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## *Chapter 1.3*

### THE INDIVIDUAL BASIS FOR SUMMARY MEASURES OF POPULATION HEALTH

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#### INTRODUCTION

In chapter 1.2, we reviewed some of the uses and conceptual debates relating to summary measures of population health (SMPH) and presented minimal criteria for evaluating SMPH. Much of the literature on SMPH has grown out of the demographic and epidemiological traditions, which take a population perspective as their starting point. For some uses such as measuring inequalities in health across individuals or measuring the health of individuals in clinical settings or intervention trials, it is important to formulate SMPH in terms of the health of some set of individuals. Many of the challenges identified in chapter 1.2 are intimately related to the linkage between population and individual health measures. Distinctions between incidence and prevalence perspectives, or period and cohort perspectives, for example, can be recast in terms of different choices as to the set of individuals (real or hypothetical) whose health is aggregated into a population measure. Recent efforts have been made to develop formal expressions of population health as aggregations of individual health measures (Cutler and Richardson 1997; 1998; Fleurbaey, forthcoming). In this paper, we attempt to set out a systematic framework for characterizing the individual basis for summary measures of population health.

To facilitate later debates in this volume, this paper addresses the question “When is one person healthier than another?” Five different answers to this question are formalized in terms of individual-level analogues to population-level health expectancies and health gaps. Precise formalization of these concepts often reveals important issues that will need to be addressed and reflected upon in future work. We end the chapter with some thoughts on the implications of this work for the development of alternative SMPH.

## IS PERSON A HEALTHIER THAN PERSON B?

Imagine a casual conversation in which one participant says that John is healthier than Jack. What is the common-sense meaning of this statement? How does the use of the phrase “is healthier than” correspond to various measures of individual health? We believe that there are at least three more precise formulations of the question: “Is person A healthier than person B?”

1. Taking into account only *current* levels in various domains of health, is person A in a better state of health than person B?
2. After both person A and person B have died, will person A have lived a healthier life overall than person B?
3. For the remainder of their lives, will person A have a healthier life than person B?

We believe that the last question may be closest in meaning to the common usage of the phrase “is healthier than”.

Let us illustrate the distinction between these three perspectives with a simple example. Carol and Patricia are both 35 years old, and in all domains of health (e.g., pain, mobility, cognition, affect, dexterity, vision, etc.), they have identical levels at present. Carol and Patricia have had different past health experiences: Carol was paralysed from the waist down between age 5 and age 34, at which time she underwent successful surgery that resolved her paralysis; Patricia has had full mobility all of her life. Carol and Patricia also differ in terms of current risk factors for health: Patricia has a strong family history of early onset ischaemic heart disease and smokes 2 packs of cigarettes per day, while Carol does not share either risk factor.

From the perspective of question 1, Carol and Patricia are in the same current state of health.

We do not have sufficient information to answer question 2, but Carol’s experience of paralysis from ages 5 to 34 might result in Carol having a less healthy life overall than Patricia, evaluated over their entire lifespans. This depends critically on whether a family history of ischemic heart disease and tobacco consumption will eventuate in a shorter life for Patricia than Carol, and how this shortened longevity would compare to the reduction in health attributable to paralysis.

In terms of question 3, we would conclude that Carol is healthier than Patricia because of the known risks to Patricia’s health that Carol does not have, all else being equal.

### *EX ANTE*, *EX INTERIM* AND *EX POST* PERSPECTIVES

It is easy to confound the three questions asked about person A and person B with the vantage point in time when the question is asked. In fact, however, the time perspective constitutes a separate dimension along

which different characterisations of individual health may be distinguished.

Question 1, which asks about individual health states, can only apply at a particular moment in time, since it refers only to the state of health of an individual at that moment in time.

Health over the entire lifespan (question 2) can be asked from three different vantage points in time:

- The *ex post* perspective reviews the lifespans of person A and person B after they have both died. The question of who had the healthier life is evaluated by adding up their experience of health at all different ages in some way.
- The *ex ante* perspective compares the expected lifespans of person A and person B at birth, before any of the health events have been realized. An *ex ante* evaluation is based on a comparison of the risks of being in different health states (including death) at different ages for person A and person B. Such an *ex ante* view of health over the lifespan is the basis of the framework for measuring health inequality presented by Gakidou et al. (2000)
- The *ex interim* perspective is located at an intermediate vantage point. For two people such as Carol and Patricia described above, the *ex interim* answer would take into account the actual health states they lived in from birth until now and their risks of being in different health states from now into the future. It is interesting to note that Williams (1997) has proposed an *ex interim* view of life expectancy as the basis for assessing inequality.

Question 3, which asks whether person A or person B will have a healthier life from now forward, is by its formulation an exclusively *ex ante* view. For two individuals evaluated at the (same) moment of birth, Question 3 is identical to the *ex ante* formulation of Question 2. At all other ages, this question differs from Question 2 by ignoring past differences in health and focusing only on the health of individuals from the present until death. This question is probably closest in spirit to the common usage of the phrase “is healthier than”.

The three questions and the three time perspectives lead to five different variants of the simple question: “Is person A healthier than person B?” (Table 1). In the next sections of this paper, we present formal specifications for each of these five variants.

## INDIVIDUAL HEALTH STATE

As considered in much more detail elsewhere in this volume (part 7), we assume that the health state of an individual at a particular moment in time can be characterized completely in  $J$  domains. Examples of domains include pain, affect, cognition, mobility, dexterity, vision, etc. The core set

**Table 1** Different questions and time perspectives for describing individual health

	<i>Ex post</i>	<i>Ex ante</i>	<i>Ex interim</i>
Current health		(no time dimension)	
Lifespan health	<i>Ex post</i> healthy lifespan and <i>ex post</i> health gap	<i>Ex ante</i> healthy lifespan and <i>ex ante</i> health gap	<i>Ex interim</i> healthy lifespan and <i>ex interim</i> health gap
Future health		Health expectancy and health gap	

of domains that should be used to describe a health state are discussed in part 7. For each domain, we assume further that the level for an individual may be characterized on a cardinal scale. We postulate that there is some valuation function such that any combination of levels on the  $J$  domains can be translated to a single cardinal value on a scale anchored by 1 (complete health) and 0 (a state comparable to death). The form and nature of this function is a major subject in this volume (part 10) and in the literature (Brazier et al. 1998; Dolan 1997; Torrance et al. 1995). In this paper, our objective is to formalize comparisons of individual health assuming that such a function is given.

More formally, we represent the valuation of a health state as follows:

$$h_i(t) = f(y_{1i}(t), y_{2i}(t), \dots, y_{ji}(t))$$

where  $h_i(t)$  is the valuation of an individual  $i$ 's health state at time  $t$  and  $y_{ji}(t)$  is the level for individual  $i$  on domain  $j$  at time  $t$ . This formulation assumes for simplicity that the valuation function  $f(\cdot)$  mapping between levels on the  $J$  domains is the same for all individuals.

Person A is in a better state of health than person B at time  $t$  if and only if:

$$h_A(t) > h_B(t)$$

Thus, to answer the question "Is person A in a better state of health than person B?", we need only know their levels in the  $J$  domains of health and the form of the valuation function. It is possible to imagine that a valid, reliable and cross-population-comparable survey instrument could provide sufficient information to answer this type of question for the set of survey respondents.

### EX POST LIFESPAN HEALTH

Imagine that two individuals have been observed from birth to death so that at every age their state of health is known. To summarize their life-

time experiences of health, we need to aggregate the time spent in health states at different ages in some way. Aggregation over age presents many challenges, and many different solutions may be possible. We present four different alternatives for aggregation over the lifespan of an individual that all have SMPH analogues. Perhaps the simplest is to sum the experience of health over all ages, giving equal weight to the level of health at every age. In this formulation, we can define healthy lifespan as:

$$EPHL_i = \int_0^{\infty} h_i(a) da$$

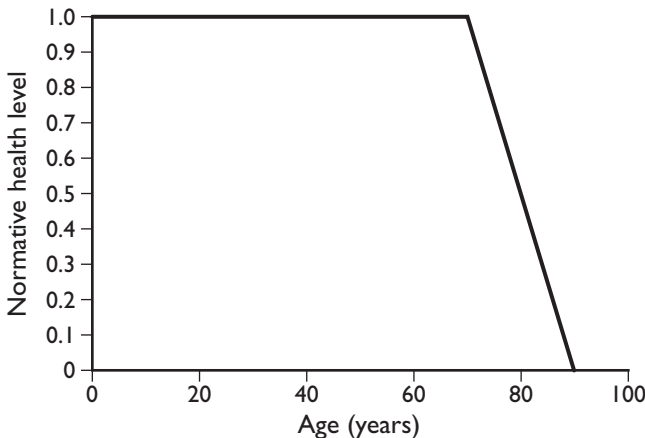
where  $EPHL_i$  is the *ex post* healthy lifespan for individual  $i$ , and  $h_i(a)$  is the health state valuation for individual  $i$  at age  $a$ . Using this metric, person A lived a healthier life than person B if and only if:

$$EPHL_A > EPHL_B$$

The *ex post* healthy lifespan of an individual is naturally related to the health expectancy family of SMPH. In some sense, it is the realization for an individual of a health expectancy.

We can also formalize an individual health gap, which requires specification of a norm for health against which a person’s experience is compared. In principle, the norm could be defined either in aggregate or age-specific terms. We define  $\rho(a)$  as the normative health function that specifies a target level of health at each age for the construction of a health gap. Figure 1 illustrates a norm where individuals live in full health until age 70 years and then in somewhat less than full health until age 90.

**Figure 1** Example of a norm for individual health



The norm illustrated in Figure 1 represents a combined norm for survivorship and health level; in this example, the implied survivorship goal is age 90, above which the normative health level is 0. A more complicated formulation of the normative health function would allow for separate specifications of a survivorship norm and a norm for health conditional on being alive at a particular age. This more flexible, two-dimensional specification may be particularly useful in accommodating complex norms that shift depending on the age that has been attained, but we use the simpler one-dimensional formulation in this paper for purposes of explication.

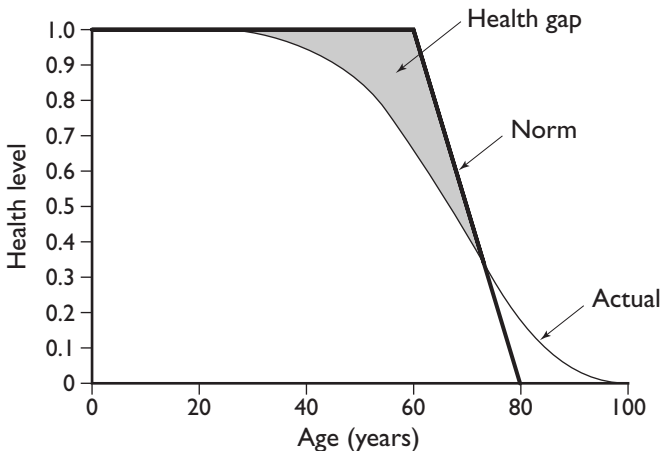
The healthy lifespan of an individual whose health followed the normative health curve at each age would be:

$$NHL = \int_0^{\infty} \rho(a) da$$

A basic health gap could be formulated simply by subtracting the *EPHL* for an individual from the total *NHL*. In this formulation, the health gap depends only on the difference between the total healthy life span in the norm and the realized lifespan, irrespective of when person *i* lived in different states of health. For all values of *EPHL* that fall below the *NHL*, this health gap formulation would produce the same ordering as *EPHL*, since each different *EPHL* is simply subtracted from a constant.

On the other hand, in defining an individual health gap, we may be concerned with the age pattern of the norm and not only with the total normative healthy lifespan. A more exacting formulation would therefore compare an individual's health to the health norm at each age, rather than simply in the aggregate. The key difference in this formulation is that any

**Figure 2** Example of an individual health gap



value of  $h(a)$  that exceeds  $\rho(a)$  counts the same as if  $h(a) = \rho(a)$ ; in other words, when  $\rho(a)$  is less than  $h(a)$ , the negative value is not added to the health gap. This is tantamount to saying that exceeding the norm at some ages does not make up for those other ages at which an individual falls short of the norm. Figure 2 illustrates such a case to make this distinction clearer.

Using the age-specific approach, we can formalize this type of health gap as:

$$EPHG_i = \int_0^{\infty} (\rho(a) - h_i(a)) \delta_i(a) da$$

where  $\delta_i(a)$  is an indicator variable that equals 1 if  $\rho(a) \geq h_i(a)$  and 0 otherwise. Based on this measure, we would say that person A lived a healthier life than person B if and only if

$$EPHG_A < EPHG_B$$

It is important to note that if an individual exceeds  $\rho(a)$  at any age, the comparison based on *EPHG* may produce a different ordering than the comparison based on *EPHL*.

Both the *EPHL* and the *EPHG* measures presented above are based on simple aggregation functions whereby any time spent in the same health state receives equal weight, irrespective of the age at which the state of health is experienced (with the exception of cases where health exceeds the normative level for a health gap). Other aggregations over different ages of an individual's lifespan are possible. A general form of aggregation incorporates a function  $k(a)$  which assigns weights to time lived at different ages. A non-uniform aggregation function can be thought of as the individual analogue to age weights in SMPH. The *ex post* healthy lifespan with age-weights would be:

$$EPHL_i = \int_0^{\infty} h_i(a) k(a) da$$

and the *ex post* health gap with age weights would be:

$$EPHG_i = \int_0^{\infty} (\rho(a) - h_i(a)) \delta_i(a) k(a) da$$

In equations that follow, we include the  $k(a)$  term in all formulations, as aggregation functions without age weights may be considered a special case of the general formulation, with  $k(a) = 1$  for all  $a$ .

This section has presented four different types of *ex post* lifespan measures, and conclusions as to whether person A lived a healthier life than person B may be different depending on whether the metric used is *ex post* healthy lifespan, *ex post* healthy lifespan with age-weights, *ex post* health gap or *ex post* health gap with age-weights. Whether one should use the healthy lifespan or the health gap approach, and whether with or with-

out age-weights, are themselves normative choices. These choices depend critically on whether we believe that lifespan health depends only on the total health experience over the lifetime or on the shape of the health experience. Should the loss of one year in full health from age 90 to 91 count the same in the calculus of lifespan health as two years lived in 50% health at ages 20 and 21? Many people would probably believe that living to age 90 in perfect health represents a more healthy life than living to age 91 but experiencing a 50% reduction in health during early adulthood. The construction of health gaps and/or the addition of age-weights allow some limits on the equivalence of health decrements at different ages. A health gap measure, in contrast to a healthy lifespan measure, allows for the inclusion of normative health goals that may vary by age; it may be that this notion is more consistent with the vernacular meaning of “a healthier life” than the healthy lifespan measure, which improves with increasing health levels at any age, without reference to changing normative goals.

### EX ANTE LIFESPAN HEALTH

Rather than asking “*Did* person A live a healthier life than person B?” we can ask the question from birth, “*Will* person A live a healthier life than person B?” The answer to this question, *ex ante*, is a probabilistic statement, as both persons face some uncertain distribution of different lifespan paths of health. To formalize the *ex ante* view, we need to capture the probability distribution of individuals being in different health states at different ages. Because states of health at one age cannot be completely independent of states of health at other ages, we can formulate the *ex ante* view as a distribution of probabilities of different healthy lifespans under different possible states of the world:

$$EAHL_i = \sum_{s \in \Omega} r(s) \int_0^{\infty} h_i(s, a) k(a) da$$

where  $\Omega$  is the universe of all possible states of the world and  $r(s)$  is the probability of a particular state  $s$ . Gakidou et al. (2000) have used this type of formulation as the conceptual basis for the measurement of population health inequality.

It is also possible to construct an *ex ante* lifespan health gap using the same logic:

$$EAHG_i = \sum_{s \in \Omega} r(s) \int_0^{\infty} (\rho(a) - h_i(s, a)) \delta_i(s, a) k(a) da$$

The formalization of the *ex ante* forms of the healthy lifespan and the health gap have similarities to formulations of expected utility. Given this formal similarity, it might be natural for economists to suggest that the *ex ante* forms of these measures should be modified to include time preference and risk aversion. Time preference is defined as a pure preference

for utility in the near future as opposed to the distant future. Risk aversion is defined as a preference for a particular payoff that is certain rather than the same *expected* payoff that is uncertain. In this case, however, the analogy may be inappropriate. Expected utility formulations are meant to represent how individuals choose between two uncertain options. *Ex ante* healthy lifespans and health gaps, on the other hand, are not intended to be measures of individual preferences over distributions of health pathways, but rather assessments about which distribution represents the healthier lifespan. It might be reasonable to recognize that two distributions represent the same *ex ante* levels of health over the lifespan but still to *prefer* one or the other in terms of expected utility because of discounting or risk aversion.

Since the *ex ante* question asks which person will have enjoyed the healthier lifespan once both lifespans are completed, this simply implies a prospective view of the completed life. In this case, we do not see compelling arguments in favour of time preference. Since the evaluation depends on the entire course of life over time, regardless of the point at which it is evaluated, discounting of the future does not seem relevant. Risk aversion, however, deserves more careful consideration. Imagine two individuals whose anticipated healthy lifespans are distributed with the same expected value, but different ranges of uncertainty. The question of which person will have the healthier completed lifespan is different than the question of which *ex ante* distribution may be preferred. Risk averse individuals may choose for themselves the distribution with narrower uncertainty, but the expectation of the completed healthy lifespan nevertheless is the same in both distributions. We conclude that *ex ante* healthy lifespans and *ex ante* health gaps—as characterizations of expectations of healthy life rather than of individual preferences over distributions of health prospects—should not include time preference or risk aversion.

### EX INTERIM LIFESPAN HEALTH

There is a third perspective: given the past experience of health from birth until the present for person A and person B, combined with their prospects for health in the future, which person will have the healthier lifespan overall. This *ex interim* perspective combines the realization of health risks from birth to the present with an *ex ante* view of health risks from now until death. The *ex interim* healthy lifespan for an individual at age  $x$  is:

$$EIHL_i(x) = \int_0^x h_i(a)k(a)da + \sum_{s=x}^{\infty} r(s) \int_x^{\infty} h_i(s,a)k(a)da$$

The *ex interim* lifespan health gap is:

$$EIHG_i(x) = \int_0^x (\rho(a) - h_i(a))\delta_i(a)k(a)da + \sum_{s=x}^{\infty} r(s) \int_x^{\infty} (\rho(a) - h_i(s,a))\delta_i(s,a)k(a)da$$

## FUTURE HEALTH

The fifth and final option, which asks whether person A or person B will live a healthier life from now forward, is the one that is perhaps closest to the common usage of the phrase “is healthier than”. In fact, there are a number of web sites (for example, “LongToLive.com” or various “life expectancy calculators”) that will provide a computation of future health prospects based on a particular risk factor profile input by an individual. Parallels to the two families of SMPH can also be formulated to answer this question for an individual. Health expectancy for an individual can be defined as:

$$HE_i(x) = \sum_{s=x}^{\infty} r(s) \int_0^{\infty} h_i(s,a) k(a) da$$

This differs from the *ex interim* healthy lifespan because it ignores previous health experience from birth until the present. The equivalent future health gap can be formalized as:

$$HG_i(x) = \sum_{s=x}^{\infty} r(s) \int_0^{\infty} (\rho_x(a) - h_i(s,a)) \delta_i(s,a) k(a) da$$

It is worth revisiting the question of risk aversion and time preference in the context of this final perspective. While we concluded that neither risk aversion nor time preference were relevant for comparisons using lifespan health measures since these measures refer to completed lifespans viewed from various time perspectives, when we are comparing current health and future prospects across individuals, particularly in thinking about the vernacular meaning of these comparisons, it may be the case that individuals exhibit risk aversion and/or time preference in making these judgments.

## DISCUSSION

This chapter has presented a formal framework for constructing measures of individual health based on three different types of questions and three different time perspectives. A systematic examination of the different ways to characterize individual health will be essential in bolstering the conceptual foundation for evolving summary measures of population health. Logically, there must be some formal relationship between measures of population health and the aggregation of some measure of health across a defined set of individuals. The set of individuals may include those living, those that have died or those yet to be born, but if population health is not a function of the health of some set of individuals, then in what other way may it be interpreted?

The different ways of formulating the question “Is person A healthier than person B?” may have different applications. It can be argued that for studying inequality in health across individuals some variant of the ques-

tion “Did (or will) person A have a healthier lifespan than person B?” may be the most appropriate. Gakidou et al. (2000) advocate using an *ex ante* view and Williams (1997) an *ex interim* view.

The future health formulation of the question is probably closest to the vernacular notion of individual health, which may have important implications for aggregate-level comparisons, where we ask whether population A is healthier than population B. Although some currently used population health measures account for at least part of the future stream of health consequences, none of the available measures incorporates the health prospects formulation of individual measures in a comprehensive way. Depending on the intended application, new summary measures of population health may be required in order to capture the same aspects of individual health reflected in this view.

This chapter on formalization identifies many questions that remain unanswered, such as the basis for choosing an individual normative health function, the basis for choosing age-weights and the complexity of different viewpoints. Key issues of aggregation also remain to be addressed. These aggregation issues are central to measuring average levels of population health and particularly to the problem of characterizing health inequalities. We hope that our attempts to clarify the formal basis for a range of different measures of individual health will serve as a useful starting point from which to explore different options for aggregation.

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