A NEW VALUE SYSTEM FOR GRADUATING POTENTIAL LIFE LOST

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The 'years of potential life lost' (YPLL) is a health status indicator in widespread use. Although it appears to quantify elegantly the impact of death from socioeconomic perspective, difficulties may arrive in determining suitable age limits for its calculation. In this paper, the author proposes an internally standardized value system for graduating potential life lost. The resulting years-lost index is termed 'years of regrettable life lost' (YRLL). The YRLL is based on a life table, which also takes into account the effect of competing death. The author uses vital statistics in Taiwan for demonstration.

Key words: competing risk, epidemiologic methods, life table, vital statistics, years of potential life lost

INTRODUCTION

The "years of potential life lost"(YPLL) is a public health measure in widespread use[1]. It has an intuitive appeal---the statistic measures the total number of life years lost due to premature death in a population. Although it appears to quantify elegantly the impact of death from socioeconomic perspective, there is actually no consensus as to what age of death may be deemed as "premature". The age limits have been set at 65, 70, 75 years of age, or at the average life expectancy[1]. Ideally, the proper limits should vary according to the age segments of the population which engage in investing, producing, and consuming[1]. Of course, these may differ from population to population. Moreover, such information can prove difficult or even impossible to obtain.

The concept of "years lost" has been extended to "income sacrificed" (see reference 1), which is the number of years lost times the average income for each year. By this way, each year lost, depending on what age, is valued differently. The use of age-specific income data seems to eliminate the need to choose the proper age limits. However, this is based on the premise that a nationwide survey of personal income has been carried out. Thus, it seems worthwhile to look for alternative ways of representing years of life lost, which are internally standardized and do not depend on external information, such as productivity, working ages, and income, etc.

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In this paper, the author proposes a new value system for graduating potential life lost. The system values each year lost not by its "productivity" but by its "regrettability". Accordingly, the resulting years-lost index is termed "years of regrettable life lost" (YRLL). Vital statistics in Taiwan was used for demonstration.

THE YEARS OF REGRETTABLE LIFE LOST (YRLL)

The use of the life table

To calculate the new index of YRLL, we need first a life table[2]. For example, table 1 presents an abridged life table for the total Taiwanese population in 1991. This table has a total of 18 age groups which are indexed by i. Note that we assume the deaths, on average, occur at the "mid-years" for the first 17 age intervals. And for the last interval (age ≥ 85), we assume an exponential decay such that the life expectancy at the beginning of that age group is calculated

Table 1. Abridged life table for the total Taiwanese population, 1991.

Age interval	Probability of dying in the interval	Number living at the beginning of the interval	Number dying in the interval	Number of years lived in the interval	Total number of years lived beyond the beginning of the interval	Life expectancy at the beginning of the interval
0- 4	0.00796	100000.0	795.7	498010.9	7473901.5	74.74
5- 9	0.00161	99204.3	159.6	495622.7	6975890.6	70.32
10-14	0.00165	99044.7	163.4	494815.3	6480267.9	65.43
15-19	0.00440	98881.4	434.8	493319.9	5985452.6	60.53
20-24	0.00524	98446.6	515.4	490944.2	5492132.7	55.79
25-29	0.00601	97931.1	588.7	488183.9	5001188.5	51.07
30-34	0.00717	97342.5	697.6	484968.3	4513004.6	46.36
35-39	0.00958	96644.9	925.6	480910.3	4028036.3	41.68
40-44	0.01304	95719.2	1248.0	475476.3	3547126.0	37.06
45-49	0.01992	94471.3	1881.9	467651.7	3071649.6	32.51
50-54	0.03003	92589.4	2780.1	455996.8	2603997.9	28.12
55-59	0.04390	89809.3	3943.0	439188.9	2148001.1	23.92
60-64	0.06956	85866.3	5972.7	414399.7	1708812.2	19.90
65-69	0.10673	79893.6	8526.7	378151.1	1294412.6	16.20
70-74	0.17503	71366.9	12491.4	325605.8	916261.4	12.84
75-79	0.27775	58875.5	16352.9	253495.0	590655.7	10.03
80-84	0.38546	42522.5	16390.5	171636.3	337160.7	7.93
85+	1.00000	26132.0	26132.0	165524.4	165524.4	6.33

as the inverse of the mean mortality rate of this open-ended interval (the mid-year of this last interval = 85 + 6.33 = 91.33). This is of course a very rough approximation, especially in the younger and the older age groups. For a refinement, one should turn to a complete (age-grouping by one year) life table. We stop short of doing so in this paper, since the principle remains the same. The mid-year for age interval i (denoted as y_i) for the Taiwanese population in 1991 are presented in table 2.

The definition of the regrettability

As previously mentioned, the YRLL index values each year lost not by its productivity but by its regrettability. For example, if a person dies in the age interval of "35--39", he/she loses the chances of being 40 year old as well as of being 80 year old. But the losses from the two ages (40 v.s. 80) are now valued differently. For the loss of age 40, he/she would feel much regret since, on average, 95.7% (95719.2/100000, see table 1) of the subjects in the population could live to that age but he/she died before that. While the loss of age 80 arouses less regret comparatively, as only 42.5% (42522.5/100000, see table 1) of the population survives to that age. This reasoning leads naturally to our definition of "regrettability"---the regrettability at a particular age is defined as the "survival probability" to that age. However, since we rely on an abridged life table, some approximation is necessary. We treat the regrettability of each year between the mid-year of an age interval i and the mid-year of the next interval i+1 (e.g., between y_i and y_{i+1}) as a constant and denote it as R_i. And the R_i is approximated as $R_i = \frac{\Sigma_{k>i} D_k}{100000}$ for $i \leq 17$, where the D_k is the death count in the age interval k of the life table. For i=18, the

Table 2. The mid-year* and the regrettability #

Age interval	y_i	R_i
0- 4	2.50	0.9920
5- 9	7.50	0.9904
10-14	12.50	0.9888
15-19	17.50	0.9845
20-24	22.50	0.9793
25-29	27.50	0.9734
30-34	32.50	0.9664
35-39	37.50	0.9572
40-44	42.50	0.9447
45-49	47.50	0.9259
50-54	52.50	0.8981
55-59	57.50	0.8587
60-64	62.50	0.7989
65-69	67.50	0.7137
70-74	72.50	0.5888
75-79	77.50	0.4252
80-84	82.50	0.2613
85+	91.33	0.0000

* y_i: the mid-year for those died in the age interval i
# R_i: regrettability of each year between the mid-years of the present (i) and the next (i+1) age intervals

regrettability is defined as zero. The R_i for the Taiwanese population in 1991 are presented in table 2. Now we can calculate the regrettable life lost for the aforementioned subject dying in the interval "35--39". It is a weighted sum of the years he/she failed to enjoy, with the weight taken as the regrettability of each year. Numerically, the figure is $0.9572 \times 5 + 0.9447 \times 5 + 0.9259 \times 5 + 0.8901 \times 5 + 0.8587 \times 5 + 0.7989 \times 5 + 0.7137 \times 5 + 0.5888 \times 5 + 0.4252 \times 5 + 0.2613 \times (91.33 - 82.50) + 0 = 37.86$ (years).

The calculation of the YRLL

Next, we calculate the YRLL due to a particular cause of death. This is the sum of the regrettable life lost of each subject due to the particular cause. Mathematically, it can be expressed as

$$\mathrm{YRLL} = \sum_i \left\{ d_i \cdot \sum_{j \ge i} R_j \cdot \left(y_{j+1} - y_j \right) \right\},$$

where d_i is the death number in age group i due to the particular cause. The "d_i" here should not be confused with the "D_i". It is the "cause-specific" deaths tallied in a particular year and is not derived from a life table.

An example

For example we have calculated, using the formula presented above, the YRLL due to hypertension (HT) as well as bronchitis, emphysema, and asthma (BEA) in Taiwan, 1991. And the results are 20675.4 and 19469.5, respectively. Thus we see that HT has greater impact on the Taiwanese population than BEA has. For comparison, we also calculated the traditional YPLL indices due to these two causes of death, assuming different upper age limits. The results are presented in table 3. We see that when using 80 as the upper age limit, HT has a greater impact than BEA. When 75 year old was used, the two causes of death have an equal impact, whereas BEA shows a greater impact when using 70 or 65 years old as the limits. This example indicates that it is difficult to judge which cause of death is a greater "burden" to the society using the traditional YPLL, since we do not know for sure the very age beyond which the productivity declines in the Taiwanese population. By contrast, the YRLL index does not suffer from this kind of problem.

Table 3. Years of potential life lost (YPLL) assuming different upper age limits--- comparison between hypertension (HT) and bronchitis, emphysema and asthma (BEA).

Upper age limits	YPLL#	
	HT*	BEA*
65	4230.0	5882.5
70	7695.0	8677.5
75	13157.5	13157.5
80	20965.0	19757.5

YPLL: years of potential life lost
* HT: hypertension; BEA: bronchitis, emphysema and asthma

DISCUSSION

In this paper, we proposed a new years-lost index of YRLL which is based on an internally standardized value system. Also, since it values each year lost by the chance of attaining that age for the average subject in the population, it also takes into account the effect of "competing death"[3] in a proper way. For example, a particular disease may claim the same number of deaths in two different populations. Such losses will be rated the same by the traditional YPLL index. It is true that in terms of "absolute" productivity or economic loss, the two populations suffer the same. However, when we wish to compare the "relative" impacts the particular cause exerts on these two populations, we need to take a different look. We see that for the population with lower competing deaths (deaths other than the cause under concern), the subjects in it stand a good chance for a long life if he/she did not succumb to the particular cause under concern. On the other hand, in the higher-competing population, the subjects tend to die early anyway. Therefore, the relative impacts of the particular cause should be different---higher in the former population and lower in the latter. Now consider what the newly proposed YRLL index can do. In the low-competing population, the regrettability (survival probability) is higher, which implies a higher YRLL, while in the high-competing population,the reverse is true. Therefore, we see that the YRLL index, with its value system properly reflecting the effects of competing deaths, is the right measure in this scenario.

In a previous paper, we have proposed several new years-lost indices which are also based on a life table[4]. However, the role of the life table in that paper is different from the present one---in this paper, we rely on a life table to develop a new value system for graduating potential life lost, whereas in the previous one, the aim is to construct new years-lost indices which can quantify future impacts to the society. It is interesting to note that a simple mathematical probing into the methodology of the life table could lead to such useful new concepts of potential life lost.

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潛在生命損失之新評價系統

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「潛在生命損失年數」是一個常用的健康狀態指標。雖然它似乎能夠以社會經濟的層面探討死亡的影響，但是在決定生命損失的年齡上限時常有困惑及爭議。本文提出一個計算生命損失的新方法，此方法乃依據生命表計算，同時考慮競爭死因的影響；它同時有「內部標準化」的性質，因而沒有選擇年齡上限的困擾。作者以台灣衛生統計資料爲例，進行示範。

關鍵詞：競爭死因，流行病學方法，生命表，衛生統計，潛在生命損失年數