 9–54 years, but 0–27 years. This happens because the EYLL is an age-weighting system in itself, emphasizing the young. The result of piling one age-weighting system on top of the other gives an even stronger emphasis on the young than the EYLL generates by itself. Although this is unlikely to upset the results from the Global Burden of Disease study, we do not think it is desirable. And it is certainly different from what we were led to expect.*

Introduction

In 1994, Murray et al. published a series of articles in the *Bulletin of the World Health Organization* (*1–8*) on the global burden of disease and on health expenditures and intervention packages, which describe the basic studies carried out for the *World development report 1993: Investing in health* (*9*). These articles, now also available in book format (*10*), give an overview of the methodology used to assess the global cost-effectiveness of specific health expenditure packages. The sheer size of the undertaking commands respect. This respect increases considerably when examination of the *Bulletin* papers and background material (*11*) reveals the care with which this study was carried out.

The study developed and applied several innovative concepts, one of which — the disability-adjusted life year (DALY) — has attracted much attention and generated controversy. However, use of a non-disease-specific concept like a DALY is inevitable when you want to compare the burden of morbidity (and its sequelae) of different diseases. The controversy concentrates on two particular aspects of the DALY methodology, one of which we will look into — the weighting of life years by age; the other sensitive aspect is discounting of future life years (*12*).

We must stress that we do not consider age-weighting as such to be inappropriate or wrong; on the contrary, we think it may certainly make sense, depending on the purpose and circumstances. However, precisely because it is controversial it is of great importance to apply it meticulously. One weak point in the methodology as reported by Murray et al. is that the age-weighting eventually produces a different result from what might be expected from the age-weight function. To illustrate this, we will first briefly describe the DALY methodology, and then apply it using a life-table.

The DALY methodology

The methodology assesses the impact on public health, on both morbidity and mortality, of various packages of health care that might be provided. Most health care measures are disease-specific interventions, either preventive or therapeutic, and this makes it imperative to examine the effects of interventions on a disease-specific level. To compare the impact of the intervention between diseases or health care packages it is necessary to have a non-disease-specific common denominator.

The established common denominator used to be mortality or mortality-based measures such as life expectancy and "potential years of life lost" (PYLL). Including morbidity in the public health impact means adopting a non-disease-specific measure to express the burden of diseases and their sequelae. To express the combination of mortality and morbidity

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in a single measure it has become a (disputed) standard to value one year lived in good health by 1, and a year lived with less than good health by a value between 0 and 1, depending on the severity of the health problem. The years not lived (lost to premature mortality) are assigned a value of 0.

Given the disease- and age-specific mortalities, the "expected years of life lost" (EYLL) due to mortality can be estimated by multiplying the number of disease-specific deaths for each age by the life expectancy at that age (the so called "local life expectancy"), and then summing over all deaths. Years lost due to morbidity can be estimated by multiplying the years lived with disease by the value between 0 and 1, summing the thus-weighted years lived, and subtracting this number from the total unweighted number of years lived. The sum of the years lost due to mortality and morbidity then gives the total burden of this particular disease.

The DALY methodology follows this basic scheme, while adding the following features of its own.

- The objective of measuring the total burden of disease from all the important diseases combined. This requires making consistent estimates of the incidence, prevalence and mortality of a great number of diseases, a number large enough to represent the major part of the population's health. Using an incidence, prevalence and mortality model, the researchers forced their estimates to be internally consistent, and while undoubtedly some estimates may be inaccurate (*13*), this is a major achievement.

- The use of one standard life-table worldwide, and not different regional life-tables. Murray argues convincingly that this is necessary to compare "like with like", and not to value a death at a given age more in a high life-expectancy country than in a low one (*1*).

- The use of disability weights. Six classes of disability severity were distinguished; using expert panels it was determined how many people with a certain disease would as a consequence be disabled, and how these were distributed over the six classes. Needless to say, this procedure has some weaknesses, but in that respect the DALY is no exception among procedures to obtain disability weights, or equivalents such as QALYs (quality-adjusted life years) and utilities (*14*, *15*).

- The use of age-weights. Murray cites both economic and social role arguments to justify valuing lost years of life due to mortality and morbidity differently by age. Intuitively most people will agree that the death of a newborn or a 90-year-old, although tragic, is less so than that of a 15-year-old. The quantitative implementation of this notion is, on the other hand, a matter of much controversy.

Murray proposes the following general formula to weight life years by age:

$$Cxe^{-\beta x}$$

where C and β are constants, x is age, and e is the exponential. For $C = 0.16243$ and $\beta = 0.04$ (the values used in the study) the age-weight curve is as depicted in Fig. 1.

- The discounting of future years. Although in economics it goes without saying that future costs and benefits should be discounted, it is not a generally accepted concept in the health sector that future years of life should be treated similarly.

In the end, Murray presents a rather daunting general formula that calculates the DALYs lost, combining the years lost due to mortality and morbidity, the age weights, and the discounting (*1*). Because the lost DALYs are calculated using this general formula, the effects of each step made to get the end result remain obscure. This is illustrated below by taking a closer look at age-weighting and its effects.

Which ages count for more?

The age-weight function, with the parameters as mentioned above, specifies that the years lived between the ages of 9 and 54 have a weight greater than unity, and the years outside this range will have a

Fig. 1. **The age-weight function, $Cxe^{-\beta x}$, where x is the age, e the exponential, $C = 0.16243$ and $\beta = 0.04$.**

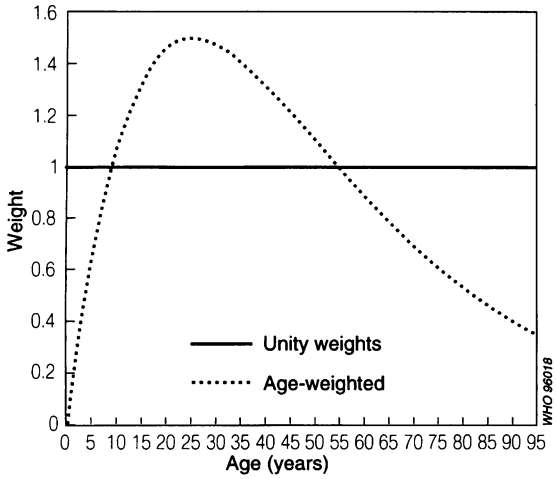
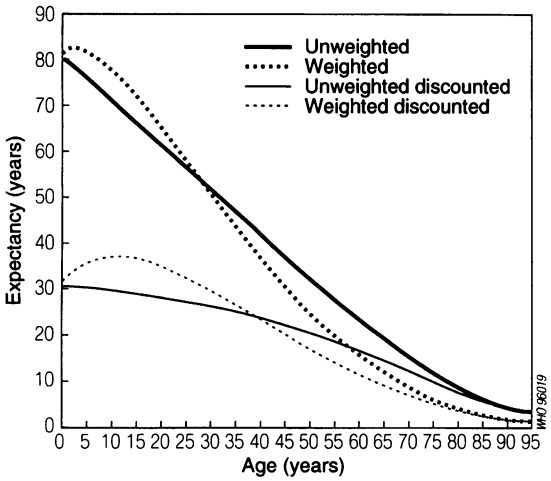


Fig. 2. **Age-specific life expectancies for Dutch women, 1986–90.** *Unweighted* values the years lived by 1 for all ages, *weighting* is done using the curve of Fig. 1, *unweighted discounted* and *weighted discounted* use a discount rate of 3%.



weight less than unity, with a weight of 0 at exact age 0 (newborns). If, for simplicity's sake, we ignore the DALYs lost due to morbidity (i.e., the disability weights) and consider only mortality, the next step is to use the age-weighted life years to calculate the age-specific life expectancies that are needed to determine the EYLL. We carried this out using the 1986–90 life-table for Dutch women (*16*), and Fig. 2 shows the resulting age-weighted and unweighted age-specific life expectancies.

The first thing to note is that the impact of age-weighting is much less than Fig. 1 would suggest: the weighted and unweighted curves are fairly close. In particular, the rather dramatic zero weight for newborns translates into an only minor downturn of the weighted curve. This is because the EYLL of a newborn reflects all the future life years the baby could expect to live, all of which are weighted more than zero.

Secondly, and importantly, the age range which becomes accentuated due to weighting (the range where the weighted curve is above the unweighted one) has shifted from between 9 and 54 years to between 0 and 27 years. This shift towards younger age becomes intuitive when one considers, for example, a woman of 40 years, with a life expectancy of 41 years. According to Fig. 1, 14 of those expected years will receive a weight greater than unity, and the remaining 27 years a weight less than unity, yielding an average weight of less than unity. Only when, going towards younger ages, the number of expected life years with a weight greater than 1 becomes large enough to counterbalance the number with a weight of less than 1 (for this life-table, at age 27, when life expectancy is about 54 years), the weighted curve will get above the unweighted one. While the calculation is correct, this result may come as something of a surprise.

Fig. 2 also shows the age-specific life expectancies with future years discounted, both with and without age-weighting. It is apparent that the impact of discounting, even at such a slight rate as 3%, is much larger than the age-weighting. The curve labelled "weighted discounted" is the familiar, "DALYs lost due to death" curve (*1*). The discounting of future years partly redresses the shift towards younger ages: the discounted age-weighted curve is above the discounted unweighted curve in the range 0–38 years. This is because the discounting mostly affects the life years lived at a higher age, years which are now more easily counterbalanced by the more-than-unity weighted years of middle age.

Discussion

We have shown that the age-weight function emphasizes deaths in the age range 0–27 years, instead of the range 9–54 years as suggested by Murray. The same will happen for disability when the disability weights are applied to the years lived: disability between 0 and 27 years will be emphasized, and outside that range played down. Adding discounting displaces the emphasized age range to 0–38 years, but, strictly speaking, this is of no consequence because discounting is concerned with time preference, and not with age. Since Murray's arguments for age-weighting are, on the one hand, economic (productive years count more), and on the other social (with middle-aged years more important than the extremes), we presume that the shift towards childhood and early adult years is unintended.

It has apparently been overlooked that expressing a death (or disability) as "expected years of life lost" implies age-weighting as well: younger deaths are emphasized. Thus, in the calculation of the DALY, one age-weighting system emphasizing the young is piled on top of another, which emphasizes the middle-aged. The result is an even stronger emphasis on the young, and de-emphasis on the old, than the EYLL generates itself. Whether this is advantageous or not is debatable (we think not), but it is certainly different from what we were led to expect.

Will our finding upset the results of the Global Burden of Disease study? That is very unlikely, given the rather small impact of the age-weight

function on the age-specific life expectancies (see Fig. 2). It might even be sensible to abandon the age-weighting function altogether, because of the disproportionally large attention it has received, relative to its impact. If it is retained, on the other hand, some rethinking seems appropriate. With the age-weight function as it is now, Alice's reaction to the Jabberwocky poem comes to mind: "Somehow it seems to fill my head with ideas — only I don't exactly know what they are!" (*17*).

Résumé

Les DALY et la pondération par l'âge

Dan les études réalisées pour le *Rapport sur le développement dans le monde 1993, Investir dans la Santé*, Murray et ses collaborateurs ont mis au point et appliqué plusieurs concepts nouveaux, dont l'un les DALY (*disability adjusted life years* ou années de vie corrigées de l'incapacité) a suscité attention et controverse, situation inévitable dans la mesure ou les comparaisons d'une pathologie à l'autre tiennent compte non seulement de la mortalité prématurée imputable à ces affections, mais aussi de la morbidité et de ses séquelles. Le présent article envisage un aspect particulier de la méthode des DALY à savoir la pondération des années de vie par l'âge.

Murray cite les arguments tant économiques que sociaux pour justifier l'évaluation différentielle en fonction de l'âge des années de vie perdues du fait de la mortalité et de la morbidité. Presque tout le monde s'accorde intuitivement sur le fait que la mort d'un nourrisson et celle d'une personne de 90 ans, aussi tragiques soient-elles, sont moindres que celle d'un jeune de 15 ans. Pour mettre en œuvre quantitativement ce concept, Murray propose une formule générale pour pondérer les années de vie en fonction de l'âge. D'après cette fonction poids de l'âge les années vécues entre 9 et 54 ans ont un poids supérieur à l'unité, les années se situant à l'extérieur de l'intervalle ayant un poids inférieur à l'unité et le poids étant de 0 à l'âge 0 (nouveau — né). Si l'on ne considère que les DALY perdues en raison de la mortalité, l'étape suivante consiste à utiliser les années de vie pondérées sur l'âge pour calculer l'espérance de vie par âge, nécessaire pour déterminer les années de vie attendues perdues (*expected years of life lost* ou EYLL). C'est ce que nous avons fait avec les courbes de survie des femmes néerlandaises pour 1986–1990, d'où nous avons tiré l'espérance de vie par âge, pondérée et non pondérée. On notera tout d'abord, que l'impact de la pondération sur l'âge est bien inférieur à ce que l'on pouvait penser: les courbes avec pondération et sans pondération sont très proches. On remarque ensuite que la tranche d'âge qui devient la plus importante en raison de la pondération (la tranche où la courbe avec pondération se situe au dessus de la courbe sans pondération) et passée de 9 et 54 ans à 0 et 27 ans. En ne tenant pas compte des années futures, la tranche d'âge devient alors 0 à 38 ans.

L'orsqu'on calcule les DALY, un système de pondération (EYLL) qui met en valeur la jeunesse s'ajoute à l'autre, ce qui donne de l'importance à l'âge moyen, et a pour résultat d'accentuer davantage l'importance de la jeunesse — et de faire perdre de l'importance aux personnes âgées — que les EYLL ne le font par elles-même. La question de savoir si c'est ou non une bonne chose (nous estimons qu'elle est mauvaise) est controversée, mais ce qui est certain c'est que le résultat obtenu est différent du résultat attendu. Il n'est guère probable que nos observations perturbent les résultats de l'étude sur le poids de la morbidité dans le monde, vu l'influence asssez faible qu'exerce la fonction poids de l'âge sur l'espérance de vie par âge. Toutefois, il serait peut-être justifié d'abandonner complètement la fonction poids de l'âge ou de repenser ses propriétés.

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