Maternal mortality, stillbirths, and neonatal mortality:

a transition model based on analyses of 151 countries

Ties Boerma, Oona M R Campbell, Agbessi Amouzou, Cauane Blumenberg, Hannah Blencowe, Allisyn Moran, Joy E Lawn, Gloria Ikilezi

Abstract

Background

Maternal mortality, stillbirths and neonatal mortality account for almost 5 million deaths a year and are often analysed separately, despite having overlapping causes and interventions. We propose a comprehensive five-phase mortality transition model to improve analyses of past progress and inform strategic planning.

Methods

We used United Nations estimates for 151 countries to assess changes in maternal mortality, stillbirths and neonatal deaths. Based on ratios of maternal to stillbirth and neonatal mortality, we identified five phases of transition, in which phase I has the highest mortality. We used global databases to examine phase-specific characteristics during 2000-2020 for causes of death, fertility, abortion policies, , health workforce and financing, and socioeconomic indicators. We analysed 326 national surveys to assess service coverage and inequalities by transition phase.

Findings

Among 116 countries in phases I to IV in 2000, 73 (63%) progressed at least one phase by 2020, six advanced two phases and three regressed. The ratio of stillbirth and neonatal deaths to maternal deaths increased from less than 10 in phase I to well over 50 in phases IV and V. Progression was associated with a declining proportion of deaths due to infectious diseases and peri-partum complications, declining total and adolescent fertility rates, changes in health workforce densities and skills mix from phase III onward, increasing per capita health spending and reduced shares of out-of-pocket health expenditures. The median coverage of first antenatal care visits increased from 78% to 98%, four or more ANC visits from 48% to 90%, institutional births from 42% to 98%, and caesarean-section rates from 3% to 27%, from phase I to V, respectively. The transition in high mortality phases involved a major increase of births in lower-level health facilities, while subsequent progress was characterized by rapid increases in hospital births. Wealth-related inequalities reduced strongly for institutional birth coverage, including a shift from top to bottom inequality.

Interpretation

The five-phase maternal mortality, stillbirth and neonatal mortality transition model can be used to benchmark current situation at national or sub-national level, identify outliers to better assess drivers of progress, and inform strategic planning and investments towards SDG targets. It can also facilitate programming for integrated strategies to end preventable maternal mortality and neonatal mortality and stillbirths.

Research in context

Evidence before this study

Maternal mortality, stillbirth rates and neonatal mortality have been declining rapidly in the second half of the 20th century and most prominently during the last two to three decades. This paper fills a critical gap in our ability to understand the drivers of past progress, analyze the current situation, and develop more effective strategies in the context of the 2030 sustainable development goals.

Building upon the demographic and epidemiological transition theories, and previous work on an obstetric transition and neonatal mortality declines, we developed a comprehensive five-phase transition model for maternal, stillbirth and neonatal mortality, considering multiple characteristics including mortality patterns, causes of death, fertility, abortion policies, health systems, socio-economic progress, health service coverage and inequalities. We quantified phase-specific patterns as countries progress from high to low mortality, using national data from 151 countries, historical data, as well as more than 300 household surveys from low-and middle-income countries since 2000.

Added value of this study

This study is the first to integrate knowledge and evidence on drivers of the maternal, stillbirth and neonatal mortality trends in a single transition model. For each of the five phases of the high-to-low mortality transition, we identified common characteristics for the multiple dimensions, such as the role of infectious diseases as a cause of death, overall and adolescent fertility levels, health workforce density, coverage of births by all health facilities and by hospitals, and inequalities in service coverage and caesarean section. We provided typical values for each phase, which allow benchmarking of a country's current situation against common patterns based on the averaged experience of other countries at the same transition phase. The approach also provides a systematic tool to better understand drivers of progress during the last few decades and to inform strategic planning by comparing current indicators with common patterns in the subsequent transition phases.

Introduction

Maternal mortality, stillbirths and neonatal mortality are major global health issues with an estimated nearly 0.3 million maternal deaths, 2.4 million stillbirths and 2.0 million neonatal deaths annually in recent years.[1-3] In 1985, the neglect of maternal mortality within "maternal and child health" strategies was recognized and stimulated the global safe motherhood initiative.[4] Neonatal mortality gained more prominence about two decades later, when under-five mortality fell rapidly, but the proportion of neonatal deaths among these increased.[5] Stillbirths remain neglected to this day.[6] These three target groups each need specific attention, but integrated and synergistic approaches are also important.[7] Yet, they are usually analyzed as separate entities in global health. Mortality determinants are interconnected for pregnant women and their babies, as are underlying health conditions, interventions, and service-delivery platforms. An integrated mortality transition model is currently lacking.

Transition models have been used to portray changes in population and health outcomes. The demographic transition model from high to low mortality and fertility is characterized by a mortality decline preceding a fertility decline, resulting in a period of substantial population growth and major changes in population age-structure.[8 9] The epidemiological transition represents changes in the causes of mortality and morbidity from a predominance of acute communicable to chronic noncommunicable conditions, while all-cause mortality declines.[10 11] Both transition models segment changes over time into phases or stages.[12]

The obstetric transition model aims to understand maternal mortality reduction in countries.[13,14] It includes four phases with mortality thresholds of 1000, 300 and 50 maternal deaths per 100,000 live births. Lawn and colleagues used a similar approach to classify countries by neonatal mortality thresholds of 45, 30, 15, and 5 per 1,000 live births, to identify differences in fertility, causes of death, and service coverage indicators, though they did not describe their work as a transition model.[5,15-17]

We developed a combined model for a maternal, stillbirth and neonatal mortality transition with five phases, and assessed how causes of death, fertility, abortion policies, health system characteristics, service coverage and inequalities changed between phases and within-phase country distributions. The transition model aims to facilitate further integration of maternal, stillbirth and neonatal mortality analyses, provide a tool for benchmarking country progress, improve understanding of past mortality change and its drivers, and inform strategic planning and programming in countries and globally. The focus is on low- and middle-income countries, but historical and contemporary data from high-income countries were also used to describe the full transition.

Methods

Data

We combined the neonatal mortality rate (0-27 days of life) with stillbirths (late gestation fetal deaths from 28 weeks of pregnancy, as per the WHO definition for international comparisons) using the same denominator of total births (i.e., live births and stillbirths) into one measure (stillbirth and neonatal mortality). Maternal deaths, expressed per 100,000 live births in line with current practice, were kept separate because maternal deaths are several orders of magnitude rarer.

Our main analysis focused on national estimates for 151 countries with a population of at least 1 million in 2000. We used United Nations (UN) estimates for 2000-2020 for maternal mortality[1], stillbirths[2] and neonatal mortality.[3] Data on causes of death, fertility, abortion policies, health workforce, health financing, and socioeconomic indicators were extracted from a range of UN and World Bank databases. Details of the data sources are provided in Annex A. For health workforce data, we used period rates as there were many years with missing data and present those as 2002 (2000-2004) and 2018 (2016-2020), matched to the transition phase in those years. For service coverage indicators, including inequalities, and neonatal mortality rates by place of birth, we analyzed data from 326 all national Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) conducted during 2000-2020. We examined historical data with time series on maternal, stillbirth and neonatal mortality from today's high-income countries, as well as prospective research on the outcomes of pregnancy in higher mortality settings in South Asia and Africa (Annex B).

Mortality thresholds

We examined trends in the rate ratios of stillbirths to neonatal mortality, and of maternal to the sum of stillbirth and neonatal mortality (stillbirth+neonatal). Stillbirth rates and neonatal mortality are highly correlated in historical data, in prospective studies of pregnancy outcomes, and in global estimates (Annex B). The ratio of stillbirths to neonatal deaths generally ranged from 0.7-1.1 and was weakly correlated with levels of mortality, except at low levels of mortality when stillbirths became more prominent. We combined stillbirths and neonatal deaths into one measure (stillbirths+neonatal deaths per 1,000 births).

Maternal mortality ratios are highly correlated with stillbirth[18] and neonatal mortality rates. The ratio of stillbirth and neonatal deaths to maternal deaths increased from less than 20, to over 75 as mortality declined in the historical data and the UN estimates (Annex A). In prospective studies of pregnancy outcomes, the median ratio was 27 (IQR: 17-33) and the ratios did not vary systematically by mortality levels.[19,20]

Using thresholds from a published obstetric transition model as a starting point,[13] we reviewed historical data on maternal mortality from today's high-income countries. Prior to the 1930s, maternal mortality levels differed greatly between countries from about 300 per 100,000 live births in the Scandinavian countries and the Netherlands, to 500 in England and Wales and 700 in the United States.[21-23] Historical trends from Malaysia and Sri Lanka, both heralded as success stories in maternal health, support these thresholds.[24] We selected 700, 300, 100 and 20, where the lowest value indicated that a population was approaching elimination of all preventable maternal deaths. For stillbirth and neonatal mortality, we used the previously published neonatal mortality thresholds of 45, 30, 15 and 5 per 1,000 live births. These thresholds roughly corresponded to stillbirth+neonatal mortality of 80, 55, 30 and 15 or less per 1,000 births, respectively.

We combined these mortality thresholds into a five-phase transition model where phase I was characterized by the highest maternal and stillbirth+neonatal mortality levels ($\geq$700 and $\geq$80, respectively) and phase V by the lowest mortality levels (<20 and <15, respectively). The ratios of stillbirth+neonatal mortality to maternal mortality increased from 11 to 18, 30 and 75 in the phase I to V transition knots. A country was considered to have reached the next transition phase only when both mortality indicators passed the required thresholds.

Phase characteristics

As the transition progresses, changes in cause of death, fertility, health systems, service coverage and inequalities in coverage can be expected, based on theory and on historical and contemporaneous data. We examined these changes using multiple datasets of global estimates and household surveys.

A common cause of death structure is part of an integrated transition model. The main causes of maternal death,[25] stillbirth,[26] and neonatal death[27] were combined into three broad groups: infectious diseases (group 1, including abortion), causes related to the woman's or baby's health and nutritional status (group 2, including indirect causes for maternal deaths, prematurity and intrauterine growth restrictions), and peripartum complications (group 3) (Annex C). In historical data, the transition is characterized by declining importance of infectious diseases and, to a lesser extent, group 3 causes, while group 2 causes become more prominent.[23,24,28]

Regarding fertility, the demographic transition posits that the all-cause mortality decline precedes fertility decline. Historical data from Sri Lanka and Malaysia indicated that maternal and neonatal mortality were already declining before the onset of fertility decline.[24] A mutually reinforcing effect of mortality and fertility declines is likely, as fertility influences maternal, stillbirth and neonatal mortality risks by changes in the age-parity-birth interval distribution.[29] Fewer children may also contribute to increasing service coverage and quality, and have a generational effect on health and nutrition of women. We analyzed long term trends of fertility and neonatal mortality from 1960 onward. Such trends were not available for stillbirths or maternal mortality trends in most countries. For abortion policies, we generated a score based on five legal grounds for abortion, where the lowest score indicated that abortion was not permitted in any circumstances and the highest score that abortion is available on demand (Annex A).

To assess changes in health systems, we considered phase-specific changes in total health expenditure per capita, total health expenditure as a percent of GDP, and out-of-pocket expenditure as a percent of total health expenditure, as well as density of core health professionals (physicians, nurse-midwives) and skills mix (nurse-midwives to physicians).

Historical data also provided evidence of the association between coverage of institutional delivery care with mortality.[21-24,30] We examined the trends in antenatal care visits (first visit (ANC-1), and four or more visits (ANC-4)), institutional births, and caesarean section by phase based on the household surveys. For institutional births, we further analyzed coverage mortality by place of birth (hospital, lower-level health facilities, home).

Empirical data on social inequalities in the timing and pace of the epidemiological transition within countries have shown considerable heterogeneity.[31-34] We assessed inequalities in institutional birth coverage by wealth quintiles, focusing on the absolute gaps and the wealth-related inequality patterns by phase. We used the inequality patterns index, defined as the difference between the gap of bottom and top quintiles with the national mean and explored transitions from top (only the richest have relatively high coverage) to linear and bottom inequality (the poorest are left behind).[35] In addition, we analysed C-sections per 1000 live births among the poorest and richest wealth quintiles by phase. Finally, we assessed the extent to which socioeconomic changes occur concurrently with the mortality transition. using per capita income and female education levels.

All analyses were conducted in Stata 17.0 and Microsoft Excel.

Ethical clearance

All data used in this study are in the public domain. No ethical clearance was required.

Results

Figure 1 shows the transition phases with UN country mortality estimates for 2000 and 2020. In 2000, 21 of the 151 countries (14%) were in phase I, of which 18 were in sub-Saharan Africa, and 29 (19%), 34 (23%), 32 (21%) and 36 (23%) in phases II to V, respectively. By 2020, the number of phase I countries were y five (3%), while 23 (15%), 32 (21%), 42 (28%) and 49 (32%) countries were in phases II to V, respectively. The ratios of stillbirth+neonatal deaths to maternal deaths increased from 10 or less in phase I to 50 and over 70 in IV and V, respectively (Figure 2A).

Among the 116 countries in phases I to IV in 2000, 73 (63%) progressed at least one phase during 2000-2020. Six countries progressed two phases: Angola, Bangladesh, Ethiopia, Kazakhstan, Rwanda and Tanzania. Three countries reversed one phase: United States, Venezuela, and Vietnam, all because of increases in maternal mortality. Country-specific data are shown in Annex C.

We also classified countries based on the lower and upper bounds of the uncertainty ranges of the mortality estimates. This results in markedly different distributions of countries by phase, with a mean difference of 0.5 and 0.6 phase between the lower and upper bounds in 2000 and 2020, respectively. (Annex C).

Among neonates, cause-of-death distributions differed by transition phase: group 2 causes became more prominent (from 41% in phase I to 72% in phase V), while group 1 (24% to 6%) and group 3 (26% to 13%) less so (Figure 2B). For maternal mortality, only a modest decrease in the relative importance of group 1 causes, and group 3 (peri-partum causes) was observed in global estimates (Annex D).

There was a strong association between total fertility rate and transition phase. The country median for total fertility rate in 2000 was 6.1 in phase I (IQR: 5.8-6.9), declining to 5.35 (4.0-5.8), 2.8 (2.0-3.5), 2.2 (1.6-2.7) and 1.5 (1.4-1.8) in the subsequent phases. Fertility by transition phase in 2020 showed a similar pattern (Figure 2C). Adolescent fertility also declined from levels over 100 births per 1,000 women aged 15-19 years in phase I and II, to about 60 in phase III, 40 in phase IV and about 15 in phase V, in both 2000 and 2020 (Figure 2D).

In low- and middle-income countries with neonatal and fertility trend data before 1980, the neonatal mortality declines either preceded or ran in parallel to the fertility declines. For instance, 59 of 62 countries with data for both indicators from 1970-74 already had ongoing neonatal mortality declines. Among these 59 countries, 45 (76%) had contemporaneous fertility declines and 14 (24%) had not yet had a fertility decline (Annex E).

The abortion policy score was lowest (most restrictive) in phase I and highest (most permissive) in phase V, gradually increasing from scores of 51% and 40% in phase I to 68% and 59% in phase III and 86% and 91% in phase V, in 2000 and 2021, respectively (Annex A and F),

Both gross national income (GNI) per capita and female education levels, measured by gross female secondary enrollment, increased strongly by phase in 2000 and 2020 (Annex F). Income increased most prominently from phase III. Gross secondary enrollment among females increased dramatically during the first three phases, doubling from phase I to II and again from II to III, reaching 75%.

Total health expenditure per capita in 2020 was as below US $45 in the first two phases and then nearly doubled in countries in phase III and again tripled in phase IV to over US $300 per capita (Figure 3A). Government spending on health remained 4-5% in the first three phases and increased in phase IV to 6.7% (Figure 3B). Out-of-pocket spending was higher in the early phases but the large variability between countries in phases II to IV was notable (Figure 3C). Annex E compares the results for 2000 and 2020.

The median density of core health professionals was low in the first two phases (4 and 8 per 10,000 population), increased to 20 and 43 in phases III and IV, respectively (Figure 3D). The transition was initially associated with greater increases in nurses-midwives than physicians (ratio nurse-midwives to physicians was 4 to 6 phase I and II, in both 2002 and 2018) but subsequently the ratio declined to less than 2 in phase IV. A notable change occurred in phase III where the median skills mix was 2.0 (IQR: 1.5-3.6) in 2002 but a higher country median of 4.5 with a much wide interquartile range (1.8-7.1) in 2018, suggesting greater diversification of human resource strategies in recent years. (Figure 3E and 3F).

Based on surveys during 2000-2020, median coverage of ANC-1 increased from 66% to 98%, ANC-4 from 44% to 94%, institutional deliveries from 36% to 99%, and caesarian-section rates from 2% to 25% during phase I to V (Figure 4A-4D). Rapid increases occurred early in the transition (ANC-1), throughout from phase I-IV (institutional births) and in the middle phases (ANC-4 and caesarean-sections) (Annex H).

The distribution of institutional births between hospitals and lower-level facilities varied by phase (Figure 4E and 4F). Hospital births became more prominent as coverage increased across phases. The transition from phase I to II primarily involved a major increase of births in lower-level health facilities but not in subsequent phases. The progression from phase III into IV and V was associated with major increases in hospital births to near universality (Annex H).

The absolute gaps in institutional births coverage between the poorest and richest wealth quintile were largest in the early phases of the transition, reduced marginally between phases I to III, and rapidly between III and IV: from a difference of 50 to 7 percentage points (Figure 5A). The pattern of inequality by wealth changed from top inequality in phase I and II, to bottom inequality in III and IV Annex G)..

Caesarean-section rates among the poorest were below 1% in phase I, and still below 2% in phase II. A major increase occurred from phase III to IV (from 4% to 15%, Figure 5B). Among the richest the main increase took place earlier from phase II to III (from 10% to 28%).

Discussion

The utility of a transition model depends on whether it is possible to identify meaningful phases in the transition, and whether those phases have a set of characteristics that help understand past changes, current situations and facilitate planning of future strategies. We showed that it is possible to develop a combined transition model for maternal and neonatal mortality, and stillbirths. The big picture of the transition is intuitive and aligned with other transition theories.[31-33]

As maternal and stillbirth+neonatal mortality decline, there were reductions in the relative share of infectious diseases and peri-partum complications as a cause of death, and in adolescent and total fertility, as well as major improvements in health systems and service coverage, overall and among the poorest. The phase-specific characteristics were independent of time as the effects were remarkably similar in 2000 and 2017.

Deliveries in smaller health facilities played a major role in the initial transition phases, but from phase III hospital deliveries became predominant. In the last two phases, the majority (but not all) of women and babies were reached with quality interventions in higher level facilities, and over-intervention, notably non-medically indicated caesarean sections, could be a challenge.[36] The 2030 mortality targets of the Sustainable Development Goals lie within phase IV which is still a long way for many countries with the pace of progress achieved during the last two decades.[37,38]

A transition model allows the identification of outlying countries. Some countries have atypical combinations of maternal and stillbirth+neonatal mortality, which should lead to further investigation of data quality and, if the data are valid, the reasons for the aberrant mortality patterns. This approach can be taken further to assess whether a country's characteristics of mortality (cause-of-death patterns, fertility, health system, coverage, inequalities, and socioeconomic development) are typical (within the interquartile range) for a particular phase. In Annex H we have provided these median and quartile values obtained from our multi-country analyses. There are three applications for this approach. First, it allows benchmarking of a country's current situation against common patterns based on the averaged experience of other countries at the same transition phase. Second, it provides a tool to assess potential drivers of progress by comparing country indicators with a previous phase during the last 2-3 decades. Third, the transition model informs strategic planning by comparing current indicators with common patterns in the subsequent transition phases.

It is beyond the scope of this paper to discuss the multiple implications of a complex mortality transition, but one example stands out. The shift from predominance of home deliveries to lower-level health facilities (health centers and below) and then to hospitals (which are more likely to be capable of providing comprehensive emergency obstetric care and small and sick neonatal care) is a central element of the transition. Almost all countries that transited from phase I to II and early III with major increases in coverage of antenatal and institutional birth services in lower-level health facilities need further dialogue on delivery strategies to move to subsequent phases and achieve global mortality targets.[39,40] Facility birth *per se* does not necessarily convey a survival benefit, emphasising the importance of adequate capacity to deliver emergency obstetric and newborn care.[41] An effective referral system may bridge across some delivery platforms if geographical barriers are minimal and infrastructure is advanced, but a much greater prioritization of hospital deliveries is an essential correlate for further mortality reductions. More embedded research on this subject is urgently required to inform country strategies.

There are several limitations of the model. The metric of stillbirths+neonatal mortality was introduced to counter some of the unnatural fragmentation in the field of maternal and newborn health. The availability of national neonatal mortality data and time trends is better than for stillbirths. The use of neonatal mortality alone is a viable alternative, using the same transition phases with the neonatal mortality rate cut-offs of 45, 30, 15 and 5 per 1,000 live births. The thresholds between phases are, to some extent, arbitrary, with only some having good evidence, such as the correspondence of the widespread adoption of neonatal intensive care with neonatal mortality rates of 15 per 1,000 live births or below.[42] We combined historical and contemporary data, thresholds from previous publications on maternal and neonatal mortality, and the ratio maternal to stillbirth+neonatal mortality to define the thresholds for the phase transitions. The phases should be interpreted as indicative, to help assess country situation, progress and future strategies.

Similarly, the transition model should not be interpreted as a unidirectional uniform pathway towards mortality reduction. Heterogeneity in pathways, counter-transitions and variation in pace and drivers of progress are common features of all transition models.[1] Our model intends to help recognize such developments and support strategy debates for appropriate action.

Another caveat relates to the quality of mortality data. In the absence of reliable death registration systems, most low- and middle-income estimates are primarily based on household surveys with sibling survival histories for maternal mortality,

and birth and reproductive histories for stillbirth and neonatal mortality rates. Data availability and quality is a major issue. Stillbirths are often heavily underreported in surveys, and misclassification of stillbirths and neonatal deaths is also a concern.[43,44] Neonatal death reporting is generally more complete, though omission and misclassification is a problem in some surveys.[45] Cause-of-death information is poor in most countries for maternal deaths, stillbirths, and neonatal deaths, and much needs to be done to obtain reliable trend information.

We used the UN estimates of mortality to classify countries. These estimates have large uncertainty intervals, especially maternal mortality, and we showed how the difference between lower and upper mortality bounds leads to, on average, half a phase difference. The use of common covariates in the global estimation models for maternal mortality and stillbirths (e.g., using neonatal mortality as a co-variate for stillbirth rates estimates) affects correlations between these outcomes. The strong associations between the mortality indicators in empirical studies is however reassuring. Given the mortality data limitations, the transition model may also be used as a tool to check data quality. Atypical consistency between mortality estimates should prompt further data quality considerations. Major outlying observations related to the components of the model, such as fertility or coverage of interventions, should also lead to queries of the mortality data used to classify a country according to transition phase.

In conclusion, the maternal, stillbirth and neonatal mortality transition model provides a mechanism to understand change, benchmark current status, and inform strategy development, as well as data quality improvement, for countries and globally. Our model brings together maternal, stillbirth and neonatal mortality perspectives, including mortality levels and trends, cause of death, fertility, health systems, coverage, inequalities and general development, to inform efforts to sustain and accelerate of country progress.

Acknowledgement

This work was conducted as part of the Maternal and Newborn Health Exemplars study, which is supported by Global Health Exemplars initiative of Gates Ventures, and the work of the Countdown to 2030 for Women's, Children's and Adolescents' Health, supported by the Bill & Melinda Gates Foundation.

Contributions

TB, OC, AA and GI conceptualized the paper. TB and CB were responsible for the analyses. TB produced the first draft in close collaboration with OC and AA. All authors provided inputs on multiple drafts and approved the final version.

Conflict of interest

The authors report no conflict of interest.

References

1. World Health Organization. Trends in maternal mortality 2000 to 2020: estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division. February 2023.
2. Hug L, You D, Blencowe H, Mishra A, et al. Global, regional, and national estimates and trends in stillbirths from 2000 to 2019: a systematic assessment. Lancet. 2021;398(10302):772-785.
3. Sharrow D, Hug L, You D, et al. Global, regional, and national trends in under-5 mortality between 1990 and 2019 with scenario-based projections until 2030: a systematic analysis by the UN Inter-agency Group for Child Mortality Estimation. Lancet Glob Health. 2022 Feb;10(2):e195-e206.
4. Rosenfield A, Maine D. Maternal mortality--a neglected tragedy. Where is the M in MCH? Lancet. 1985 Jul 13;2(8446):83-5.
5. Lawn JE, Cousens S, Zupan J; Lancet Neonatal Survival Steering Team. 4 million neonatal deaths: when? Where? Why? Lancet. 2005 Mar 5-11;365(9462):891-900.
6. Matthews Z, Horton R. Bringing stillbirths out of the shadows. Comment. Lancet 2011, 377:1291-92.
7. Goldenberg RL, McClure EM. Maternal, fetal and neonatal mortality: lessons learned from historical changes in high income countries and their potential application to low-income countries. Matern Health Neonatol Perinatol, 2015 Jan 22; 1: 3.
8. Caldwell JC, Caldwell BK, Caldwell P, McDonald PF, Schindlmayr T. *Demographic Transition Theory*. Dordrecht, The Netherlands: Springer. 2006.
9. Kirk D. Demographic transition theory. Popul Stud 1996; 50: 36187.
10. Omran AR. An epidemiologic transition: a theory of the epidemiology of population change. Milbank Mem Fund Q 1971; 49: 50938.
11. Salomon J, Murray C. The epidemiologic transition revisited: compositional models for causes of death by age and sex. Pop Dev Rev 2002, 28:205-228.
12. Bongaarts J, Watkins SC. Social interactions and contemporary fertility transitions. Pop Dev Rev 1996, 22: 639-682.
13. Souza JP, Tunçalp Ö, Vogel JP, et al. Obstetric transition: the pathway towards ending preventable maternal deaths. BJOG. 2014;121 Suppl 1:1-4.
14. Chaves S da C, Cecatti JG, Carroli G, et al. Obstetric transition in the World Health Organization Multicountry Survey on Maternal and Newborn Health: exploring pathways for maternal mortality reduction. Rev Panam Salud Publica. 2015 May;37(4-5):203-10.
15. Lawn JE, Blencowe H, Oza S, et al. Every Newborn: progress, priorities, and potential beyond survival. Lancet 2014; 384(9938):189-205.
16. Lawn JE, Kinney M, Lee AC, et al. Reducing intrapartum-related deaths and disability: can the health system deliver? Int J Gynaecol Obstet. 2009;107 Suppl 1: S123-42
17. Lawn JE, Kinney MV, Belizan JM, Mason EM, McDougall L, Larson J, Lackritz E, Friberg IK, Howson CP; Born Too Soon Preterm Birth Action Group. Born too soon: accelerating actions for prevention and care of 15 million newborns born too soon. Reprod Health. 2013;10 Suppl 1(Suppl 1):S6.
18. McClure EM, Goldenberg RL, Bann CM. Maternal mortality, stillbirth and measures of obstetric care in developing and developed countries Int J Gynaecol Obstet. 2007;96:139-46.
19. Goudar SS, Goco N, Somannavar MS, et al. Institutional deliveries and stillbirth and neonatal mortality in the Global Network's Maternal and Newborn Health Registry. Reprod Health. 2020;17(Suppl 3):179.
20. Alliance for Maternal and Newborn Health Improvement (AMANHI) mortality study group. Population-based rates, timing, and causes of maternal deaths, stillbirths, and neonatal deaths in south Asia and sub-Saharan Africa: a multi-country prospective cohort study. Lancet Glob Health. 2018;6(12):e1297-e1308.
21. Loudon I. The transformation of maternal mortality. BMJ 1992; 305(6868): 1557-60.
22. Loudon I. Maternal mortality in the past and its relevance to developing countries today. Am J Clin Nutr. 2000;72 (1 Suppl): 241S-246S
23. De Brouwere V, Tonglet R, Van Lerberghe W. Strategies for reducing maternal mortality in developing countries: what can we learn from the history of the industrialized West? Trop Med Int Health 1998; 3(10): 771-82.

24. Pathmanathan I, Liljestrand J, Martins JM et al. Investing in Maternal Health: *Learning from Malaysia and Sri Lanka.* World Bank Health Population Nutrition Series. 2003: Washington DC.
25. Say L, Chou D, Gemmill A, Tunçalp Ö, Moller AB, Daniels J, et al. Global causes of maternal death: a WHO systematic analysis. Lancet Glob Health 2014;2(6):e323-33.
26. Lawn JE, Blencowe H, Waiswa P, Amouzou A, Mathers C, Hogan D, et al. Ending Preventable Stillbirths Series study group; Lancet Stillbirth Epidemiology investigator group. Stillbirths: rates, risk factors, and acceleration towards 2030. Lancet. 2016 Feb 6;387(10018):587-603.
27. Perin J, Mulick A, Yeung D, Villavicencio F, Lopez G, Strong KL, et al. Global, regional, and national causes of under-5 mortality in 2000-19: an updated systematic analysis with implications for the Sustainable Development Goals. Lancet Child Adolesc Health 2022;6(2):106-115.
28. McCaw-Binns AM, Campbell LV, Spence SS. The evolving contribution of non-communicable diseases to maternal mortality in Jamaica, 1998-2015: a population-based study. BJOG. 2018 Sep;125(10):1254-1261.
29. Jain AK. Measuring the effect of fertility decline on the maternal mortality ratio. Stud Fam Plan 2011, 42(4): 247-260.
30. Kaunitz, Andrew M ; Spence, Craig et al. Perinatal and maternal mortality in a religious group avoiding obstetric care. Am J Obs Gyn 1984, 150 (7), 826-831.
31. Santosa A, Wall S, Fottrell E, Högberg U, Byass P. The development and experience of epidemiological transition theory over four decades: a systematic review. Glob Health Action. 2014; 7:23574.
32. Frenk J, Bobadilla JL, Stern C, Frejka T, Lozano R. Elements for a theory of the health transition. Health Trans Rev 1991; 1: 21-38.
33. Caldwell JC, Caldwell P. What have we learnt about the cultural, social and behavioural determinants of health? From selected readings to the first Health Transition Workshop. Health Trans Rev 1991; 1: 3-19.
34. Kahn K, Garenne ML, Collinson MA, Tollman SM. Mortality trends in a new South Africa: hard to make a fresh start. Scand J Public Health Suppl 2007; 69: 26-34.
35. Victora CG, Joseph G, Silva ICM, Maia FS, Vaughan JP, Barros FC, Barros AJD. The Inverse Equity Hypothesis: Analyses of Institutional Deliveries in 286 National Surveys. Am J Public Health. 2018;108(4):464-471.
36. Miller S, Abalos E, Chamillard M, Ciapponi A, Colaci D, Comandé D, et al. Beyond too little, too late and too much, too soon: a pathway towards evidence-based, respectful maternity care worldwide. Lancet. 2016 Oct 29;388(10056):2176-2192.
37. Sustainable Development Goal 3: Health. http://www.who.int/topics/sustainable-development-goals/targets/en/ (accessed September 8 2022)
38. WHO, UNICEF. Every Newborn: an action plan to end preventable deaths. Geneva: World Health Organization, 2014.
39. Campbell OM, Calvert C, Testa A, et al. The scale, scope, coverage, and capability of childbirth care. Lancet. 2016;388(10056):2193-2208.
40. Roder-DeWan S, Nimako K, Twum-Danso NAY, *et al*. Health system redesign for maternal and newborn survival: rethinking care models to close the global equity gap. *BMJ Global Health* 2020;5:e002539.
41. Gabrysch S, Nesbitt RC, Schoeps A, et al. Does facility birth reduce maternal and perinatal mortality in Brong Ahafo, Ghana? A secondary analysis using data on 119 244 pregnancies from two cluster-randomised controlled trials. Lancet Glob Health. 2019 Aug;7(8):e1074-e1087.
42. Darmstadt GL, Bhutta ZA, Cousens S, et al.; Lancet Neonatal Survival Steering Team. Evidence-based, cost-effective interventions: how many newborn babies can we save? Lancet. 2005 Mar 12-18;365(9463):977-88.
43. Blencowe H, Bottecchia M, Kwesiga D, et al. Stillbirth outcome capture and classification in population-based surveys: EN-INDEPTH study. Popul Health Metr. 2021 Feb 8;19(Suppl 1):13.
44. Liu L, Kalter HD, Chu Y, et al.. Understanding misclassification between neonatal deaths and stillbirths: empirical evidence from Malawi. PLoS One. 2016 Dec 28;11(12):e0168743.
45. Hill K, Choi Y. Neonatal mortality in the developing world. Dem Res 2006, 14: 429-452.

[1] Frenk J, Bobadilla JL, Stern C, Frejka T, Lozano R. Elements for a theory of the health transition. Health Transit Rev. 1991 Apr;1(1):21-38.