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Title:	Mortality Impact of Achieving Essential Universal Health Coverage in Low- and Middle-Income Countries
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Introduction

For countries seeking to move towards universal health coverage (UHC), a fundamental challenge is identifying which health interventions should receive priority for public finance.[1] This issue is especially important in highly resource-constrained low-income (LI) and lower middle-income (LMI) countries where coverage of potentially cost-effective interventions is often low, and the investments needed to achieve UHC very large. *Disease Control Priorities, Third Edition* (DCP3) has proposed a concrete notion of UHC that could be affordable and feasible in LI and LMI countries. Volume 9, Chapter 3, of DCP3, entitled "Universal Health Coverage and Essential Packages of Care," draws on the content of 21 packages of essential health interventions contained in DCP3 and synthesizes them into a model health benefits package, termed "essential UHC" (EUHC).[2,3] A subset of these interventions have been distilled into a "highest-priority UHC package" (HPP) that is designed to address the specific health needs of – and be feasible to implement in – LI countries by the end of the Sustainable Development Goal (SDG) period in 2030.[4]

Although the HPP and EUHC packages are based interventions that provide good value for money and are likely to be feasible in low-resource settings, these packages would likely still face political hurdles and require a significant increase in domestic and external resources in most countries.[5] A practical question that health ministers might face from their governments, external donors, and other stakeholders is whether a UHC package based on DCP3's EUHC or HPP model packages would, on the whole, provide good value for money and facilitate the country meeting one or more SDG 3 targets. To address this question, we seek to quantify the potential mortality impact of EUHC and the HPP in LI and LMI countries. We frame our

analysis within the context of the SDG 3 supplementary target proposed by Norheim and colleagues, "Avoid in each country 40% of premature (under-70) deaths that would be seen in the 2030 population at 2010 death rates."[6]

Methods and Data Sources

Analytic Framework

A variety of analytic approaches can be used to estimate the potential health impact of interventions. For analyses that focus on a single health topic, fairly complex outcomes models have been developed, particularly for infectious diseases.[7] For analyses of closely related health topics, such as causes of under-five mortality, a handful of models have been developed that employ consistent assumptions and strive to avoid double-counting costs or benefits of multiple simultaneous interventions.[8] The WHO's OneHealth Tool represents one of the more advanced and widely-used such tools.[9]

DCP3 has strived to be comprehensive in addressing health conditions and identifying interventions. This comprehensiveness prohibits the use of existing, off-the-shelf outcomes models, even OneHealth Tool. Hence for the present analysis, we use a simplified approach that attempts to handle mortality impacts over a limited time period, 2015-2030, using assumptions and inputs that are consistent with *DCP3*'s related work on the cost of UHC.[10]

Our methods draw on the "comparative statics" approach that is commonly used in economic analysis.[11] In the case of mortality estimation, this approach would treat population coverage of a specified set of interventions as an exogenous parameter and hold constant all other variables – e.g., population size and structure, cause-specific mortality rates, intervention

effectiveness, and other disease modifiers not addressed by the specified interventions. The resulting estimate of deaths averted, then, would be interpreted as a counterfactual estimate of deaths that could be averted from an instantaneous shift in the exogenous parameter (in this case, coverage of selected interventions).

Our analysis has three steps. First, we project hypothetical mortality patterns by cause in 2030 in LI and LMI countries assuming current (2015) death rates are unchanged. Second, we identify the reduction in mortality that would be possible with a subset of very high-impact EUHC and HPP interventions. Third, we calculate incremental (counterfactual) reductions in mortality by age group and cause of death that would be expected following an increase in coverage from current levels to 80%.

Step 1. Projection of mortality patterns by cause in 2030

We obtained United Nations Population Division (UNPD; 2017 revision) medium projections of population size and structure in LI and LMI countries in 2030.[12] We also obtained estimates of cause-specific mortality rates by age, sex, and income group in the year 2015 from the most recent WHO Global Health Estimates (GHE).[13] These rates were applied to the UNPD dataset to obtain projected cause-specific death counts by age, sex, and income group in 2030. (NB: the use of 2015 mortality rates is a variant of the original "40x30" analysis, which specified 2010 death rates.)

Unlike GHE, UNPD does not disaggregate population size 0-4 years into neonatal (0-28 days) and post-neonatal (1-59 months) groups. We thus assumed that the distribution of the 2030 population into the neonatal and post-neonatal groups would be the same in 2030 as it was in 2015. (GHE estimates that the neonatal population comprised about 2% of the total under-five

population in 2015 but about 35% and 50% of the under-five deaths in LI and LMI countries, respectively.)

Step 2. Identification of EUHC and HPP effects on cause-specific mortality

As discussed previously, *DCP3*'s work on UHC benefits packages identified 229 unique health sector interventions that were been deemed to (1) provide good value for money, (2) be feasible in low- and middle-income countries, and (3) address a significant disease burden. These interventions together are referred to as EUHC.

A subset of these interventions, referred to as the HPP, was identified as appropriate for LI countries during the SDG period. These 109 interventions were judged by the DCP3 author group to (1) provide the very best value for money (i.e., at usual levels of willingness to pay in LI countries), (2) give preference to the worst off (i.e., focusing on causes that lead to the least lifetime health among those affected in the absence of intervention), and (3) provide significant financial risk protection. The methods used to develop the EUHC and HPP are described elsewhere.[14] The full list of interventions can be found online at www.dcp-3.org.

We took a hybrid approach to estimating the mortality reduction due to EUHC and HPP interventions. For a subset of Group I causes (i.e., communicable, maternal, perinatal, and nutritional conditions), we drew on the impact modeling undertaken for the *Lancet* Commission on Investing in Health report.[9] These included under-five deaths from all causes and deaths among individuals 5-69 years from tuberculosis, HIV/AIDS, and maternal conditions. For other

Group I causes and for Group II (noncommunicable diseases) and Group III (injuries) causes, we used effect sizes from the literature or expert opinion.

We assumed that effect sizes would be similar in LI and LMI countries but that the increases in coverage required to reach 80% target coverage would be smaller in LMI countries. A companion working paper on the cost of EUHC and the HPP details the data sources and assumptions used to estimate current intervention coverage in LI and LMI countries.[5] We also assumed that intervention effect sizes would be the same across all age groups and that the increase in coverage would equally benefit all cases regardless of age. Since this analysis focuses on premature mortality only, we view this as a very plausible assumption.

Table 1 summarizes effect sizes and changes in coverage for the major causes addressed in this analysis. A forthcoming Supplementary Appendix will list all effect sizes and the interventions that are included in the HPP and EUHC packages.

It is important to note how to interpret the effect sizes in Table 1. These are "ex post" assessments of relative reduction in mortality, compared to current levels, assuming full implementation of the intervention(s) among the target population. In some cases they reflect the combined effect of several interventions. For instance, provision of comprehensive diabetes care would be expected to reduce the long-run risk of death among individuals with diabetes by 13% overall. Along these lines, the EUHC effect is in many cases larger than the HPP effect, since EUHC contains more interventions against many causes. We sought to identify effect sizes that would be plausible over a 15-year (i.e., 2015-2030) time horizon. This led us not to consider in

this analysis some EUHC interventions whose mortality effects were likely to emerge after 2030, such as primary prevention of ischemic heart disease.

For neoplasms, the effect sizes only account for the overall mortality impact of early detection and treatment of early stage cancer; they thus assume a significant reduction in death but in a minority of cases – i.e., stage I or II at presentation. (*DCP3* does not recommend cancer screening in its HPP or EUHC packages with the exception of cervical cancer screening, which is more likely to be cost-effective in limited resource settings.)

Step 3. Calculation of deaths avertable from increased intervention coverage

The final step in the analysis was to calculate the number of deaths avertable (D_{av}) by either EUHC or the HPP:

$$D_{av} = \sum_{i=1}^{n} D_{proj,i} \times Eff_i \times \Delta Cov_i \times Qual$$

Where $D_{proj,i}$ is the projected number of deaths under 70 for cause i in 2030; Eff_i is the combined effect size of all interventions for cause i in either the HPP or EUHC, i.e., the relative reduction in mortality compared to baseline, ΔCov_i is the increase in intervention coverage (compared to coverage in 2015) for cause i such that the intervention is implemented at 80% coverage in 2030, and $Qual$ is a "quality" factor that scales down the effectiveness of the intervention to reflect realistic, suboptimal delivery of the interventions. For this analysis, $Qual$

was assumed to be 80%, i.e., that the impact of the intervention in the real world would only be about 80% of what would be predicted with perfect intervention delivery and patient adherence.

Other considerations

A forthcoming set of sensitivity analyses will consider the impact of different assumptions on our baseline estimates. First, we plan to calculate 2030 deaths based not on 2015 death rates but on projected rates that are based on the rate of change in mortality rates over 2000-2015 (i.e., assuming secular trends continue into the future). We will also use more optimistic and pessimistic assumptions about intervention effect sizes (say, 10-20% higher or lower) and quality (ranging 60-100%).

Findings

Table 2 provides an overview of the counterfactual impact of EUHC and HPP in LI and LMI countries in 2030. Because of projected demographic and epidemiological changes, we estimate that the mortality consequences of UHC would be different by age group, cause of death, and income group.

We project about 6.4 and 19.0 million deaths among individuals 0-69 in LI and LMI countries in 2030, respectively. The Norheim and colleagues SDG 3 target would imply a reduction by 2.5 and 7.6 million deaths (respectively) in 2030. The 40x30 target would be nearly

met with the HPP and met by EUHC in LI countries. However, in LMI countries would under-shoot the 40x30 target by about a third.

The major reason for this discrepancy is that under-five deaths are over-represented in LI countries, and on the whole the health sector interventions for those conditions are more effective. By contrast, in LMI countries, adult deaths are over-represented, and on the whole these interventions are somewhat less effective.

At the same time, substantial progress could be made in age-specific rates for certain causes. For example, EUHC could reduce 5-69 death rates from Group I causes by 23% in LI countries, ranging 16% for tuberculosis to 37% for malaria. Similarly, EUHC could reduce 5-69 death rates from Group II causes by 15% in LI countries, ranging 5% for neoplasms to 30% for cardiovascular diseases.

Interpretation

We found that our proposed EUHC and HPP interventions could make substantial progress towards the SDG3 target proposed by Norheim and colleagues. In LI countries, the target would be much easier to reach than in LMI countries where deaths from noncommunicable diseases and injuries predominate and continue to grow in importance. Put another way, LMI countries are facing demographic and epidemiological headwinds that make the SDG target more challenging to reach.

One major reason the DCP3 packages are not expected to facilitate LMI countries meeting the SDG target is the lack of progress on cancer mortality, which is a major contributor to overall mortality from noncommunicable diseases. Part of the challenge is the lack of population impact

from cancer treatment in the absence of organized screening programs, the latter of which are effective in high-income settings but are not cost-effective in LI or LMI countries.[15] Our findings suggest that intersectoral measures to reduce tobacco use, especially excise taxes on tobacco, will be a critical component of these countries' overall health strategy. At the same time, the health impact of large increases in tobacco taxes will probably not emerge until after 2030, raising the real chance that it will be impossible for most LMI countries to reach the SDG 3 target.

At the same time, the fact that health sector interventions alone – and even the relatively modest HPP – could facilitate LI countries reaching the 40x30 target is very encouraging. Recent global reports have suggested that inequalities in health outcomes between low-income and middle-/high-income countries are widening at least for some indicators.[16] Implementation of the HPP in LI countries could be a major step towards reducing those inequalities.

Although the impact of EUHC on premature mortality in LMI countries would not be sufficient to reach the 40x30 target, we note other important health and non-health consequences of EUHC. These include mortality among individuals over 70, reductions in disability, reductions in fertility and increases in educational attainment, and perhaps most importantly, financial risk protection. (A few extended cost-effectiveness analyses suggest that financial protection outcomes may be relatively more impressive than health outcomes for a variety of interventions, including those against noncommunicable diseases.[17]) Hence we suspect that the full spectrum of benefits from EUHC, if monetized, would likely be much larger than the benefits from reduced premature mortality. While data and methods for conducting benefit-cost analysis of UHC schemes are still in their infancy, this sort of broad assessment of EUHC would

be warranted and would further the case for investing in the health sector, particularly in LMI

countries.

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Tables

Table 1. Effect size and coverage assumptions used in this analysis

	Effect size, HPP	Effect size, EUHC	Coverage gap, LI	Coverage gap, LMI
Group I				
All under-five causes	77%	77%	27%**	20%**
Causes for ages 5-69				
Tuberculosis	77%*	84%*	24%**	26%**
HIV/AIDS	82%*	91%*	43%**	43%**
Malaria	75%	75%	61%	31%
Maternal conditions	76%*	83%*	43%**	35%**
Neglected tropical diseases	90%	90%	61%	31%
Lower respiratory infections	75%	75%	61%	31%
Nutritional deficiencies	25%	25%	41%	30%
Group II				
Neoplasms				
Colon and rectum cancers	9%	12%	75%	70%
Breast cancer	9%	12%	75%	70%
Cervix uteri cancer	15%	80%	41%	30%
Pediatric blood cancers	50%	90%	75%	70%
Cardiovascular diseases				
Rheumatic heart disease	80%	80%	76%	49%
Hypertensive heart disease	67%	67%	76%	49%
Ischemic heart disease	67%	88%	76%	49%
Ischemic stroke	67%	67%	76%	49%
Cardiomyopathy	67%	67%	76%	49%
Other diseases				
Diabetes mellitus	13%	16%	76%	49%
Sickle cell disorders and trait	80%	80%	75%	70%
Epilepsy	80%	80%	50%	30%
Schizophrenia	25%	25%	55%	40%
Alcohol use disorders	25%	25%	75%	70%
Opioid use disorders	25%	25%	75%	70%
COPD	10%	10%	76%	49%
Asthma	80%	80%	76%	49%
Group III				
Road injury	32%	40%	48%	43%
Falls; burns	32%	40%	48%	43%

* Aggregate effect as estimated by Boyle and colleagues.[9] ** approximate coverage gap (actual coverage levels vary from those used by Boyle and colleagues).

Table 2. Estimated deaths avertable by Essential UHC (EUHC) and the Highest Priority UHC Package (HPP) in low-income and lower middle-income countries in 2030.

	Low-income countries				Lower middle-income countries			
	Projected deaths, 2030	40x30 reduction target	Expected reduction, HPP	Expected reduction, EUHC	Projected deaths, 2030	40x30 reduction target	Expected reduction, HPP	Expected reduction, EUHC
By age group								
0-4	2.19	**1.46**	1.69	1.86	3.64	**2.42**	2.76	3.03
5-69	4.16	**1.08**	0.65	0.72	15.45	**5.21**	1.74	1.99
0-69	6.35	**2.54**	2.34	2.58	19.08	**7.63**	4.50	5.02
By cause group (5-69)								
Group I	1.75	**0.63**	0.39	3.49	**1.63**	0.52	0.55	3.49
Tuberculosis	0.23	**0.15**	0.03	1.01	**0.67**	0.16	0.17	1.01
HIV/AIDS	0.43	**0.29**	0.12	0.52	**0.35**	0.15	0.16	0.52
Malaria	0.08	**0.06**	0.03	0.06	**0.04**	0.01	0.01	0.06
Maternal conditions	0.17	**0.11**	0.04	0.21	**0.14**	0.04	0.05	0.21
Other diseases	0.84	**0.02**	0.16	1.68	**0.42**	0.15	0.15	1.68
Group II	1.74	**0.37**	0.22	9.84	**3.00**	1.13	1.32	9.84
Neoplasms	0.45	**0.15**	0.01	2.04	**0.68**	0.12	0.15	2.04
Cardiovascular diseases	0.62	**0.21**	0.16	4.33	**1.44**	0.86	1.01	4.33
Other diseases	0.67	**0.01**	0.06	3.47	**0.87**	0.15	0.15	3.47
Group III	0.68	**0.08**	0.03	2.12	**0.58**	0.10	0.12	2.12
Road injuries	0.22	**0.07**	0.03	0.62	**0.21**	0.07	0.08	0.62
Other injuries	0.46	**0.01**	0.01	1.50	**0.38**	0.03	0.04	1.50

Notes: All estimates are in millions of deaths. The 40x30 reduction target includes a 40% reduction in deaths 0-69 overall, a two-thirds reduction in under-five deaths and adult deaths from tuberculosis, HIV/AIDS, malaria, and maternal conditions, and a one-third reduction in deaths from major noncommunicable diseases. The quantitative targets above reflect these goals; however, targets for the residual categories ("other diseases" and "other injuries") have been calculated in light of the targets for specific causes of death so that the total number of target deaths 5-69 is sufficient to meet the 40x30 target.