Progress towards universal health coverage and inequalities in infant mortality: an analysis of 4·1 million births from 60 low-income and middle-income countries between 2000 and 2019

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Summary

Background Expanding universal health coverage (UHC) might not be inherently beneficial to poorer populations without the explicit targeting and prioritising of low-income populations. This study examines whether the expansion of UHC between 2000 and 2019 is associated with reduced socioeconomic inequalities in infant mortality in low-income and middle-income countries (LMICs).

Methods We did a retrospective analysis of birth data compiled from Demographic and Health Surveys (DHSs). We analysed all births between 2000 and 2019 from all DHSs available for this period. The primary outcome was infant mortality, defined as death within 1 year of birth. Logistic regression models with country and year fixed effects assessed associations between country-level progress to UHC (using WHO's UHC service coverage index) and infant mortality (overall and by wealth quintile), adjusting for infant-level, mother-level, and country-level variables.

Findings A total of 4 065 868 births to 1 833 011 mothers were analysed from 177 DHSs covering 60 LMICs between 2000 and 2019. A one unit increase in the UHC index was associated with a 1·2% reduction in the risk of infant death (AOR 0·988, 95% CI 0·981–0·995; absolute measure of association, 0·57 deaths per 1000 livebirths). An estimated 15·5 million infant deaths were averted between 2000 and 2019 because of increases in UHC. However, richer wealth quintiles had larger associated reductions in infant mortality from UHC (quintile 5 AOR 0·983, 95% CI 0·973–0·993) than poorer quintiles (quintile 1 0·991, 0·985–0·998). In the early stages of UHC, UHC expansion was generally beneficial to poorer populations (ie, larger reductions in infant mortality for poorer households [infant deaths per 1000 per one unit increase in UHC coverage: quintile 1 0·84 *vs* quintile 5 0·59]), but became less so as overall coverage increased (quintile 1 0·64 *vs* quintile 5 0·57).

Interpretation Since UHC expansion in LMICs appears to become less beneficial to poorer populations as coverage increases, UHC policies should be explicitly designed to ensure lower income groups continue to benefit as coverage expands.

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Introduction

Universal health coverage (UHC) is the essential platform within health systems needed for making progress towards the Sustainable Development Goals and achieving health for all.[1,2] UHC means ensuring everyone receives the high-quality health services they need without resulting in financial hardship. UHC is enshrined in Sustainable Development Goal 3.8, committing countries to achieve UHC by 2030, and is based on the principle of leaving no-one behind. The current year, 2024, leaves just 6 years until the SDG period concludes and is a crucial juncture at which to examine whether a more explicit focus on low-income populations within UHC is necessary in the future.

Over recent decades, there has been progress towards UHC in many countries,[1,3] with concomitant improvement in health outcomes, such as lower child and adult mortality, higher life expectancy, and reduced catastrophic health expenditure.[4,5] However, the projected progress is insufficient to achieve UHC and associated Sustainable Development Goals,[1] and equity in access to health care is a challenge globally.[1] UHC is the modern manifestation of WHO's egalitarian goal of health-for-all, encompassing the principles of fairness and equity.[6] However, the path chosen for expanding UHC differs between countries, and outcomes might not be inherently equitable without targeting or prioritisation of disadvantaged groups.[6]

The inverse equity hypothesis outlines how new health interventions are often first adopted by wealthier populations, with poorer populations left behind and inequalities widening in the short term (panel 1).[25,26]

Research in context

Evidence before this study

On May 3, 2023, we searched MEDLINE, Embase, Global Health, Health Management Information Consortium, EconLit, WHOLIS and the World Bank's Open Knowledge Repository for the terms "Universal Health Coverage" AND "Universal Health Care" AND "(in)equity/(in)equality" (and synonyms) in the title and abstracts for publications from any year in English. A broad range of studies and conceptual articles, with no population or study design restrictions, were included that contributed to the literature on the expansion of universal health coverage (UHC) and health inequalities. There was no clear consensus in the literature on the association between expanding UHC and health inequalities across income groups. Some studies evaluating specific reforms from a range of low-income and middle-income countries (LMICs), including Bangladesh, Burkina Faso, Chile, India, Türkiye, Thailand, Zambia, and Latin American countries, identified improvements in some equity indicators, mainly in financing and coverage outcomes, but inequalities in health outcomes were infrequently studied. However, other studies and systematic reviews found contrary evidence pointing to fewer benefits to poorer populations of UHC reforms. One systematic review concluded that benefits from public health-care financing were accrued by wealthier populations more than poorer populations in many LMICs, and multiple systematic reviews suggested that the expansion of insurance schemes did not benefit poorer populations.
One cross-country study identified that transitions from out-of-pocket dominant systems to government-funded or insurance-based financing were associated with reductions in catastrophic health expenditure and improvements in health. However, there were no cross-country studies examining associations between overall progress to UHC and health inequalities in LMICs.

Added value of this study

This study analyses 4 million births across 60 LMICs and uses WHO's UHC service coverage index to show that UHC expansion was associated with reductions in infant mortality over the period 2000–19. Overall, this association generally favoured wealthier populations (ie, it resulted in larger reductions in infant mortality for richer households), both in absolute and relative terms, and moved from benefitting poorer populations to wealthier populations as countries increased UHC coverage. This study uses individual-level data controlling for key infant-level, mother-level, and country-level confounders, and validates its findings with a range of robustness checks. Associations between the subcomponents of UHC and infant mortality showed that reproductive, maternal, newborn, and child health coverage and infectious disease coverage were associated with greater reductions in infant mortality in poorer households, yet the service capacity and access elements of UHC were associated with larger reductions in infant mortality in wealthier households.

Implications of all the available evidence

Despite a range of promising case studies and analyses of specific health system reforms showing the nature of UHC in benefitting poorer populations in LMICs, our comprehensive, global analysis suggests that although UHC can deliver infant health gains, these might be becoming more beneficial to wealthier populations as countries progress towards UHC. Potential explanations include persistent socioeconomic barriers to access, inequalities in structural health system factors, the reliance on contributory (rather than non-contributory) health insurance schemes, and a misalignment between publicly subsidised health services and the needs of target populations.

However, with the diffusion of interventions across populations, poorer populations can catch up, meaning that equity improves at higher coverage.[25,26] It can be argued that interventions targeted towards lower-income populations, such as UHC, are not essential because poorer populations eventually catch up. However, universalist approaches to UHC aimed at prioritising poorer populations are widely argued to be essential,[27] with UHC expansions targeted towards poorer, vulnerable populations with lower existing access to health care.[28] In many low-income and middle-income countries (LMICs), health-care financing prioritises higher-income populations[23,29,30] and vulnerable communities do not have access to high-quality health services,[31] with high rates of mortality or morbidity.[32] The expansion of UHC can create inequalities by reducing out-of-pocket payments for already covered populations or expanding coverage to low-priority services at the expense of expanding coverage and reducing costs for uncovered populations. Many LMICs have also adopted contributory health insurance schemes to make progress towards UHC, yet the low-income, informal workers and unemployed people are often excluded.[33,34] Despite the global attention on UHC and the risk of inequalities skewing towards higher-income populations, there is little empirical evidence about the health inequality effects of UHC progress.

This study examines the association between progress towards UHC and inequalities in infant mortality and tests the inverse equity hypothesis in this context. Multiple studies document inequalities that favour higher-income populations in child and maternal health interventions, such as antenatal care and skilled birth attendance coverage.[35–39] Associations with health outcomes are poorly explored. Some evidence shows that expansion of universal antenatal care might contribute to reductions in inequalities in infant mortality.[40,41] These studies often use aggregate-level analysis, using either concentration indices or slope indices of inequality, limiting the in-depth understanding of inequalities and not adjusting for individual-level and household-level factors. Inequalities in the effects of UHC at different stages of UHC expansion (ie, the inverse equity hypothesis) are scarcely explored. This study examines how country-level progress towards UHC is associated with inequalities in infant mortality across wealth quintiles. Infant mortality is a key population health outcome; it has been a major health challenge in LMICs, is sensitive to changes in health-care provision, and data are readily available. This study explores and tests WHO's UHC service coverage index as a measure for annual UHC.[42,43] This index was published in 2018 and is based on 14 tracer indicators; however, the potential in using this index analytically is underexplored. Many of these tracer indicators, including antenatal care, family planning, immunisation, hospital beds, and the health workforce, are associated with improved infant health.[44–53] This analysis explores how the association between UHC and inequalities in infant mortality varies across wealth quintiles, by baseline UHC in 2000 and by components of the UHC service coverage index.

Panel 1: The inverse equity hypothesis

The inverse equity hypothesis outlines how new interventions often reach the wealthiest populations and countries first, being adopted by poorer populations when the wealthiest populations reach near universal coverage. After the introduction of new health interventions, the health gaps between wealthier and poorer populations can initially widen before narrowing as poorer populations catch up.[7]

Although the concept has been extensively cited, evidence on the inverse equity hypothesis is mixed.[8] The hypothesis was corroborated in some public health interventions, including chronic disease monitoring and management,[9] cancer screening,[10] HIV and AIDS screening and treatment,[11] and infectious diseases prevention.[12] However, these studies were mostly based on high-income countries.[9–11,13]

However, evidence on the coverage of reproductive, maternal, newborn, and child health interventions is less conclusive. Although the inverse equity hypothesis is supported in some studies in low-income and middle-income countries (LMICs),[14,15] it was rejected by studies from China,[16] India,[17] Bangladesh,[18] Nepal,[19] Cambodia,[20] Ecuador,[21] and Burkina Faso.[22] Notably, these countries all introduced policies or reforms over the last decades that have been targeted towards poorer populations. One LMIC-based study suggested that delivery channels can be important for equity in coverage of reproductive, maternal, newborn, and child health interventions.[23] Community-based primary health care was often more equitably distributed[23] and associated with improvements in child mortality.[24]

Methods

Study design and data sources

This is a retrospective analysis of data obtained from Demographic and Health Surveys (DHSs), available from the DHS programme. We included all DHSs where at least two surveys were carried out in a country between 2000 and 2019. This time period was chosen to align with the availability of the UHC service coverage index. For this analysis, birth recode datasets were obtained that include a complete birth history for the interviewed women, including information on the infant's date of birth, sex, and survival status. From the surveys, we included all births between 2000 and 2019.

For the **DHS programme** see https://dhsprogram.com/

Data on UHC were obtained from WHO's UHC service coverage index,[42,43] including the overall UHC index and its four subindices (reproductive, maternal, newborn, and child health [RMNCH] services; infectious diseases services; non-communicable diseases services; and service capacity and access). WHO's UHC service coverage index is calculated as the geometric mean of 14 tracer indicators (panel 2) scaled between 0 and 100. The tracer indicators are computed on the basis of compiled national health and household surveys, with imputation for missing data and linear interpolation of missing years. Despite concerns over the validity of WHO's UHC service coverage index,[3] we used it as our proxy for UHC given its widespread adoption by multilateral institutions, comparability across countries,[43] and additionally to test the validity of using this index analytically. The World Bank Development Indicators database was also consulted for country-level indicators on development, health, wellbeing, and economic factors, as described later.

Study population and variables

The primary outcome was infant mortality, defined as death within 1 year of birth. Infant mortality was chosen because it is available by wealth quintile from the DHS data, is widely used as a barometer of a country's health,[54] and is particularly sensitive to changes in access to health care and health-care quality.[55]

A range of other variables was included in the analyses as confounders. At the infant level, these were year of birth; sex (male or female); and multiple birth (yes or no). Previous evidence indicates that male sex and multiple births are associated with an increased risk of infant mortality.[56,57] At the mother level, the mother's age, place of residence (urban or rural), and household wealth index quintile in the year of the survey were included. Maternal age is included as a confounder given that low maternal age is associated with an increased risk of infant death.[58] Urban or rural location is an important proxy for socioeconomic status, with rurality associated with lower living standards, poorer access to health services, and an increased risk of infant death.[59] The wealth index is a composite measure of household wealth based on household ownership of goods, access to services, and living facilities. Quintiles of the wealth index are estimated from the wealth index distribution of each survey's sample, thus representing a country-specific and year-specific estimate of relative wealth. We

Panel 2: **Components of WHO's Universal Health Coverage (UHC) service coverage index and sub-indices**

WHO's UHC service coverage index (Sustainable Development Goal 3.8.1) is computed as the geometric mean of 14 tracer indicators:

Reproductive, maternal, newborn, and child health

1 Family planning: percentage of women of reproductive age (15–49 years) who are married or in-union who have their need for family planning satisfied with modern methods
2 Pregnancy and delivery care: percentage of women aged 15–49 years with a livebirth who received antenatal care four or more times
3 Child immunisation: percentage of infants receiving three doses of diphtheria, tetanus, and pertussis-containing vaccine
4 Child treatment: percentage of children younger than 5 years of age with suspected pneumonia in the 2 weeks preceding the survey taken to an appropriate health facility or provider

Infectious diseases

5 Tuberculosis: percentage of incident tuberculosis cases that are detected and successfully treated
6 HIV and AIDS: percentage of people living with HIV currently receiving antiretroviral therapy
7 Malaria: percentage of population in malaria-endemic areas who slept under an insecticide-treated net the previous night (only for countries with high malaria burden)
8 Water and sanitation: percentage of households using at least basic sanitation facilities

Non-communicable diseases

9 Hypertension: age-standardised prevalence of non-raised blood pressure (systolic blood pressure <140 mm Hg and diastolic blood pressure <90 mm Hg) among adults aged 18 years and older
10 Diabetes: age-standardised mean fasting plasma glucose (mmol/L) for adults aged 18 years and older
11 Tobacco: age-standardised prevalence of adults aged 15 years and older not smoking tobacco in the past 30 days

Service capacity and access

12 Hospital access: hospital beds per person
13 Health workforce: health professionals (physicians, psychiatrists, and surgeons) per person
14 Health security: International Health Regulations core capacity index, which is the average percentage of attributes of 13 core capacities that have been attained

More information is available in the WHO statistical annexes.

For the **statistical annexes** see https://www.who.int/docs/default-source/documents/2019-uhc-report.pdf

For the **World Bank data** see http://data.worldbank.org/

See Online for appendix 1

assumed that household-level characteristics at the time of the survey represented household-level characteristics at the year of birth.

A range of country-level variables were included to adjust for society-wide changes in wellbeing and development that were potentially associated with both infant mortality and UHC. The set of country-level variables were chosen on the basis of cross-country evidence about their potential association with both the infant mortality rate and UHC and data availability. We chose confounders on the basis of their potential association both with the treatment or exposure (UHC coverage) and the outcome (infant mortality), and ensure these do not lie on the causal pathway between UHC and infant mortality (ie, they are not potential mediators of how UHC could affect health outcomes, such as service provision variables).[60] Country-level variables were matched to birth data on the basis of year and country of birth using data from the World Bank. Specifically, these variables were: access to electricity (% of population); age dependency ratio (the proportion of dependents [people aged younger than 15 years or older than 64 years] per 100 people in the working-age population [those aged 15–64 years]); crude birth rate (per 1000 people); contraceptive prevalence by any method (% of married women aged 15–49 years); total fertility rate (births per woman); gross domestic product per person (constant 2015 US$ [ie, adjusted for changes in power purchasing parity to ensure comparability to 2015 USD values]); female labour force participation rate (% of female population aged 15 years or older); people practising open defecation (% of population); pupil–teacher ratio at primary schools; people using at least basic drinking water services (% of population); people using at least basic sanitation services (% of population); unemployment rate (% of total labour force); and suicide mortality rate (per 100 000 population). Many of these confounders aim to capture general country-level factors that might be associated with UHC and are known to be associated with infant mortality, for example development factors (eg, infrastructure, electricity, improved sanitation, and education),[61] economic factors (eg, employment and gross domestic product per person),[62] and factors related to female empowerment (eg, birth rate, fertility rate, and female employment).[63,64]

Statistical analyses

The data were first presented descriptively. Infant, maternal, and household characteristics were presented as frequencies and percentages or means, unweighted and weighted using individual DHS weights. Infant mortality rates by country and wealth quintiles were described and their associations with the country-level UHC index were shown graphically. Separate trend lines, by wealth quintile, were plotted on the basis of locally weighted smoothed regression lines (between UHC and infant mortality).

Logistic regression models were used in all analyses as appropriate for binary outcomes (infant death or not; appendix 1 p 13). Models accounted for the clustered nature of the data (ie, individuals clustered within countries) with country-level dummy variables (ie, country fixed effects) and clustered SEs. Huber–White cluster robust SEs were used in all models (clustered at the country level). Models were weighted using individual DHS weights, which were calculated using two-stage unequal probability samples, informed by the most recent census in most surveys,[65] considering both sampling design and non-response.

These models were used to test the association between country UHC index and risk of infant death, adjusted for all infant-level, mother-level, and country-level variables noted earlier. The models were expanded to examine inequalities across wealth quintiles by including an interaction term between the UHC index (at year of birth) and wealth quintiles, generating an association between country UHC and the risk of infant death for each wealth quintile. Adjusted odds ratios (AORs) were reported and interpreted relative to a one unit increase in the UHC index. Where possible, we classified identified associations as disproportionately benefitting higher-income or lower-income households (ie, having larger reductions in infant mortality associated with UHC).

To test the inverse equity hypothesis, we explored associations between infant mortality and UHC across different levels of UHC coverage. Observations were grouped into four quartiles on the basis of country UHC at birth (very low <30, low 30–36, low–middle 36–46, and middle–high >46). An interaction term between UHC group and UHC at birth was added to the model, which tested whether the relationship between UHC and infant mortality varied depending on the level of UHC by the country level at the year of birth. This method differed from the previous models where a one-unit increase in the UHC was modelled the same regardless of the level of UHC index obtained by a country. A three-way interaction between UHC at time of birth, the four groups of UHC level, and wealth quintiles were also added to the model. This method allowed the UHC at birth–infant mortality relationship to vary across both the UHC group and wealth quintile, and indicated whether the UHC at birth–infant mortality relationship became more or less unequal (ie, disproportionately benefitting either higher or lower income households) as overall UHC increased.

In the final analysis, separate models were estimated for each of the four UHC subindices, with and without wealth–quintile interactions. These models explored the extent to which subcomponents of the UHC index might be driving the findings.

The rdhs package in R version 4.3.1 was used to identify, download, and compile surveys.[66] Stata version 15 was used for statistical analyses.

Absolute measures of association

The regression models provided relative measures of association (ie, the AORs). To translate these AORs into absolute measures of association, we predicted the marginal associations between UHC and infant mortality using the estimated AORs. All other variables were held at their observed values. These absolute measures of association were expressed as the absolute change in the infant mortality rate given a one unit increase in the UHC index.

To calculate averted deaths associated with UHC expansion, we compared estimated infant deaths under a counterfactual no-UHC expansion scenario with actual infant deaths. Annual birth and infant death data for the 60 LMICs were obtained from the UN Department of Economic and Social Affairs website. Assuming the estimated absolute point estimates for UHC (ie, change in infant mortality rate per one unit increase in UHC index) obtained from the regression analysis were constant over countries and time, a counterfactual infant mortality rate was calculated. This rate represented infant mortality in the absence of any change in UHC relative to the year before for each country and year. Counterfactual infant deaths were then estimated by multiplying this counterfactual mortality rate with the number of births in the corresponding country and year. The total number of infant deaths under the counterfactual no-UHC expansion scenario over the period 2000–19 were totalled up for each country, and the actual number of infant deaths over the period 2000–19 were subtracted to estimate the averted deaths by country.

Robustness checks

Alternative specifications were used to check the robustness of the findings and included unadjusted models, unweighted models, and models with different time trends (ie, linear, quadratic, and linear country-specific trends). We also repeated the main analyses, restricting the sample to only first births per mother (n=1 833 011), to test for biases related to multiple births per mother.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

We identified 268 surveys from 84 countries between 1986 and 2021. After excluding countries with only one survey (n=22) and surveys conducted before 2000 (n=93), our final sample included 177 surveys from 60 LMICs. The majority (32) of the countries were in sub-Saharan Africa, followed by Latin America and the Caribbean (8), Europe (6), south Asia (5), east Asia and the Pacific (5), and northern Africa and the Middle East (4). A total of 4 073 227 reported births from 2000 to 2019 were obtained for the analysis, of which 7359 (0·18%) were excluded because of missing survey weight data. A total of 4 065 868 births to 1 833 011 mothers were analysed. 5·0% of infants died before their first birthday (n=203 709).

The mean UHC index of the 60 LMICs increased by 75·2%, from 30·87 in 2000 to 53·87 in 2019 (appendix 1 pp 3–4). The UHC index increased in all countries over the 20-year period, with a mean increase of 23·12 points. There was no clear association between initial country UHC index in 2000 and the change over the period (appendix 1 pp 5–6). The mean infant mortality rate of the 60 LMICs decreased by 52%, from 64·1 infant deaths per 1000 livebirths in 2000 to 30·5 in 2019 (appendix 1 pp 7–8). As UHC coverage increased, there

For the **UN Department of Economic and Social Affairs website** see https://population.un.org/dataportal/

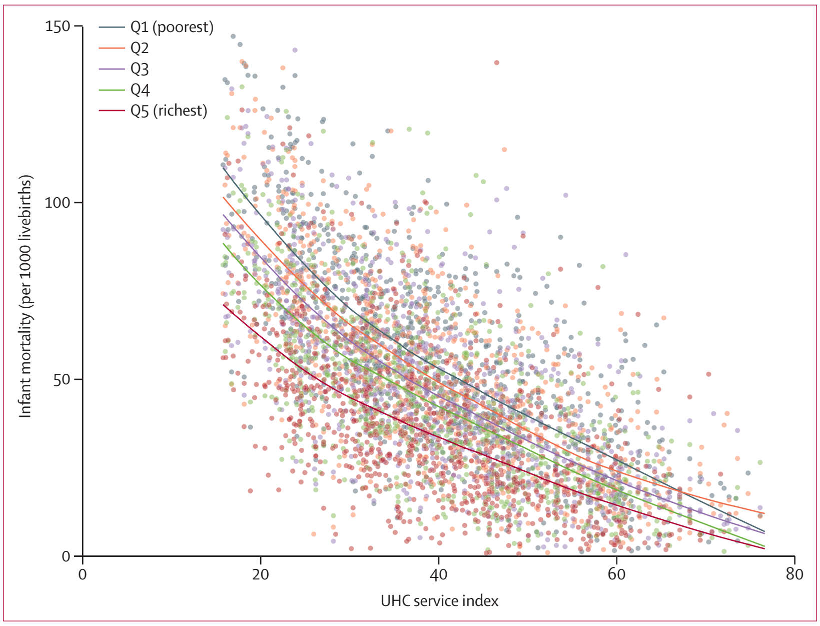

Figure 1: **Associations between infant mortality estimates by country wealth quintile and country-level UHC service coverage index**
Each dot represents a quintile-country-year observation; plotted infant mortality rates are crude, unadjusted rates; overall trend lines are based on adjusted locally weighted (smoothed) regression models. UHC=universal health coverage.

was a decreasing trend in infant mortality and narrowing wealth inequalities (figure 1), although this relationship was not adjusted for confounders and differences by wealth quintiles were not tested statistically.

In adjusted regression models, infants in the fifth wealth quintile (ie, the richest quintile) were 44% less likely to die (AOR 0·56, 95% CI 0·48–0·65) than the first quintile (ie, the poorest quintile; table; appendix 1 pp 14–15). On average, a one unit increase in the country-level UHC index was associated with a 1·2% reduction in the risk of infant death (AOR 0·988, 95% CI 0·981–0·995). This finding translates into an absolute measure of association of 0·57 infant deaths per 1000 livebirths. Given that the mean increase in the UHC index over the period was 23·12, reductions in infant mortality for the average country associated with the mean increase in UHC were estimated as 13·2 deaths per 1000 livebirths. On the basis of UN estimates of 1·67 billion births and 86·2 million infant deaths in the 60 LMICs over the period 2000–19 (and assuming a constant absolute point estimate across countries and time), we estimated that increases in UHC were associated with 15·5 million averted infant deaths between 2000–19 (appendix 1 p 16).

Associations between infant mortality and the UHC index differed across wealth quintiles. Infants born in wealthier quintiles had larger reductions in the risk of infant mortality associated with increases in UHC than those from poorer quintiles (0·9% reduction for the poorest (quintile 1) compared with 1·7% reduction for the wealthiest quintile (quintile 5); statistically significant difference p=0·0260; table; appendix 1 pp 17–18). In absolute measures of association, the largest reductions in infant mortality were accrued by those in the middle wealth quintiles (Q1: 0·488 infant deaths per 1000 livebirths; Q2: 0·611; Q3: 0·607; Q4: 0·624; and Q5: 0·567). Overall, infants born in the poorest quintile had the smallest relative and absolute reductions in mortality associated with UHC.

To test the inverse equity hypothesis, the association between UHC and infant mortality was varied by banding of increased UHC at birth. Generally, increases in UHC were consistently associated with reductions in infant mortality regardless of UHC level (appendix 1 p 19). There was some indication that at higher levels of UHC, increases in UHC were associated with smaller relative reductions in infant mortality (appendix 1 p 20); for example, 1·8% for very low UHC at birth (AOR 0·982, 95% CI 0·974–0·990) compared with 1·3% for middle–high UHC at birth (0·987, 0·980–0·994; overall interaction p=0·0111; and difference between very low UHC and middle–high UHC p=0·0086). Furthermore, the relative reductions in infant mortality were similar across wealth quintiles in the very low UHC category at birth (difference between quintile 1 and quintile 5 p=0·8986), but benefitted those in the wealthiest quintile (ie, larger relative reductions in quintile 5 compared with quintile 1) when UHC was higher. This finding was mainly caused by poorer quintiles accruing smaller reductions in infant mortality at higher levels of UHC, with a 1·8% reduction in infant mortality associated with a one unit increase in the UHC index for quintile 1 with very low UHC at birth (AOR 0·983, 95% CI 0·974–0·994) versus 1·0% for middle–high UHC at birth (0·990, 0·982–0·997; p=0·0112). These patterns were similar to the predicted absolute reductions in infant mortality associated with UHC. Where UHC at birth was very low, infants in wealth quintile 1 had an estimated reduction of 0·84 infant deaths per 1000 associated with a one unit increase in UHC coverage, which reduced to 0·64 where UHC coverage was middle–high. Infants in quintile 5 had similar absolute reductions in infant mortality associated with increases in UHC, regardless of country-level UHC (eg, 0·59 for low UHC and 0·57 for middle–high UHC).

Exploring UHC subindices showed that expansions in the UHC service capacity and access (AOR 0·989, 95% CI 0·979–0·999) and the UHC RMNCH subindices (0·989, 0·983–0·994) were negatively associated with infant mortality (appendix 1 p 21). In interactions with wealth quintiles (figure 2), notably the capacity and access subindex were beneficial to the wealthiest quintile in the associations with infant mortality, whereby the richest wealth quintiles had reductions in infant mortality compared with no significant association in the poorest quintiles. The RMNCH subindex was consistently associated with reductions in infant mortality across

	Model 1: infant death			Predicted change in infant mortality rate per 1000 livebirths for model 1			Model 2: infant death with UHC index and wealth quintile interaction			Model 3: infant death with quintile-specific effects			Predicted change in infant mortality rate per 1000 livebirths for model 2 and 3		
	AOR	95% CI	p value	Absolute measure	95% CI	p value	AOR	95% CI	p value	AOR	95% CI	p value	Absolute measure	95% CI	p value
Wealth quintile															
Q1 (poorest)	1 (ref)	..	..	..	..	..	1 (ref)*	..	..	1 (ref)	..	..	..	..	..
Q2	0·891	0·848 to 0·937	<0·0001	..	..	..	1·000	0·920 to 1·087	0·9965	1·000	0·920 to 1·087	0·9965	..	..	..
Q3	0·794	0·740 to 0·852	<0·0001	..	..	..	0·927	0·838 to 1·025	0·1390	0·927	0·838 to 1·025	0·1390	..	..	..
Q4	0·705	0·628 to 0·792	<0·0001	..	..	..	0·876	0·765 to 1·004	0·0575	0·876	0·765 to 1·004	0·0575	..	..	..
Q5 (richest)	0·556	0·477 to 0·648	<0·0001	..	..	..	0·735	0·608 to 0·889	0·0015	0·735	0·608 to 0·889	0·0015	..	..	..
UHC index at year of birth	0·988	0·981 to 0·995	0·0006	−0·574	−0·900 to −0·247	0·0006	0·991	0·985 to 0·998	0·0112	..	..	..	..	..	..
UHC index for Q1	..	..	..	..	..	..	1 (ref)*	..	..	0·991†	0·985 to 0·998	0·0112	−0·488	−0·870 to −0·107	0·0112
UHC index for Q2	..	..	..	..	..	..	0·997*	0·995 to 0·999	0·0010	0·988†	0·981 to 0·995	0·0007	−0·611	−0·971 to −0·251	0·0007
UHC index for Q3	..	..	..	..	..	..	0·996*	0·993 to 0·998	0·0030	0·987†	0·980 to 0·994	0·0001	−0·607	−0·914 to −0·300	0·0001
UHC index for Q4	..	..	..	..	..	..	0·994*	0·989 to 0·999	0·0149	0·985†	0·977 to 0·994	0·0007	−0·624	−0·968 to −0·281	0·0007
UHC index for Q5	..	..	..	..	..	..	0·992*	0·985 to 0·999	0·0260	0·983†	0·973 to 0·993	0·0012	−0·567	−0·888 to −0·247	0·0012

4 065 868 observations total. Models adjusted for all infant-level, mother-level, and country-level variables, and time and country fixed effects. Absolute measures of association are the predicted change in infant mortality rate (deaths per 1000 livebirths). Overall interactions between UHC index and wealth quintile were significant at p=0·011, and difference in point estimates for between UHC index for Q1 and UHC index for Q5 was significant at p=0·026. AOR=adjusted odds ratio. UHC=universal health coverage. *Marginal associations. †Quintile-specific associations.

Table: **Results from logistic regression models on risk of infant death relative to a one-unit increase in the UHC index**

wealth quintiles (ie, no significant difference across quintiles). The infectious disease UHC subindex was only associated with small reductions in infant mortality for the poorest wealth quintile (AOR 0·996, 95% CI 0·992–1·000), whereas there were no statistically significant associations between the non-communicable diseases subindex and infant mortality in any of the model specifications.

The main findings were supported in alternative regression model specifications, including unweighted and unadjusted models (appendix 1 pp 14–15, 17–18). The point estimates were larger when country covariates and fixed effects were included. Alternative time and fixed-effects specifications yielded highly similar results (appendix 1 p 22). A quadratic UHC index variable was non-significant, suggesting that a linear specification was appropriate, and indicating no evidence of non-linear associations. Restricting the main analyses to only first-born children per mother yielded highly concordant findings (UHC overall 1·7%; AOR 0·983, 95% CI 0·972–0·994).

Discussion

In this study of 4·1 million births in 60 LMICs, the expansion of UHC was associated with reductions in infant mortality. However, on average this relationship benefitted wealthier quintiles, whereby babies born in wealthier households benefitted disproportionately more than those born in poorer households in terms of both relative and absolute reductions in infant mortality. Regarding UHC and the inverse equity hypothesis, the expansion of UHC from a low starting point was beneficial to poorer quintiles (in absolute terms), but as UHC increased, the relationship shifted to be more similar across wealth quintiles (and beneficial to wealthier quintiles in relative terms). RMNCH components of UHC appeared to deliver equitable reductions in infant mortality across wealth quintiles, whereas service capacity and access components benefitted wealthier populations.

Reductions in infant mortality associated with UHC are unsurprising. Evidence shows that basic services (such as family planning, antenatal care, and immunisation, all key tracer indicators within the UHC index) are consistently associated with reduced infant mortality.[44–47,50] Health system investments, such as hospital beds and health workforce availability, are included in the UHC index, with evidence from multiple settings demonstrating their importance in reducing infant deaths.[51–53]

The finding that UHC expansion is associated with inequalities skewed towards wealthier populations in

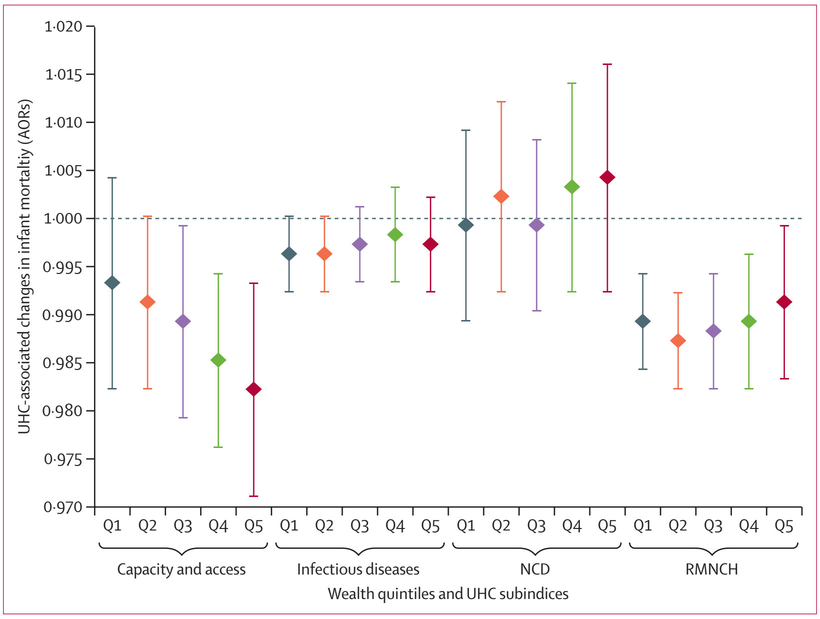

Figure 2: **Relative changes in infant mortality associated with four UHC subindices by wealth quintile**
Results from four logistic regression models including interactions between wealth quintile and UHC subindices. Models adjusted for all infant-level, mother-level, and country-level variables and time and country fixed effects. UHC=universal health coverage.

reductions in infant mortality is contrary to the underlying spirit of UHC, which is based on fairness and equality.[6] Yet, there is some concordance with evidence on inequalities in service coverage. Inequalities in access, coverage, and quality of child and maternal health interventions that benefit wealthier populations are widely documented.[23,35–39,67] Lower-income individuals face financial barriers, little health insurance coverage, and geographical disparities impeding access to health care.[68,69] These individuals also have a lower quality of care, such as lower access to essential medications, diagnostic services, skilled health-care providers, and timely treatments.[70–72] This finding also aligns with the inverse care law, whereby high-quality health care is inversely available in relation to population needs.[31] However, the use of quintiles in this analysis obscures the depth of the inequality in many LMICs, where higher wealth quintiles might still be poor in absolute terms, both globally and within countries. For the 60 LMICs studied, the country-mean absolute poverty rate (at <USD$6·85 a day) was more than 60% of the population.

The inverse equity hypothesis states that newly introduced health interventions are first adopted by relatively wealthier population groups who have lower health needs for these interventions, and as expansion and coverage increases, poorer populations catch up.[7] This study suggests a more nuanced picture. UHC is not often a newly introduced intervention, but often a progressive expansion of access, coverage, services, and reduced cost-sharing. UHC generally appears to be more beneficial to poorer populations in its early stages, but as coverage increases, the further expansion of UHC shifts to benefitting wealthier populations. These the findings both corroborate other studies showing reductions in inequalities in LMICs over past decades, but they also partly explain why there are increases in UHC.[73,74] However, a wide range of other social, development, and economic factors probably contributed to these reduced inequalities. Furthermore, changes in infant mortality are only one proxy for the health benefits accrued by households from UHC, and combined with other limitations, suggest the inverse equity hypothesis might have little value when exploring UHC and infant mortality.

There are multiple potential explanations for this finding. Many UHC programmes were targeted towards poorer populations during early expansion (often focusing on RMNCH),[75,76] for example by expanding primary care services or introducing public insurance schemes for low-income populations.[76] Infant mortality in low-income populations might be more sensitive to expanded health-care coverage, even if approaches targeting poorer populations are not taken, because a large proportion of infant deaths in low-income populations are from easily treatable and preventable causes.[77] However, as UHC is expanded, there might be fewer easily treatable conditions, and persisting socioeconomic and health system barriers to high-quality care might play an increasing role for low-income populations. Evidence from Brazil suggests that the health effects from expanding primary care are partly dependent on timely access to secondary care and medical technologies.[78] Notably, in our study, the effects of the service capacity and access subindex of UHC on infant mortality were those that most benefitted the wealthiest quintile. The UHC index does not comprehensively assess the depth, breadth, quality, and costs of services, and these might be socially patterned, explaining the reduced effectiveness of UHC for poorer populations. At higher levels of UHC, it might also be more politically challenging to maintain schemes that benefit poorer populations, whereby middle-income and higher-income populations, who are more politically active and influential, can steer the targeting of schemes and services.[75,79]

What are the implications of these findings for the Sustainable Development Goal timeline? Few countries are at the incipient stages of UHC, where the majority of benefits for poorer populations can be accrued. In 2019, only two countries (Somalia and Chad) had a UHC coverage index of less than 30 and only 15 countries had an index of less than 40. Thus, although UHC schemes that benefit poorer populations have been important during early UHC expansion,[80] UHC expansion in many LMICs in the present day might be less beneficial to such populations. One explanation is that many countries have opted for contributory health insurance schemes to expand UHC, which often exclude low-income individuals, unemployed individuals, and informal workers.[33] Often, services such as RMNCH might be free of charge, yet more routine services might incur out-of-pocket fees. Additionally, the deep-rooted socioeconomic challenges, barriers to accessing services, and disparities in quality and coverage probably play larger roles as UHC increases beyond basic levels of population coverage.

This point is arguably a problematic position to be in, especially after the health equity setbacks that occurred as a result of the COVID-19 pandemic. Further increases in UHC in many LMICs might benefit low-income groups less, failing to alleviate the sizeable health inequalities and impoverishing financial health-care costs that persist within many countries.[81] Key areas for policy intervention include building strong and comprehensive primary health-care systems as a platform for UHC,[2,82] increasing sustainable UHC financing mechanisms with a higher allocation of funds to areas and populations with greater health needs,[83–85] incorporating equity as a clear objective in the financing and expansion of UHC, basing services and coverage on the concept of progressive universalism,[6,86] aligning local benefits and services of UHC with the target population's needs,[80] and introducing interventions and service adaptions to overcome socioeconomic, demographic, geographical, cultural, and ethnic barriers to high-quality UHC.[87] Health policies should aim to correct existing inequalities in coverage. An important prerequisite is to comprehensively map out the coverage, costs, and quality of different services and programmes, identifying which individuals are and are not covered. Lastly, there is a need for more robust, comprehensive evidence on who does and does not benefit from expanding UHC within LMICs, including better knowledge on the quality and depth of covered services as well as access and costs, disaggregated geographically and by socioeconomic groups.

The key limitations in this study should be acknowledged. The DHS data might be biased from recall bias and self-reporting, and there was potential undersampling of vulnerable or marginalised groups. Although we controlled for a range of individual-level, household-level, and country-level factors, and for unobservable time-invariant country-level factors, the estimated relationships can hardly be considered true causal estimates, since some sources of endogeneity and unmeasured confounding could not be controlled for. We only adjusted for 13 potential confounders. There was also potential for model mis-specification not identified by our robustness checks. WHO's UHC index is limited in the services it measures, and access and quality aspects were not measured in depth. The underlying data feeding into the index might have limitations, because they stem from household surveys and use imputation and linear interpolation. There was also the absence of validation of the index to measure a true picture of UHC in different countries. Specific definitions of UHC and the exact methods to achieve UHC also differ between countries,[88] and the use of the UHC index obscures differences in UHC packages and services, presenting only a rough average picture. Some of the tracer indicators in the index might not be uniformly relevant to all wealth quintiles (eg, tuberculosis, HIV, and malaria, which are higher among poorer populations), probably skewing the coverage of relevant services by different wealth quintiles. Unfortunately, wealth-quintile-specific measures of UHC were not available. Information on mother's wealth quintile and socioeconomic factors were relative to survey year, but the mortality data were analysed at the year of birth. However, changes in wealth quintile over time are unlikely to be strongly related to overall UHC, limiting potential bias. Socioeconomic status was established using wealth index quintiles, which are a survey-specific relative measure of wealth and are not comparable across countries and years. The harmonisation of wealth quintiles across countries in relative terms means extremely poor populations and marginalised groups (who might be excluded even from UHC schemes that generally benefit poorer populations) are amalgamated with low-income groups, obscuring the potential finding that they do not benefit from UHC. Lastly, the modelling approaches used to translate relative estimates into absolute measures assumed that the average AORs estimates were constant over countries and time, and the results should be interpreted with this in mind.

UHC expansion is associated with reductions in infant mortality in LMICs, but the distribution of benefits skewed towards higher-income populations indicates a challenging picture for UHC schemes. Although poor populations benefitted more in the early stages of UHC, this no longer appears to be the case. Moving beyond access and costs is essential to progressing UHC and leaving no-one behind, and a focus on socioeconomic, cultural, and health system barriers to high-quality health care is crucial.

Contributors

THo contributed to the conceptualisation, methodology, access to raw data, data verification, data curation, analysis, paper drafting, and reviewing and editing of the study. JG contributed to the conceptualisation, methodology, analysis, paper drafting, reviewing, editing, and had final responsibility for the decision to submit the study for publication. PS contributed to the conceptualisation, data curation, access to raw data, data verification, paper drafting, and reviewing and editing of the study. RM-S contributed to the conceptualisation, methodology, and reviewing and editing of the study. RR contributed to the methodology and reviewing and editing of the study. IG contributed to the conceptualisation and reviewing and editing of the study. VB contributed to the reviewing and editing of the study. THi contributed to the reviewing and editing of the study. CC contributed to the reviewing and editing of the study. MS contributed to the conceptualisation and reviewing and editing of the study. CM contributed to the conceptualisation and reviewing and editing of the study.

Equitable partnership declaration

The authors of this paper have submitted an equitable partnership declaration (appendix 2). This statement allows researchers to describe how their work engages with researchers, communities, and

See Online for appendix 2

environments in the countries of study. This statement is part of *The Lancet* journals' broader goal to decolonise global health.

Declaration of interests

All authors declare no competing interests.

Data sharing

All data used in this study are from publicly available sources (https://dhsprogram.com/Data/, https://databank.worldbank.org/, and https://www.who.int/data/gho/data/indicators/indicator-details/GHO/uhc-index-of-service-coverage).

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