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CURRENT OPINION

Guiding Health Resource Allocation: Using Population Net Health Benefit to Align Disease Burden with Cost Effectiveness for Informed Decision Making

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Abstract

Limited healthcare resources necessitate a strategic approach to their allocation. This paper highlights the importance of population net health benefit (NHB) metric as a means of aligning two existing concepts used for resource prioritization in health: burden of disease and cost effectiveness. By explicitly incorporating health opportunity costs and eligible patient population size, NHB provides a clearer understanding of the likely scale of impact of interventions on population health. Moreover, when expressed in disability-adjusted life years (DALYs) averted, NHB enables policymakers to effectively communicate the population-level health gains from interventions relative to the existing disease burden. Using a stylized example, we demonstrate the estimation of population NHB for four alternative health interventions and its use in resource allocation decisions. The analysis reveals how variations in patient population size and health opportunity costs can significantly impact NHB estimates, ultimately influencing resource allocation decisions. The results further illustrate how NHB can be expressed as a proportion of the total disease burden, allowing for the consideration of the percentage of the overall burden addressed by each intervention. The paper demonstrates how population NHB combines cost effectiveness with components of disease burden, offering a more comprehensive approach to health intervention selection and implementation. As countries move towards universal health coverage, this metric can aid policymakers in making informed, evidence-based decisions.

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Key Points for Decision Makers

The population net health benefits (NHBs) metric offers a comprehensive view of an intervention’s value, considering both its cost effectiveness and potential impact on disease burden.

Population NHBs can inform strategic decision making at both national and international levels, ensuring that health resources are allocated effectively and contribute to achieving health system goals.

1 Introduction

National and international health policymakers frequently need to make decisions regarding the allocation of limited resources. This necessitates determining the most effective

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allocation of these funds by considering two separate but related concepts: disease burden and cost effectiveness.

The term burden of disease refers to the expected prospective health loss resulting from a given disease within a population. The Global Burden of Disease (GBD) studies [1] are widely recognized as a resource that quantifies the health burden resulting from various diseases, injuries, and risk factors. Using disability-adjusted life years (DALYs), a generic measure of burden, which incorporates both mortality and morbidity, these studies offer insights into global disease burden. However, while valuable for decision making, burden of disease cannot directly inform how health system resources should be allocated to improve population health, as it does not consider the effectiveness of interventions for alleviating burdens nor the resource requirements of doing so [2].

In contrast, cost-effectiveness analysis (CEA) has emerged as an effective prioritization tool for decision making, used by health systems worldwide to inform funding decisions. The CEA facilitates assessment of the expected health benefits and opportunity costs associated with delivering interventions to tackle a range of diseases, thereby supporting strategic allocation of healthcare resources to address the most pressing health challenges. In CEA, health outcomes are commonly measured using DALYs or a similar metric, quality-adjusted life years (QALYs). The results of CEA are then typically summarized using the incremental cost-effectiveness ratio (ICER), which indicates how much additional resource is required to achieve a unit improvement in health.

The decision rule to determine whether a new program is worth implementing is if its ICER is below a predefined cost-effectiveness 'threshold' (CET). In any collectively funded healthcare system with limits on increasing expenditure, healthcare costs can be considered in terms of the health that could be gained by the same resources if it was spent on other currently funded healthcare (i.e., the health opportunity cost). The CETs can be founded on evidence regarding a health system's health opportunity cost (i.e., the marginal cost per unit of health produced by the healthcare system). If the CET used reflects the rate at which the healthcare system produces health, ICERs enable a binary assessment of whether the intervention produces health at a better (or worse) rate than interventions already funded at the margin by the health system. However, since ICERs are expressed as a ratio and serve as a summary measure of relative value (cost per unit of health gain), they mask valuable information about the (absolute) magnitude of the health benefits (or losses) associated with providing an intervention at an individual or population level [3–5].

An alternative measure of cost effectiveness is 'net benefit' [3, 6, 7]. Calculating net benefit requires an explicit assessment of the health opportunity costs associated with allocating expenditure to a particular intervention. This makes it possible to estimate the scale of the potential impacts on overall health outcomes offered by an intervention net of the opportunity costs imposed on the health of others. Using a CET that reflects the likely health opportunity cost, additional costs can be put on the same scale as health gained by converting additional costs into their health equivalent. The incremental net health benefit (NHB) of an intervention can then be described as its incremental direct health benefit minus the forgone health benefit for other patients resulting from the incremental cost of the intervention. By quantifying the opportunity costs, NHB reveals that investing in a cost-ineffective program is not simply an unwise use of money in some vague sense – it is a forgone opportunity to achieve gains in other people's health [3].

The NHB can be represented in terms of both QALYs and DALYs. In low- and middle-income countries (LMICs), where DALYs are more widely used (see Box 1) [8, 9], NHB can be expressed using DALYs averted. Unlike disease burden, where DALYs capture the health lost from disease, DALYs averted represents a measure of health gained from interventions, aligning with CEA. Moreover, when combined with information about the size of potential beneficiary populations, NHB can convey the population-level magnitude of benefit from health interventions in terms of "net DALYs averted". This adaptation effectively aligns CEA results with disease burden metrics and allows the expression of population-level gain (or loss) from an intervention as a proportion of current disease burden (measured in DALYs).

It is important to recognize that while burden of disease provides valuable information, it should not be the sole basis for decision making. High burden alone does not reflect what health can be gained by interventions to address it, and an inappropriate focus on diseases with high burden can significantly impact available resources by potentially diverting funds from more productive activities. Therefore, the resource allocation process should be informed by the expected health benefits of the intervention relative to its opportunity costs. Ultimately, what matters most is understanding the impact of different interventions, rather than solely focusing on the burden of different diseases [2]. In the following sections, we will demonstrate, using a stylized example, the importance of population-based NHB metric in guiding the consideration of interventions for implementation.

2 Box 1: Disability-Adjusted Life Years (DALYs)

The DALY burden for a disease or health condition can be defined as a measure of years in perfect health lost. It can be calculated as

$$\text{DALY} = \text{YLL} + \text{YLD},$$

where YLL is years of life lost due to premature mortality and YLD is years of life lived with disability due to prevalent cases of the disease or health condition in a population. The YLD is calculated in the inverse of QALYs: dT, where d is a DALY weight for disability, 0 (perfect health) to 1 (death), and T is the time spent in that state of health [11]. Many DALY disability weights are found in the Global Burden of Disease study series. The DALYs are a measure of health loss compared to full and healthy life expectancy, instead of health gain, so most health interventions seek to avert DALYs, and in doing so, to increase the number of years that a person lives in good health. The CEAs (cost-effectiveness analyses) using DALY averted as the health effect measure have become standard for health programs in global health, especially in low- and middle-income countries (LMICs) [12–16]

3 Methods

3.1 Stylized Example

Table 1 presents four non-mutually exclusive alternative health interventions, with different eligible population sizes. For each intervention, we will assess the population NHB compared to a 'do-nothing' strategy to emphasize its implications for decision making. While a do-nothing strategy is not typically associated with zero costs and health benefits, we have assumed for simplicity that it is in our stylized example. It represents the option of offering no care or active treatment for the target population, ensuring that the analysis is not limited to any existing treatment or standard of care. Table 1 presents illustrative costs ($US) and health benefits (measured in DALYs averted), both per patient and in population terms.

3.2 Guiding Intervention Choice: Analysis of Net Health Benefits

To make informed choices about interventions that deliver the greatest value, considering both opportunity costs and reduction in disease burden, we utilize “net DALYs averted.” This represents the NHB and is defined as the difference between the DALYs averted by a given intervention and the DALYs that could have been averted if the resources required to deliver it had been spent on other interventions [10]. Where the intervention is cost saving, it is the sum of the DALYs averted by the intervention and the DALYs that can also be averted with the cost savings offered. Usually costs and health benefits are presented per-patient treated or receiving the intervention. However, to capture the scale of the potential net impact of an intervention on population health, the per-patient DALYs averted, and costs are multiplied by the size of the eligible patient population in need of the intervention (as shown in Table 1). The resulting NHB is known as the ‘population NHB’ and quantifies the magnitude of increase or decrease in the overall disease burden within the population.

$$\text{Population NHB(Net DALYs averted)} = \sum_{i=1}^{n}\left(\Delta \text{DALY}s_{ij} - \frac{\Delta C_{ij}}{k}\right). \tag{1}$$

Equation 1 can be used to calculate the population net DALYs averted, where $\Delta\text{DALY}s_{ij}$ is the change in DALYs averted per patient i treated with the new intervention j,

Table 1 Interventions targeting different patient populations and associated DALYs averted and costs (US$)

Interventions	Per patient costs ($)	Per patient DALYs averted (DALYs)	Eligible patient population	Population costs‡ ($)	Population DALYs averted † (DALYs)
Do nothing comparator	0	0			
Intervention 1	600	2	200,000	120,000,000	400,000
Intervention 2	400	0.4	140,000	56,000,000	56,000
Intervention 3	200	2.5	75,000	15,000,000	187,500
Intervention 4	150	1.5	25,000	3,750,000	37,500

DALYs disability-adjusted life years

*Eligible patient population

†Population DALYs averted = per patient DALYs averted

‡Population costs = per patient cost*eligible patient population

ΔC_{ij} is the change in cost per patient i imposed on the healthcare system by the new Intervention j, n is the number of patients eligible for intervention j, and k is the country-specific estimate of health opportunity cost to avert a single DALY (i.e., the CET).

4 Results

Table 2 estimates the population net DALYs averted for all the interventions in Table 1. All calculations assume a CET of $500 per DALY averted, which are assumed to represent opportunity cost (i.e., an additional $500 spent on the intervention will result in 1 additional DALY being imposed on other patients). Interventions that should be considered for implementation are those that generate a positive net DALYs averted (or NHBs), indicating an improvement in overall population health. According to our analysis in Table 2, this includes Interventions 1 (160,000), 3 (157,500), and 4 (30,000). Since Intervention 2 yields negative net DALYs averted (−56,000) because its additional benefits over the comparator are less than the opportunity costs it imposes, this indicates that its implementation would result in a decline in population health, therefore, it should be excluded from consideration for implementation. If an intervention resulted in zero net DALYs averted, then a decision maker would be indifferent towards it.

Different healthcare systems are likely to face different health opportunity costs, and therefore different CET estimates. Reasons for this include, among others, different levels of funding, choices of interventions to fund, and productivity. Given their central role in the estimation of NHB, the choice of CET can also impact the scale of net DALYs averted by each intervention. Table 3 displays population NHB considering an alternative CET of $200 per DALY averted. Per-patient costs and benefits associated with each intervention could also vary across healthcare systems, but for our analysis, we assume these to be consistent. Our analysis from Table 3 reveals that differences in scale of health opportunity costs affect the magnitude of NHB and the decision to implement an intervention. For instance, in Table 2, with a threshold of $500/DALY averted, Intervention 1 is deemed acceptable since it demonstrates positive net DALYs averted (160,000). However, at a lower threshold of $200/DALY averted, it is rejected since it shows negative net DALYs averted (−200,000) (see Table 3). A lower CET reflects the increased opportunity costs of the healthcare system when additional costs are imposed on it. Thus, while Intervention 1 may be considered for implementation in one healthcare system, it may not be in another. For other interventions, although the decision to implement or not remains consistent across both thresholds (Interventions 3 and 4 remain accepted; Intervention 2 remains rejected.), their net DALY averted impact is notably lower at the lower threshold. Specifically, Intervention 3 averts 45,000 fewer DALYs, Intervention 4

Table 2 Population NHB for interventions in Table 1 using a $500 per DALY averted CET based on opportunity cost (US$)

Interventions	Population costs ($)	Population health opportunity costs (DALYs averted)	Population DALYs averted	Population NHB (DALYs averted)	Decision
Do-nothing comparator					
Intervention [1]	120,000,000	240,000	400,000	160,000	Accept
Intervention [2]	56,000,000	112,000	56,000	−56,000	Reject
Intervention [3]	15,000,000	30,000	187,500	157,500	Accept
Intervention [4]	3,750,000	7500	37,500	30,000	Accept

CET cost-effectiveness ‘threshold’, *DALYs* disability-adjusted life years, *NHB* net health benefit

Table 3 Population NHB for the interventions in Table 1 using $200 per DALY averted CET based on opportunity cost (US$)

Interventions	Population costs ($)	Population health opportunity costs (DALYs averted)	Population DALYs averted	Population NHB (DALYs averted)	Decision
Do-nothing comparator					
Intervention [1]	120,000,000	600,000	400,000	−200,000	Reject
Intervention [2]	56,000,000	280,000	56,000	−224,000	Reject
Intervention [3]	15,000,000	75,000	187,500	112,500	Accept
Intervention [4]	3,750,000	18,750	37,500	18,750	Accept

CET cost-effectiveness ‘threshold’, *DALYs* disability-adjusted life years, *NHB* net health benefit

Table 4 Share of disease burden averted by each intervention using US$500 per DALY averted CET and US$200 per DALY averted CET

Interventions	k = $500 per DALY averted			k = $200 per DALY averted		
	Population NHB (DALYs averted)	% of overall Disease burden averted*	% range of disease-specific burden averted[¥]	Population NHB (DALYs averted)	% of overall disease burden averted*	% range of disease-specific burden averted[¥]
Do-nothing comparator						
Intervention [1]	160,000	1.52%	160,000 to 400,000 (4–10%)	− 200,000	− 1.90%	− 200,000 to 400,000 (− 5% to 10%)
Intervention [2]	− 56,000	− 0.53%	− 56,000 to 56,000 (− 2.8% to 2.8%)	− 224,000	− 2.13%	− 224,000 to 56,000 (− 11.2% to 2.8%)
Intervention [3]	157,500	1.5%	157,500 to 187,500 (10.5–12.5%)	112,500	1.07%	75,000 to 187,500 (7.5–12.5%)
Intervention [4]	30,000	0.29%	30,000 to 37,500 (1–1.25%)	18,750	0.18%	18,750 to 37,500 (0.63–1.25%)

In this case, we are assuming that the health opportunity costs (marginal productivity estimates) for disease-specific budgets are equivalent to those of the entire health system (i.e., we assume efficient budget setting)

DALYs disability-adjusted life years, *NHB* net health benefit

% disease burden = population NHB/total DALY burden

*a +ve change signifies decline in burden; a −ve change signifies an increase in burden

[¥]Disease-specific burden for Intervention 1: 4 million DALYs; Intervention 2: 2 million DALYs; Intervention 3: 1.5 million DALYs; Intervention 4: 3 million DALYs averts 11,250 fewer DALYs, and Intervention 2 results in additional 168,000 DALYs.

The use of population NHB in CEA can also effectively communicate the magnitude of the impact of an intervention on the burden of disease. Table 4 illustrates this using the example from Table 1. Suppose the overall disease burden from all causes is 10.5 million DALYs; the population net DALYs averted by the intervention can then be presented in terms of the proportion of the total DALY burden, indicating the percentage of the overall burden addressed by each intervention (columns 3 & 6, Table 4).

Additionally, columns 4 and 7 in Table 4 give the percent of disease-specific burden averted (as opposed to overall burden across all diseases). For example, at a \$500/DALY averted threshold, intervention 1 reduces the disease-specific burden by 4%–10% and at a \$200/DALY averted threshold, the impact ranges from −5% to 10%. This is expressed as a range to account for the uncertainty of not knowing which disease the health opportunity costs will fall upon (with the range reflecting all opportunity costs falling within the disease or entirely on other diseases). However, it is important to note that these percentage estimates should not influence the funding decision, with the choice of intervention solely based on population NHB.

As demonstrated, the health opportunity costs of a healthcare system influence the scale of net DALYs averted by an intervention, which in turn affects its impact on disease burden. Column 3 of Table 4 shows the percentage of overall disease burden averted under a healthcare system with a CET of \$500 per DALY averted. However, with a lower CET of \$200 per DALY averted (while assuming the same burden of disease), the implications change (see column 6, Table 4). For instance, with a CET of \$500 per DALY averted, Intervention 1 leads to a 1.52% reduction in disease burden. But with a lower CET (or higher health opportunity costs), Intervention 1 actually causes a 1.9% increase in disease burden. Similarly, Interventions 2, 3, and 4 show smaller reductions in DALY burden at a CET of \$200 per DALY averted compared to \$500 per DALY averted

Expressing the net population DALYs averted as a percentage of the overall DALY burden (from all causes) enables comparative assessment of interventions targeting different diseases. It also provides a way to circumvent the uncertainty about where the opportunity costs actually fall, which is whether or not the intervention that is displaced when a new one is funded is for the same disease area. However, the GBD estimates are widely reported by disease areas. If disease-specific burdens are used (see footnote in Table 4, which provides the disease-specific burden used for this example), the uncertainty of health opportunity costs can be addressed by calculating a range (see columns 4 & 7, Table 4). This helps decision makers grasp the potential impact depending on where the opportunity costs lie. If the opportunity costs (i.e., the displaced intervention) lie within the same disease category, then it would be more appropriate to express the net population DALYs averted as a percentage of the disease-specific burden (see lower bound value, column 4, Table 4). However, if the displaced interventions are in different disease areas, it would be more appropriate to use the population DALYs averted (i.e., estimates in column 4, Tables 2 and 3) to express the percentage of disease-specific burden averted by the new intervention (see upper bound value, column 4, Table 4). Regardless of whether the opportunity costs come from the same or a different disease category, we can expect that the disease burden averted will fall within the estimated range.

5 Discussion and Conclusion

Our example showcases the ability of population NHB to capture the population health impact of an intervention, reflecting the size of the patient population, the health benefits of the intervention and the health opportunity costs. This approach can provide policymakers with valuable information for health resource allocation decisions. Country-level opportunity cost-based CETs [17, 18] are available for a wide range of high-income and LMICs. Some CETs do not reflect health opportunity costs and may, instead, reflect an empirical estimate of a population's willingness to pay for health, some concept of social value (e.g., the disease severity 'modifiers' used by NICE in the UK) or be arbitrary [17]. Such CETs – which might more generally be described as 'approval norms' [19] – are not suitable for the calculation of NHB for cost-effectiveness analysis or as a measure of disease burden, and decisions based on them would not be expected to improve population health, thereby limiting their value in guiding decision making.

By estimating the net DALYs averted by interventions and potential combinations of interventions, decision makers can undertake an evidence-driven approach to health policy and planning. These estimates can be aggregated by individual countries, groups of countries (i.e., by income levels or another category) or globally [10]. More importantly, it can help with understanding the likely scale of the impact of interventions on the overall disease burden, enhancing the communication of its effects and serving as a valuable tool for advocacy and raising awareness.

This paper has used DALYs as they are more widely used in economic evaluations in LMICs, and more often used to estimate disease burden, which has historically guided resource allocation [20, 21]. However, our approach is not limited to LMIC contexts or the use of DALYs. The QALYs have been more widely used in economic evaluation in high-income contexts and in a similar way been used to estimate net health impacts and disease burden – the approaches advocated here are readily applicable. Furthermore, recent developments, such as the increasing efforts to elicit DALY weights directly from general populations (which have nearly doubled since 2010 [22]), support the alignment of our approach with methodological standards expected for CEAs in non-LMIC settings. Evidence suggests that although QALY- and DALY-based ratios for the same intervention can differ, differences tend to be modest and, as a rule, do not materially affect comparisons to common cost-effectiveness thresholds [15].

The net benefit approach aligns the concepts of disease burden and cost effectiveness and provides a unitary measure of population health gain, and its application is becoming increasingly prevalent in informing strategic planning efforts. This includes designing health benefits packages [23] and highlighting the value of health system strengthening [24]. It has also been used to assess the value of research to guide prioritization decisions [25], the benefit to countries of adhering to global guidance (as seen with HPV vaccination [26]), which could aid negotiations with donors and pricing discussions, as well as project the affordability and public health value of new health investments (e.g., Leishmaniasis vaccine as shown in [27]). Moreover, this approach can provide insights into the potential gains from investing in policies which reduce or remove constraints to implementation, both at the level of specific interventions and the broader health system. Such evidence is relevant for public sector, global, and philanthropic organizations (like WHO, the Global Fund, GAVI – the Vaccine Alliance, or the Gates Foundation), for guiding their health investment decisions.

This approach has considerable scope for future expansion. Currently, we assume that health opportunity costs, as determined by the CET, are exogenously set and fixed. However, opportunity costs can be influenced by the choice of interventions and other internal factors within the healthcare system, such as changes in policy, resource availability, and interaction between different interventions, making them potentially endogenous and dynamic. Further, CET estimates reflecting opportunity cost are typically based on marginal changes in expenditure and do not reflect the likely effect of non-marginal budget impacts on health opportunity costs [28], which can be substantial when interventions are scaled up to full implementation at the population level. In such instances, the appropriate CET would be lower for interventions with a non-marginal budget impact [29]. Moreover, in the example, we assume that interventions and their costs and effects are independent of one another, but they may interact (e.g., complement or substitute) with one another. Accounting for these interactions would be valuable as the cost effectiveness of interventions potentially vary in the extent to which interventions are implemented simultaneously. In the example, we also assume that interventions are implemented at full scale and that the average cost remains constant throughout the course of implementation. However, these assumptions may not hold due to factors such as economies of scale and last-mile challenges. In the real world, these factors should be considered to more accurately reflect the cost effectiveness. Lastly, intervention adoption decisions require careful consideration of budget impacts alongside cost effectiveness [30]. Budget impact analysis (BIA) can offer valuable insights into the population-level costs of an intervention and assess whether its implementation has a non-marginal effect on the overall health budget. If such an impact is identified, adjusting the CET may be necessary to account for the resulting changes in opportunity costs. Further research on how BIAs can complement the proposed framework would be beneficial.

We are not suggesting that this measure should serve as the sole basis for establishing healthcare priorities; instead, we emphasize its importance in facilitating informed decision making and understanding the trade-offs involved. Importantly, it can also serve as a powerful tool for advocacy for increased health budgets.

Declarations

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Author Contributions MR, SW, and PR conceptualized and designed the study. MR drafted the initial manuscript, while SW and PR provided critical revisions and edits. AP, MS, JO, KC, and SB reviewed and offered guidance on the final manuscript revisions. All authors approved the manuscript for submission.

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