Maternal Health in the Perinatal Period and Beyond 1

A global analysis of the determinants of maternal health and transitions in maternal mortality

João Paulo Souza, Louise Tina Day, Ana Clara Rezende-Gomes, Jun Zhang, Rintaro Mori, Adama Baguiya, Kapila Jayaratne, Alfred Osoti, Joshua P Vogel, Oona Campbell, Kidza Y Mugerwa, Pisake Lumbiganon, Özge Tunçalp, Jenny Cresswell, Lale Say, Allisyn Carol Moran, Olufemi T Oladapo

The reduction of maternal mortality and the promotion of maternal health and wellbeing are complex tasks. This Series paper analyses the distal and proximal determinants of maternal health, as well as the exposures, risk factors, and micro-correlates related to maternal mortality. This paper also examines the relationship between these determinants and the gradual shift over time from a pattern of high maternal mortality to a pattern of low maternal mortality (a phenomenon described as the maternal mortality transition). We conducted two systematic reviews of the literature and we analysed publicly available data on indicators related to the Sustainable Development Goals, specifically, estimates prepared by international organisations, including the UN and the World Bank. We considered 23 frameworks depicting maternal health and wellbeing as a multifactorial process, with superdeterminants that broadly affect women's health and wellbeing before, during, and after pregnancy. We explore the role of social determinants of maternal health, individual characteristics, and health-system features in the production of maternal health and wellbeing. This paper argues that the preventable deaths of millions of women each decade are not solely due to biomedical complications of pregnancy, childbirth, and the postnatal period, but are also tangible manifestations of the prevailing determinants of maternal health and persistent inequities in global health and socioeconomic development. This paper underscores the need for broader, multipronged actions to improve maternal health and wellbeing and accelerate sustainable reductions in maternal mortality. For women who have pregnancy, childbirth, or postpartum complications, the health system provides a crucial opportunity to interrupt the chain of events that can potentially end in maternal death. Ultimately, expanding the health sector ecosystem to mitigate maternal health determinants and tailoring the configuration of health systems to counter the detrimental effects of eco-social forces, including though increased access to quality-assured commodities and services, are essential to improve maternal health and wellbeing and reduce maternal mortality.

Lancet Glob Health 2024; 12: e306–16

Published Online December 6, 2023 https://doi.org/10.1016/S2214-109X(23)00468-0

See Comment page e185

This is the first in a Series of four papers about maternal health in the perinatal period and beyond, to be published in conjunction with *eClinical Medicine*. All papers in the Series are available at www.thelancet.com/series/maternal-perinatal-health

Department of Social Medicine, Ribeirao Preto Medical School, University of São Paulo, São Paulo, Brazil (Prof J P Souza MD, A C Rezende-Gomes MSc); **BIREME, Department of Evidence and Intelligence for Action in Health, Pan American Health Organization (PAHO)–World Health Organization Americas Regional Office, São Paulo, Brazil** (Prof J P Souza); **Department of Infectious Disease Epidemiology and International Health, London School of Hygiene & Tropical Medicine, London, UK** (L T Day MRCOG, Prof O Campbell PhD); **Ministry of Education and Shanghai Key Laboratory of Children's Environmental Health, Xinhua Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China** (Prof J Zhang MD); **Graduate School of Medicine, Kyoto University, Kyoto, Japan** (Prof R Mori MD); **Kaya Health and Demographic Surveillance System (Kaya-HDSS), Research Institute for Health Sciences (IRSS), Ouagadougou, Burkina Faso** (A Baguiya MD); **Family Health Bureau, Ministry of Health, Colombo, Sri Lanka** (K Jayaratne MD); **Department of Obstetrics, University of Nairobi, Nairobi, Kenya** (A Osoti MD); **Department of**

Introduction

In 2015, world leaders committed to promoting peace, prosperity, health, and global cooperation to ensure the sustainability of human civilisation by setting the Sustainable Development Goals (SDGs).[1] However, emerging priorities, such as the COVID-19 pandemic with its evolving consequences, the pressing climate emergency, conflicts, and political instabilities, have competed for attention and resources.[2–5] In this context, previous and persistent challenges, such as maternal mortality, risk being neglected.[5,6] At the halfway mark to 2030, the goal of reaching a global maternal mortality ratio (MMR) of 70 maternal deaths per 100 000 livebirths remains elusive, with 223 maternal deaths per 100 000 livebirths reported in 2020. This figure is much less than the MMR for 2000, which was 339 maternal deaths per 100 000 livebirths. However, since 2016, the MMR has decreased in only two regions: central and south Asia, and Australia and New Zealand. Sub-Saharan Africa, Oceania (excluding Australia and New Zealand), east and southeast Asia, and north Africa all experienced a stagnation in the MMR. During this time period, the MMR increased in Europe, North America, Latin America, and the Caribbean.[6]

The reported stagnation in global MMR is an urgent matter: an estimated 287 000 women died from causes related to pregnancy, childbirth, and the postpartum period in 2020 alone.[6] The preventable loss of almost 3 million lives of women between 2010 and 2020 is not only a global tragedy, but also an indicator of gross health inequality between and within countries and a flagrant human rights violation.[7,8] Despite the large gains made in many countries in terms of improved agency, education, employment, and fertility desires for women, these advances have not been universal—most maternal deaths remain preventable and are largely clustered among groups of socioeconomically disadvantaged women. Disease outbreaks, conflicts, and other public health emergencies aggravate the situation by increasing the risk of pregnancy complications, disrupting health systems, and posing additional constraints to maternal and perinatal healthcare.[9]

The most common approach to tackling maternal mortality by the global community has been to direct investments to address the leading biomedical causes of maternal death, particularly during the perinatal period. Compared with biomedical causes, less attention has been paid to the underlying determinants of adverse pregnancy and childbirth outcomes and how health systems could be configured to implement effective interventions and mitigate the adverse effects of social factors on maternal

Key messages

- Maternal health is a social issue: maternal ill-health and disability are not just medical problems, but outcomes of a complex interplay of eco-social forces, lifestyles and exposures, and individual-level factors
- Focusing solely on biomedical causes of maternal mortality is insufficient, and has possibly been the cause of many countries remaining at the same maternal mortality transition stage for decades (121 out of 185 countries analysed have been in the same maternal mortality transition stage for 20 years)
- Addressing maternal health issues and reducing maternal mortality are complex endeavours, due to both modifiable and unmodifiable factors that affect outcomes; a broad, multipronged approach, including promotion of social development and gender equality at national level, will be necessary to tackle determinants that act upstream in the chain of events that leads to severe morbidity and death
- The health sector has a crucial role in saving the lives of women with pregnancy, labour, or postpartum complications, and should be expanded to mitigate the detrimental effects of maternal health determinants
- Expanding demand for and access to high-quality reproductive health services and commodities (including safe abortion, modern contraception, and antenatal, intrapartum, and postpartum care) are needed for primary prevention, early identification, and adequate management of pregnancy, labour, and postpartum complications
- Achieving universal health coverage is essential to ensure access to quality care during pregnancy, childbirth, and the postpartum period, and to reduce maternal mortality

Global Health, University of Washington, Seattle, WA, USA (A Osoti)**; Maternal, Child and Adolescent Health Program, Burnet Institute, Melbourne, VIC, Australia** (Prof J P Vogel MD)**; Department of Obstetrics and Gynecology, Makerere University, Kampala, Uganda** (K Y Mugerwa MD)**; Department of Obstetrics & Gynecology, Khon Kaen University, Khon Kaen, Thailand** (Prof P Lumbiganon MD)**; UNDP–UNFPA–UNICEF–WHO–World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP), Department of Sexual and Reproductive Health and Research** (Ö Tunçalp MD, J Cresswell PhD, L Say MD, O T Oladapo MD) **and Department of Maternal, Newborn, Child, Adolescent Health and Ageing** (A C Moran PhD)**, World Health Organization, Geneva, Switzerland**

Correspondence to: Prof João Paulo Souza, Department of Social Medicine, Ribeirao Preto Medical School, University of São Paulo, São Paulo 14049-900, Brazil
jp.souza@usp.br

See Online for appendix

health. Although pre-existing medical conditions (eg, chronic anaemia, chronic hypertension, diabetes) are a growing concern, direct obstetric complications (such as postpartum haemorrhage, pre-eclampsia, and infection) remain the leading biomedical causes of maternal mortality.[10] The necessary technologies, commodities, and services to effectively reduce maternal mortality already exist. Mortality could be substantially reduced if quality-assured maternal health commodities and services were consistently available, and if unwanted pregnancies were prevented in the first place by increasing access to modern contraception.[11,12]

However, an exclusive focus on maternal mortality could be restrictive because surviving pregnancy is no longer sufficient to achieve the global targets related to maternal health.[13–16] Beyond survival, the focus in maternal health is evolving, towards promoting health and wellbeing across the life course. This expanded focus requires a holistic and integrative approach, centred on a positive experience of care.[14–16] The integrative efforts towards the SDGs are intentionally designed to converge and align with this broader vision for maternal health—a world in which all women have the highest possible level of health and wellbeing during pregnancy and beyond. Therefore, a rapid acceleration of global efforts to improve maternal health is required if the SDG targets are to be met by 2030, and the promise of a better world for all is to be realised.[6,17]

For this first paper in the Series on maternal health in the perinatal period and beyond, we conducted a systematic analysis of the determinants of maternal health and factors associated with maternal mortality, and examined the relationship between these determinants and the gradual shift over time from a pattern of high maternal mortality to a pattern of low maternal mortality, a phenomenon described as the obstetric transition or maternal mortality transition.[18,19] The appendix presents the methods used in this analysis, together with additional information. Our aim was to provide a broad, overarching conceptualisation of distal and proximal determinants that shape maternal health outcomes, to enable an informed reflection on the appropriate strategies to accelerate countries' transition from high to low maternal mortality burden stages. We hope this paper—together with the other papers in the Series on vulnerability during pregnancy, childbirth, and the postpartum period,[20] neglected medium-term and long-term complications following labour and childbirth,[21] and an intersectional approach to address maternal health inequities[22]—highlights often overlooked, yet crucial, pathways to accelerate progress to end preventable maternal deaths and improve maternal health and wellbeing. In this paper, the terms "woman" and "women" are used to reflect all populations with the reproductive capacity for pregnancy and birth, including transgender and gender-diverse people, as well as adolescent girls.

Maternal health as the product of a multifactorial process

We reviewed the literature for conceptual frameworks of the determinants of maternal health (appendix p 3). We identified 23 frameworks portraying maternal health and wellbeing as the result of a multifactorial process (appendix p 5). The core themes or elements commonly found in the included frameworks are summarised in the figure. This figure presents a high-level illustration of a health production process, in which eco-social forces (ie, elements of the superdeterminants and social determinants described in the next section) and contexts, as well as individual-level factors and lifestyle patterns, substantially contribute to maternal health and wellbeing. The panel lists the core themes we identified, informed by our multisource literature review; it maps the factors associated with maternal mortality and severe morbidity (appendix p 8). In the following sections, we use the factors identified from this literature review to further describe and elaborate on the connections and interdependencies of the key forces illustrated in the figure.

Superdeterminants and social determinants of maternal health

The superdeterminants of maternal health are the underlying contexts and forces that broadly influence the health and wellbeing of women before, during, and after pregnancy.[24] These mutually interacting superdeterminants include the characteristics of the biosphere (eg, climate, ecosystem), biological features of the human species (eg, the endocrinology of human

parturition and the anatomy of the female pelvis), and the economic, political, and cultural bases of societies (eg, health insurance policies and health budgetary allocations, health-care policies and legislations on reproductive rights and access to care, societal norms and expectations related to gender roles and cultural beliefs surrounding pregnancy and childbirth).[25–34] The evolution of modern humans, *Homo sapiens*, has largely been shaped by the characteristics of the environment. This evolution is an ongoing process driven by natural selection and other mechanisms, in which traits and characteristics that offer advantages for survival and reproduction become sustained in populations over time.[35] Characteristics, such as the shape of the female pelvis and the complex endocrinology of human parturition, which underlie the biological and physiological bases of pregnancy, labour, and childbirth, are responsible for reproductive success (as well as challenges) that persist across generations.[28–33] Adaptation to different environmental challenges over time encouraged the development of social structures and cooperative behaviours, culminating in a diverse range of cultural practices, social norms, political structures, and economies across different contexts.[36,37] As the dominant species on the planet, the activities of humans over time, such as deforestation, industrialisation, and pollution, have had profound effects on the environment. These behaviours have led to disruptions in ecosystems, loss of biodiversity, escalating and more frequent climate events (such as heat waves, droughts, and floods), and the emergence of new health threats, including zoonotic diseases (eg, COVID-19), all with detrimental effects on maternal survival and wellbeing.[25,37–41] Although applicable to other health areas, the combination of intrinsic biological and behavioural characteristics of human beings, the manifestations of human interactions with the environment, and society's cultural, political, and economic adaptations are superdeterminants with substantial effects on maternal and perinatal health.[24]

The social determinants of health are derived from economic, political, and cultural superdeterminants, and are defined as the non-biomedical factors that influence health risks and outcomes throughout life.[34] With regard to maternal health, social determinants of health are the conditions in which women are born, grow, work, and live before pregnancy, and during pregnancy, childbirth, and the postpartum period. These social determinants substantially affect maternal health outcomes, and are indirectly responsible for the disparities observed in maternal mortality and morbidity rates between different populations. The list of social determinants of maternal health in the literature is extensive, but the importance of structural biases related to gender, ethnicity, and socioeconomic class cannot be overemphasised.[34,42,43] Gender disparities, income, education, ethnicity, and race are strong predictors of death and disability during pregnancy, childbirth, the postpartum period, and beyond.[42–44] Discrimination, systemic bias, and social injustice are frequently associated with poor maternal outcomes for racial and ethnic minority women; for instance, a health-care system that routinely minimises the pain reported by Black women is more likely to miss warning signs for severe morbidity.[42,43] Apart from the direct effects of exposure to conflicts and other forms of violence on pregnant women, conflict-induced displacement and forced migration are recognised disruptors of health-care systems and infrastructure, restricting access to life-saving maternal health services, and causing severe psychological stress and trauma for pregnant and postnatal women.[45–47] Women who are migrants and pregnant have to navigate several barriers to access care in host countries, such as language, immigrant status, and unfamiliarity with health-care systems.[46,47]

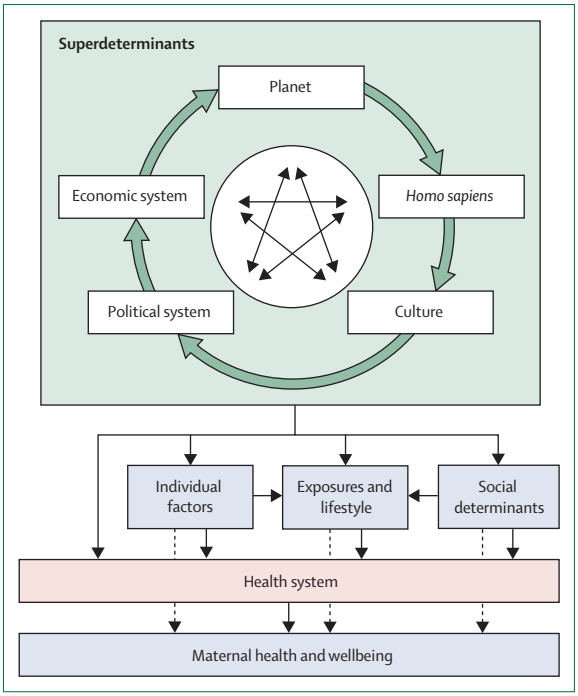

Figure: **Maternal health production process**
The diagram illustrates the relationships and interdependencies of superdeterminants, showing how the characteristics of the planet shape biological and physiological evolution of reproduction in human species (*Homo sapiens*), and how continual adaptations of humans to the planet culminate into cultural practices, social norms, and political and economic systems, that influence the contexts in which pregnancy and childbirth takes place (social determinants), as well as the individual-level traits, lifestyle patterns, and exposures to external agents. The resultant effect of these forces on maternal health and wellbeing depends on the efficiency of the health system at neutralising detrimental forces and enhancing beneficial ones. In this representation, exposures and lifestyles are influenced both by individual factors and social determinants. The performance of the health system is also dependent on superdeterminants and influenced by individual-level factors and social determinants.

Individual-level factors and exposures contributing to maternal health

Individual-level factors or characteristics specific to each pregnant woman (eg, age, genetics, pre-existing health

***Panel*: A non-exhaustive list of determinants of, contributors to, and causes of maternal mortality (derived from the literature review)**

Social determinants
- Gender dynamics that favour sexism and gender injustice (inequity and inequality)
- Low income and low socioeconomic status
- Ethnic and racial dynamics that favour racism and discrimination
- Low maternal education
- Sociocultural factors that sustain gender and social bias against women, including but not limited to gender roles, and restricted agency over sexual and reproductive rights
- Exposure to sources of hyperinformation and disinformation
- Living in a rural area
- Hunger
- Corruption
- Armed conflict
- Violence (including but not limited to intimate partner violence)

Individual and family factors
- Extremes of maternal age (<18 years and >35 years)
- High parity
- Marital status (single and equivalent marital status is associated with increased risk)
- Absence of or low partner involvement in antenatal care and intrapartum care
- Low partner socioeconomic status
- Lifestyle, including:
  - Poor diet
  - Low physical activity and exercise
  - Use and abuse of substances (eg, alcohol, tobacco)
  - Other aspects of lifestyle, including risk exposure

Health services and health education*
- Low knowledge of danger signs related to obstetric complication (first delay)
- Absence of agency and autonomy for health-care seeking (first delay)
- Poor access to health services (second delay; includes no antenatal care visits and long distance to a health facility)
- Substandard care (third delay)

Causes of maternal mortality
- Biomedical causes:
  - Obstetric conditions: haemorrhage, hypertensive disorders, infection, complications of abortion, obstructed labour, etc (conditions known as direct causes of maternal mortality)
  - Non-communicable diseases and previously existing conditions (conditions usually included in the set of conditions known as indirect causes of maternal mortality)
- External causes, including accidents and homicide
- Suicide
- Femicide
- Complications of health interventions (includes anaesthetic and surgical complications, such as intraoperative bleeding and surgical infection)

The common final pathway to death
- Multiorgan dysfunction
- Sepsis (ie, infection-related organ dysfunction)

*The three-delay model was proposed by Thaddeus and Maine and explores how delays affect the interval between the onset of obstetric complication and its outcome.[23]

conditions) and exposure to external agents (eg, physical, chemical, and biological hazards, infections, accidents, and violence) are major maternal health determinants. Teenage pregnancies and pregnancies in women older than 35 years are associated with an increased risk of some complications, such as pre-eclampsia.[48,49] Women with pre-existing conditions, such as hypertension, diabetes, cardiac disease, and obesity, are at a higher risk of dying during pregnancy, childbirth, and the postpartum period than those who do not have pre-existing conditions. Genetic disorders, such as haemoglobinopathies (eg, sickle-cell anaemia, thalassaemia major), haemophilia, hereditary thrombophilia, and hypertrophic cardiomyopathy, can increase the risk of maternal complications and potentially lead to death.[50–53] Exposure to environmental toxins and industrial chemicals (eg, lead, mercury, pesticides, air pollutants), medications and recreational drugs, ionising radiation, pathogenic threats (eg, Ebola virus, SARS-CoV-2), intimate partner violence, and accidents resulting in physical trauma and injuries have varying degrees of detrimental effects on maternal health outcomes, depending on a woman's unique circumstances and level of exposures. Violence against women deserves special mention: although violence is often more visible in conflict-affected areas, the effects on pregnancy outcomes are equally devastating even in non-conflict areas, particularly when perpetrated by an intimate partner.[54–57] As a result of the influence of superdeterminants of maternal health—particularly cultural, political, and economic systems—individual-level factors that are shaped by family and community characteristics tend to give rise to lifestyle patterns, which in turn mitigate or elevate the risk of dying or having pregnancy-related ill-health. Examples of lifestyle patterns with substantial effects on maternal health include diet (eg, low iron and low calcium intakes increase the risk of iron-deficiency anaemia and pre-eclampsia, respectively), physical activity, substance use and smoking, and sexual behaviours during pregnancy

(eg, harmful sexual practices resulting in HIV seroconversion).[58–64]

Interplay between maternal health determinants and the concept of embodiment

The pregnant woman is at the centre of a dynamic and multifaceted web of interactions between superdeterminants, social determinants, and her individual-level factors, exposures, and lifestyle pattern. These determinants operate at several levels and are interconnected and inter-related, with each factor continuously influencing and being influenced by others, leading to a resultant effect that collectively shapes maternal health outcomes throughout pregnancy, childbirth, and the postpartum period. For example, the climate and environment in which pregnant women live can affect their health, both directly, by modifying their individual level-factors and exposures, and indirectly, by disrupting their social support structures and health systems. Extreme weather events, poor air and water quality, and exposure to pollutants can directly or indirectly influence maternal health outcomes.[65–68] Cultural norms surrounding pregnancy and childbirth shape maternal health behaviours and health-care seeking practices, by acting as modifiers of individual-level factors, such as age to start a family, number of children to have, and to what extent the partner is involved in care of the woman.[69] Cultural factors also influence decisions on nutrition, antenatal care practices, and childbirth practices. Societal expectations and gender roles can affect pregnant women's autonomy, access to education, resources, and health care, and influence their decision-making power within their households, as well as their ability to make decisions about their own health, where they work, and what they do.[70]

Lifestyle patterns arising from social determinants can influence individual-level factors by initiating or exacerbating pre-existing conditions that have serious effects on maternal health. For example, low-income status can result in poor nutritional intake or unhealthy dietary practices, and consequently increased risks of pre-pregnancy deficiency anaemia or maternal obesity. Maternal obesity can increase the risk of gestational diabetes; and an unhealthy diet during pregnancy can contribute to excessive maternal weight gain, leading to various complications, including gestational diabetes.[71] Similarly, unresolved anaemia during pregnancy has detrimental effects on the growing fetus and predisposes the pregnant woman to adverse outcomes, including postpartum haemorrhage and death.[72]

Lifestyle pattern and the health-care system can also affect the interaction of factors, and converge as a net force that influences overall maternal outcomes. However, lifestyles and the configuration of a health system are also products of the prevailing context and social forces; the capacity and resilience of a health system reflect the state of social development. Intersections between factors, particularly gender, ethnicity, and socioeconomic class, are highly relevant in determining inequities in income (affecting the quality of care a woman can access), education (affecting how informed a woman is about her choices during pregnancy and childbirth), and personal agency (affecting how able a woman is to advocate for her needs).[22]

Thus, this complex interplay of forces might produce concrete events that substantially disrupt maternal physical and mental health. For example, take a woman born and raised in poverty with little access to education, income, good nutrition, and family planning methods. At an older age, as a multiparous pregnant woman with nutritional anaemia, she faces severe bleeding after giving birth to a stillborn baby. Despite the use of uterotonics, she only survives a postpartum haemorrhage event due to an emergency hysterectomy. However, she sustains prolonged disability related to severe maternal morbidity, in addition to the grief of losing a child; her family is forced further into poverty by the large out-of-pocket expenses for the complications she experienced. Thus, the whole process can be understood as a process of embodiment, in which women internalise and embed into their bodies and minds the interactions between their being and the surrounding context and external and internal forces.[73] That is, the pregnant woman embodies the intersections of complex, multidimensional forces. Embodiment in the context of maternal health refers to the integration of the physical, social, psychological, and cultural aspects of a woman's lived experiences and how these factors collectively influence her health and wellbeing throughout the pregnancy journey and beyond. The concept of embodiment recognises that maternal health is not solely determined by biomedical factors that underlie pregnancy events but is deeply shaped by the broader context in which pregnancy occurs.

Specific factors associated with maternal mortality and morbidity (ie, direct and indirect causes of mortality and morbidity) represent concrete expressions of the context and the forces described earlier, which might progress with additional complications and organ dysfunctions—the final common pathway to maternal mortality (panel). Suicide, femicide, and other external causes of death during pregnancy, childbirth, and the postpartum period might follow a distinct and similarly complex path, but also represent the embodiment of the interplay between underlying social forces (eg, the patriarchy and other gender social norms) and individual, family, and community factors. This complexity highlights the reduced agency many women still experience in their maternal health trajectory, a constraint that is often observed in low-income settings.

The various individual-level factors, lifestyles, social forces, and their intersections affect the emergence of biomedical and other factors that ultimately determine maternal survival and wellbeing during a woman's pregnancy journey. The resultant effect of all these forces is dependent on how efficient the health system is at

neutralising any detrimental forces and enhancing those that are beneficial.

The role of the health system in maternal health

The health system plays a crucial role in shaping the embodiment of the inter-related forces and contexts presented earlier. Health services and commodities (eg, quality-assured uterotonics to reduce postpartum blood loss in a woman who presents with anaemia at the time of birth) can modify the effects of eco-social forces that lead to adverse maternal health outcomes. Therefore, the health system can be considered a decisive protective factor, able to neutralise or minimise the effects of detrimental risk factors. Accordingly, the negative effects of some risk factors, such as advanced maternal age or low-income status, can be attenuated by well functioning health services, particularly those with high-quality preconception, antenatal, intrapartum, and postpartum care.

In this context, quality of care emerges as a central attribute of health services that can exert a protective effect on maternal health. Quality is a multidimensional concept translated into maternity services as the interplay of available human resources, infrastructure, commodities, and efficient processes, producing a positive care experience for the woman and favourable health outcomes at an acceptable cost.[74] However, and often due to poor quality of care, health services might not be able to modify or counterbalance adverse social determinants, individual-level factors, lifestyles, and exposures. The default health system configuration in many low-resource settings features inadequate or suboptimal equipment for screening and diagnosis, health-care worker shortages or competency challenges, inadequate use of effective maternal health interventions, or a combination of these problems, which together coalesce into the so-called too little, too late situation.[12] Preventable deaths continue if the chain of events leading to maternal mortality is not interrupted. For instance, pre-eclampsia is easy and inexpensive to diagnose, and potentially preventable with health-care commodities (eg, aspirin); however, the underdiagnosis of pre-eclampsia and underuse of preventive measures continue to drive pre-eclampsia-related mortality and morbidity in low-resource settings. Furthermore, health services can be influenced by social forces. For example, disrespect, abuse, and mistreatment of women within maternity services often reflect gender, ethnic, or social class biases against women and are perpetrated by health-care providers, many of whom are women and themselves affected by the same forces and hierarchies within the health services.[75]

Although health systems have the potential to attenuate adverse health factors, they can also cause hazards. Complications of health interventions (ie, iatrogenic factors) are an important contributor to all-cause mortality and a substantial cause of or contributing factor to maternal mortality.[76,77] Health interventions are designed and implemented to improve situations in which the anticipated benefits outweigh potential risks. For example, a medically indicated caesarean section can be a life-saving intervention, and the underuse of caesarean section is associated with poor maternal and perinatal health outcomes. However, when health interventions are implemented in situations with relatively low risk of adverse outcomes, their benefits might not outweigh their risks, and indeed could lead to harm. The same intervention applied to a situation with a lower risk of adverse outcomes might have a different result. For example, the short-term and long-term complications of a non-medically indicated caesarean section outweigh the potential benefits for both the woman and the baby.[78] Ensuring rational use of caesarean sections is of great importance, especially in settings without reliable access to safe surgery.[78,79] Promoting the rational use of health interventions and preventing interventions that are not medically justified (ie, quaternary prevention) nor desired by the informed care recipient can be a strong complement to quality of care, good health outcomes, and a positive care experience.[80] In addition, using non-medically indicated health interventions can be a substantial resource drain (for both society and the individual) that could further complicate subsequent pregnancies, especially in resource-constrained settings.[78–80]

Maternal health determinants and transitions in maternal mortality

Despite the substantial number of maternal deaths every year, there is a slow but steady trend towards maternal mortality reduction.[6] This trend means that, over an extended time period, the absolute number of maternal deaths and the global MMR are gradually reducing. The first worldwide estimates in the 1980s and early 1990s indicated nearly 500 000 maternal deaths per year. Three decades later, the world has almost halved that incidence: there were an estimated 287 000 maternal deaths in 2020.[6] Countries with reliable maternal mortality data since the mid-1900s or earlier also show similar trends.[81,82] Building on demographic, epidemiological, and nutritional transitions,[83–85] a transition model to describe the gradual shift from a pattern of high maternal mortality to a pattern of low maternal mortality at the country level was developed by Souza and colleagues.[18] Based on the notion that maternal health is the product of a multifactorial process, as described earlier, this transition model relates levels of maternal mortality to social development, reproductive health indicators, biomedical causes of maternal mortality, and the organisation and quality of health care. The central hypothesis of this transition model is that social development offers protection from or mitigation of the detrimental effects of distal and proximal determinants, producing a trend towards maternal mortality reduction. In other words, as social development advances, maternal

mortality tends to decrease. The maternal mortality transition stage of a country could therefore be conceptualised as the net result of the dynamic balance between the predominant forces of determinants and the advancements in social development to counteract these forces.

Although the mortality transition model describes a continuous process, stages within the model are used to identify patterns associated with the level of maternal mortality in various countries. To propose the stages of the transition model, we adopted the MMR cutoffs used in the WHO, UNICEF, UNFPA, and the World Bank report on trends in maternal mortality from 2000 to 2020.[6] Stage 1 was proposed as a very high maternal mortality stage (MMR ≥500 maternal deaths per 100 000 livebirths), stage 2 represents high maternal mortality (MMR 300–499), stage 3 represents intermediate maternal mortality (MMR 100–299), and stage 4 represents low and very low maternal mortality (MMR <100). A theoretical stage 5, in which hypothetically all preventable maternal deaths have been prevented, is also included. The MMR cutoff for stage 5 is difficult to determine, but one could hypothesise it to be less than one maternal death per 100 000 livebirths, since maternal mortality enquiries in countries with low and very low maternal mortality (ie, those in stage 4A and 4B) continue to show potential preventability of maternal deaths.[86] The exact thresholds of transition stages should be acknowledged as arbitrary, as they are principally used to illustrate the flow of countries across typologies of social and health development. Nevertheless, the depicted stages are pointers to predominant eco-social forces and levels of social development and can be useful to explore broader, multifaceted strategies to tackle maternal health challenges at the country level (table 1). Notably, several stages of transition might co-exist within the same country.

Table 2 shows the distribution of countries according to the transition stages and years when global maternal mortality estimates were reported. Between 2000 and 2020, the number of countries in stage 1 has steadily decreased, whereas the number of countries in stage 4 has increased, particularly in stage 4B. Of the 185 countries with maternal mortality estimates during the reported period, 43 were already in stage 4B in 2000, leaving 142 that could potentially transition across stages. 63 countries progressed at least one stage, with nine countries transitioning two stages (eg, from stage 1 to stage 3). Angola, for instance, was in stage 1 in 2000, moved into stage 2 in 2010, and was in stage 3 in 2015. No country transitioned over four stages (ie, from stage 1 to stage 4A or from stage 2 to stage 4B). One country was in stage 4A in 2000 and remained in stage 3 in subsequent assessed years. Overall, 121 of the 185 countries remained at the same stage of transition during the reported period.

	Summary characteristics	Key attributes of maternal health determinants
Stage 1; very high maternal mortality, MMR ≥500	Very high maternal mortality, with high neonatal mortality rate, high fertility, and low life expectancy. The reach of the health system is small (low universal health coverage, low skilled birth attendance coverage, high risk of impoverishing expenditure for surgical care, and very low caesarean section rate). The human development index in this stage is low, with increased gender inequality.	Environmental and climate effects are moderate to serious, with low environmental protection and no climate adaptation and mitigation activities in place. Cultural practices that are unfavourable to maternal health are prevalent. Violence, conflicts, internal displacements, and political instability are common. The economy is weak and not resilient to external forces. Gender discrimination, structural bias, and poor social development are common. The health system is weak and can be influenced by the effects of social forces, allowing embodiment of overwhelming biomedical factors underlying maternal death and morbidity.
Stage 2; high maternal mortality, MMR 300–499; and stage 3; intermediate maternal mortality, MMR 100–299	Stages 2 and 3 are transition stages with intermediate to high maternal mortality, and intermediate levels of neonatal mortality, life expectancy, health system reach, and social indicators. Considering these characteristics, stage 2 is closer to stage 1 and stage 3 is closer to stage 4.	Environmental and climate effects are moderate to serious, with some environmental protection and few climate adaptation and mitigation activities in place. Cultural practices that are unfavourable to maternal health are less prevalent than stage 1. Violence, conflicts, internal displacements, and political instability are less common than stage 1. The economy is more stable and resistant to external forces compared with stage 1. Effects of gender discrimination and structural bias are increasingly addressed by social development programmes. The health system is stronger and less permeable to the effects of social forces compared with previous stages; however, the health system struggles with care for women with obstetric emergencies, pre-existing risk factors, and exposures to external agents associated with maternal death and morbidity.
Stage 4; low maternal mortality, MMR <100; includes stages 4A (MMR 20–99) and 4B (MMR<20)	A low maternal mortality stage. Stage 4 is associated with low neonatal mortality, low fertility rate, and high life expectancy. The health system has increased reach relative to previous stages, with very high coverage of skilled birth attendance. Medical interventions can occur without medical indications. Social indicators are also favourable.	Environmental and climate effects are moderate, with several environmental protection and some climate adaptation and mitigation activities in place. Cultural practices that are unfavourable to maternal health are rare. Violence, conflicts, internal displacements, and political instability are rare. The economy is strong and fairly resistant to external forces. Gender discrimination and structural bias are addressed by social development programmes, but gaps persist. Health system is stronger and more resistant to the effects of social forces compared with previous stages.
Stage 5; all avoidable maternal deaths are avoided	Stage 5 is a theoretical stage. The hypothesis is that it will be an improved version of stage 4B.	Environmental and climate effects are minimal, with robust environmental protection and climate adaptation and mitigation activities in place. Cultural practices that are unfavourable to maternal health are non-existent. Violence, conflicts, internal displacements, or political instability are practically non-existent. The economy is very strong, robust, and resilient to external forces. Social development prevails over gender discrimination and other structural biases. The health system is very strong and resistant to the effects of social forces, and it is configured to address rare or emerging complications, leaving no one behind.

MMR=maternal mortality ratio.

Table 1: **Typology of the stages of maternal mortality transition**

Table 3 presents the characteristics of the transition stages. As the transition stage progresses to higher levels and maternal mortality decreases, there are decreasing trends for neonatal maternal mortality, fertility rate, and risk of impoverishing expenditure for surgical care. In addition, reduction of maternal mortality is associated with increases in life expectancy, universal health coverage, skilled birth attendance, antenatal care coverage, and the human development index. The neonatal mortality rate shows a strong correlation with maternal mortality, suggesting that this indicator is most probably a product of similar determinants. Similarly, health-system indicators, such as universal health coverage and skilled birth attendance, tend to correlate strongly with maternal mortality levels, demonstrating the crucial role of health systems in safeguarding maternal health against external forces. In contrast, the less strong correlations between other social indicators (eg, Gini index that measures national income or wealth distribution) and maternal mortality suggests that the relationship is more distant, possibly indirect, or mediated by other factors.

Caesarean section rate as an indicator deserves further consideration, which is beyond the scope of our analysis. Notably, countries with high and very high maternal mortality (in maternal mortality transition stages 1 and 2) showed a very low median caesarean section rate at the country level (ie, a caesarean section rate well below 10%). This finding suggests that underuse of this intervention might have a contributory role in maternal mortality. However, the relationship between caesarean section rate and maternal mortality at the country level is not linear. The correlation between caesarean section rate and maternal mortality is only moderate (R^2=0·59) and might be subject to an upper limit, as countries with low and very low maternal mortality presented similar median caesarean section rates at the country level in the range of 25–27% (table 3).

This multifactorial causal pathway makes the collective goal to reduce maternal mortality a complex endeavour due to the absence of a single solution. Although maternal mortality is a complex issue, resources allocated to address it are often disproportionately low. The stratification of

	2000	2005	2010	2015	2020
Stage 1 (≥500)	41	34	25	20	19
Stage 2 (300–499)	14	17	19	17	17
Stage 3 (100–299)	25	26	31	33	32
Stage 4 (<100)	105	108	110	115	117
Stage 4A (20–99)	62	60	60	58	56
Stage 4B (<20)	43	48	50	57	61

The maternal mortality ratio is indicated in parentheses for each stage and range is given to represent number of deaths per 100 000 livebirths. Data are derived from the WHO–World Bank report on trends in maternal mortality from 2000 to 2020.[6]

Table 2: **Distribution and number of countries per maternal mortality transition stage and year (N=185)**

	Stage 1 (≥500)	Stage 2 (300–499)	Stage 3 (100–299)	Stage 4A (20–99)	Stage 4B (<20)	Pearson correlation coefficient	Correlation strength
Health outcomes							
Maternal mortality ratio	621 (553–835)	439 (384–454)	186 (127–238)	50 (30–72)	7 (5–12)	NA	NA
Neonatal mortality rate	32·9 (30·5–35·5)	25·1 (23·3–30·2)	20·2 (15·0–25·0)	8·4 (6·0–10·8)	2·7 (1·8–4·0)	0·817	Very strong
Life expectancy	56·4 (53·8–60·9)	60·4 (58·8–61·7)	65·8 (63·0–68·5)	72·3 (70·1–74·8)	77·1 (73·1–80·0)	–0·773	Strong
Fertility rate	4·6 (4·3–5·3)	4·4 (4·1–5·0)	3·5 (2·4–4·3)	2·1 (1·8–2·5)	1·6 (1·4–1·8)	0·751	Strong
Health-system indicators							
Universal health coverage	39·0 (33·0–41·0)	42·5 (38·3–46·0)	52·0 (45·0–61·0)	71·0 (64·5–76·0)	76·0 (71·0–83·0)	–0·769	Strong
Skilled birth attendance	55·3 (40·0–78·1)	69·4 (51·3–84·5)	81·4 (68·3–92·5)	99·1 (96·2–99·8)	99·8 (98·6–99·9)	–0·763	Strong
Risk of impoverishing expend for surgical care	46·0 (36·4–60·4)	60·3 (41·4–71·2)	28·4 (17·7–50·4)	8·7 (5·0–14·9)	0·1 (0·0–1·7)	0·696	Moderate
Antenatal care coverage (four visits)	80·9 (61·9–91·3)	89·8 (85·6–96·5)	94·0 (84·4–97·4)	97·6 (94·0–99·0)	98·9 (95·7–100·0)	–0·610	Moderate
Caesarean section rate	3·3% (2·5–4·7)	5·4% (4·6–8·6)	10·5% (5·8–17·0)	25·9% (10·7–33·8)	26·9% (19·4–32·1)	–0·590	Moderate
Social indicators							
Human development index	0·482 (0·451–0·522)	0·509 (0·480–0·548)	0·602 (0·547–0·691)	0·737 (0·707–0·788)	0·878 (0·822–0·924)	–0·759	Strong
Gender inequality index (modified)*	0·372 (0·266–0·396)	0·342 (0·306–0·377)	0·283 (0·243–0·315)	0·247 (0·206–0·272)	0·117 (0·069–0·187)	0·275	Fair
Gini index	42·1 (36·1–44·5)	41·1 (35·7–43·1)	41·1 (35·7–46·2)	38·8 (34·3–45·4)	32·4 (28·3–35·3)	0·275	Fair

Data are medians and IQR. The MMR is indicated in parentheses for each stage and range is given to represent the number of deaths per 100 000 livebirths. MMR=maternal mortality ratio. NA=not applicable. *Given that MMR contributes to the calculation of the Gender Inequality Index, to avoid a circular argument, the modified version of this index considers MMR as 10 for all countries.

Table 3: **Characteristics of maternal mortality transition stages**

countries according to MMR levels aims to identify patterns of determinants that would be more influential in each stage of transition. Such stratification might have several limitations, which should be considered. Nonetheless, a typology of transition stages (derived from tables 2 and 3) is presented in table 1. These transition stages, their characteristics, and key attributes of maternal health determinants could be some of the several pieces of information used in developing multisectoral strategies to improve maternal health and wellbeing.

Conclusions and recommendations for policy and research

Maternal ill-health and disability are social problems, and maternal mortality is a social tragedy. The reduction of maternal mortality and the promotion of maternal health and wellbeing are complex endeavours. This paper in the Series on maternal health describes the deep connections between maternal health outcomes and modifiable and unmodifiable factors that are often ignored in intervention programmes because of their complexity. Tackling maternal mortality will require broader actions that go beyond biomedical causes, which manifest at a late stage in the events between a healthy state and severe morbidity or death. Policy makers, particularly those in countries with high maternal mortality burden, must recognise that the main biomedical causes (eg, postpartum haemorrhage, pre-eclampsia, infection, and abortion) of preventable maternal deaths do not happen in isolation. That 121 countries have remained in the same mortality transition bracket for the past two decades is therefore unsurprising. For countries to progress across transition stages in their mortality reduction efforts, there must be renewed focus on strategies to address the underlying determinants described in the previous sections. Multisectoral action to promote social development and gender equality is necessary for sustainable reduction in maternal mortality. Although the implementation of these strategies (eg, improvements in social infrastructure and other social transformation programmes) is often slow to realise, their longer-term benefits are reasonably certain.

In this context, the health sector has a pivotal role to play. Social aspects aside, actions taken by the health system, at the health service level, represent a final opportunity to save the lives and improve the health and wellbeing of women who have birth-related complications. Expanding the health sector ecosystem and care networks to mitigate the detrimental effects of distal and proximal determinants will substantively improve maternal health. Expanding demand for and increasing access to high-quality reproductive health services and commodities (eg, modern contraception, safe abortion, and antenatal, intrapartum, and postpartum care) are needed for primary prevention, early identification, and adequate management of pregnancy complications. Achieving universal health coverage and strengthening the health system to provide quality care is essential to reduce maternal mortality and promote maternal health and wellbeing.

Future research should aim to establish the correlation between key determinants and stages of the maternal mortality transition at national or regional levels to facilitate evidence-informed and individually tailored strategies and rapidly accelerate countries towards a very low maternal mortality transition stage.

Contributors

JPS and OTO conceptualised the study. ACR-G and JPS were involved in data curation. JPS and ACR-G analysed the data. All authors interpreted the results. JPS, ACR-G, LTD, and OTO drafted the paper with the input of all coauthors. All authors approved the final version. The corresponding author attests that all listed authors meet authorship criteria and that no other authors meeting the authorship criteria have been omitted.

Declaration of interests

We declare no competing interests.

Acknowledgments

The authors alone are responsible for the views expressed in this Series paper and they do not necessarily represent the views, decisions, or policies of the institutions with which the authors are affiliated. The time contribution of ACR-G was in part supported by funds from the UNDP-UNFPA-UNICEF-WHO-World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP), a co-sponsored programme executed by WHO. United States Agency for International Development (USAID) provided some funding support to HRP for evidence synthesis related to the this Series and dissemination of all Series papers. No specific funding support was provided to any other authors. All data sharing requests should be submitted to the corresponding author for consideration.

References

1 UN General Assembly. Transforming our world: the 2030 Agenda for Sustainable Development. Oct 21, 2015. https://www.refworld.org/docid/57b6e3e44.html (accessed Nov 26, 2023).

2 Wang H, Paulson KR, Pease SA, et al. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020–21. *Lancet* 2022; **399:** 1513–36.

3 Simpson S, Kaufmann MC, Glozman V, Chakrabarti A. Disease X: accelerating the development of medical countermeasures for the next pandemic. *Lancet Infect Dis* 2020; **20:** e108–15.

4 Atwoli L, Baqui AH, Benfield T, et al. Call for emergency action to limit global temperature increases, restore biodiversity, and protect health. *Lancet Planet Health* 2021; **5:** e660–62.

5 Sepúlveda J, Murray C. The state of global health in 2014. *Science* 2014; **345:** 1275–78.

6 WHO. Trends in maternal mortality 2000 to 2020: estimates by WHO, UNICEF, UNFPA, World Bank Group and the UNDESA/Population Division. Feb 23, 2023. https://www.who.int/publications/i/item/9789240068759 (accessed Nov 26, 2023).

7 Bueno de Mesquita J, Kismödi E. Maternal mortality and human rights: landmark decision by United Nations human rights body. *Bull World Health Organ* 2012; **90:** 79A.

8 UN. Report of the Office of the United Nations High Commissioner for Human Rights on preventable maternal mortality and morbidity and human rights. Geneva: United Nations High Commissioner for Human Rights, 2010.

9 Chmielewska B, Barratt I, Townsend R, et al. Effects of the COVID-19 pandemic on maternal and perinatal outcomes: a systematic review and meta-analysis. *Lancet Glob Health* 2021; **9:** e759–72.

10 Say L, Chou D, Gemmill A, et al. Global causes of maternal death: a WHO systematic analysis. *Lancet Glob Health* 2014; **2:** e323–33.

11 Every Woman Every Child. Global strategy for women's, children's and adolescents' health (2016–2030). https://www.who.int/docs/default-source/child-health/the-global-strategy-for-women-s-children-s-and-adolescents-health-2016-2030.pdf (accessed Nov 26, 2023).

12 Miller S, Abalos E, Chamillard M, et al. Beyond too little, too late and too much, too soon: a pathway towards evidence-based, respectful maternity care worldwide. *Lancet* 2016; **388:** 2176–92.

13 Geller SE, Koch AR, Garland CE, MacDonald EJ, Storey F, Lawton B. A global view of severe maternal morbidity: moving beyond maternal mortality. *Reprod Health* 2018; **15** (suppl 1): 98.

14 Wadephul F, Glover L, Jomeen J. Conceptualising women's perinatal well-being: a systematic review of theoretical discussions. *Midwifery* 2020; **81:** 102598.

15 McNamara J, Townsend ML, Herbert JS. A systemic review of maternal wellbeing and its relationship with maternal fetal attachment and early postpartum bonding. *PLoS One* 2019; **14:** e0220032.

16 WHO. WHO recommendations on antenatal care for a positive pregnancy experience. Nov 28, 2016. https://www.who.int/publications/i/item/9789241549912 (accessed Nov 26, 2023).

17 UN. The Sustainable Development Goals Report 2022. https://unstats.un.org/sdgs/report/2022/ (accessed Nov 26, 2023).

18 Souza JP, Tunçalp Ö, Vogel JP, et al. Obstetric transition: the pathway towards ending preventable maternal deaths. *BJOG* 2014; **121** (suppl 1): 1–4.

19 Boerma T, Campbell OMR, Amouzou A, et al. Maternal mortality, stillbirths, and neonatal mortality: a transition model based on analyses of 151 countries. *Lancet Glob Health* 2023; **11:** e1024–31.

20 Sheikh J, Allotey J, Kew T, et al. Vulnerabilities and reparative strategies during pregnancy, childbirth, and the postpartum period: moving from rhetoric to action. *EClinicalMedicine* 2023; published online Dec 6. https://doi.org/10.1016/j.eclinm.2023.102264.

21 Vogel JP, Jung J, Lavin T, et al. Neglected medium-term and long-term consequences of labour and childbirth: a systematic analysis of the burden, recommended practices, and a way forward. *Lancet Glob Health* 2023; published online Dec 6. https://doi.org/10.1016/S2214-109X(23)00454-0.

22 Bohren MA, Iyer A, Barros AJD, et al. Towards a better tomorrow: addressing intersectional gender power relations to eradicate inequities in maternal health. *EClinicalMedicine* 2023; published online Dec 6. https://doi.org/10.1016/j.eclinm.2023.102180.

23 Thaddeus S, Maine D. Too far to walk: maternal mortality in context. *Soc Sci Med* 1994; **38:** 1091–110.

24 Souza JP, Bellissimo-Rodrigues F, Santos LLD. Maternal mortality: an eco-social phenomenon that calls for systemic action. *Rev Bras Ginecol Obstet* 2020; **42:** 169–73.

25 Scheelbeek PFD, Dangour AD, Jarmul S, et al. The effects on public health of climate change adaptation responses: a systematic review of evidence from low- and middle-income countries. *Environ Res Lett* 2021; **16:** 073001.

26 Veenema RJ, Hoepner LA, Geer LA. Climate change-related environmental exposures and perinatal and maternal health outcomes in the US. *Int J Environ Res Public Health* 2023; **20:** 1662.

27 Vannuccini S, Bocchi C, Severi FM, Challis JR, Petraglia F. Endocrinology of human parturition. *Ann Endocrinol* 2016; **77:** 105–13.

28 Young M, Richard D, Grabowski M, et al. The developmental impacts of natural selection on human pelvic morphology. *Sci Adv* 2022; **8:** eabq4884.

29 Trevathan W. Primate pelvic anatomy and implications for birth. *Philos Trans R Soc Lond B Biol Sci* 2015; **370:** 20140065.

30 Mitteroecker P, Fischer B. Evolution of the human birth canal. *Am J Obstet Gynecol 2023*; published online July 18. https://doi.org/10.1016/j.ajog.2022.09.010.

31 Stansfield E, Fischer B, Grunstra NDS, Pouca MV, Mitteroecker P. The evolution of pelvic canal shape and rotational birth in humans. *BMC Biol* 2021; **19:** 224.

32 Pavličev M, Romero R, Mitteroecker P. Evolution of the human pelvis and obstructed labor: new explanations of an old obstetrical dilemma. *Am J Obstet Gynecol* 2020; **222:** 3–16.

33 Dunsworth H, Eccleston L. The evolution of difficult childbirth and helpless hominin infants. *Annu Rev Anthropol* 2015; **44:** 55–69.

34 WHO. Social determinants of health. https://www.who.int/health-topics/social-determinants-of-health#tab=tab_1 (accessed Nov 26, 2023).

35 Gregory TR. Understanding natural selection: essential concepts and common misconceptions. *Evo Edu Outreach* 2009; **2:** 156–75.

36 Carmel Y, Shavit A, Lamm E, Szathmáry E. Human socio-cultural evolution in light of evolutionary transitions: introduction to the theme issue. *Philos Trans R Soc Lond B Biol Sci* 2023; **378:** 20210397.

37 Carmel Y. Human societal development: is it an evolutionary transition in individuality? *Philos Trans R Soc Lond B Biol Sci* 2023; **378:** 20210409.

38 Chersich MF, Pham MD, Areal A, et al. Associations between high temperatures in pregnancy and risk of preterm birth, low birth weight, and stillbirths: systematic review and meta-analysis. *BMJ* 2020; **371:** m3811.

39 Bekkar B, Pacheco S, Basu R, DeNicola N. Association of air pollution and heat exposure with preterm birth, low birth weight, and stillbirth in the US: a systematic review. *JAMA Netw Open* 2020; **3:** e208243.

40 Allotey J, Stallings E, Bonet M, et al. Clinical manifestations, risk factors, and maternal and perinatal outcomes of coronavirus disease 2019 in pregnancy: living systematic review and meta-analysis. *BMJ* 2020; **370:** m3320.

41 Albert JS, Carnaval AC, Flantua SGA, et al. Human impacts outpace natural processes in the Amazon. *Science* 2023; **379:** eabo5003.

42 Petersen EE, Davis NL, Goodman D, et al. Racial/ethnic disparities in pregnancy-related deaths—United States, 2007–2016. *MMWR Morb Mortal Wkly Rep* 2019; **68:** 762–65.

43 Knight M, Bunch K, Patel R, et al. Saving lives, improving mothers' care core report—lessons learned to inform maternity care from the UK and Ireland confidential enquiries into maternal deaths and morbidity 2018–20. Oxford: National Perinatal Epidemiology Unit, University of Oxford, 2022.

44 Tunçalp Ö, Souza JP, Hindin MJ, et al. Education and severe maternal outcomes in developing countries: a multicountry cross-sectional survey. *BJOG* 2014; **121** (suppl 1): 57–65.

45 Alibhai KM, Ziegler BR, Meddings L, Batung E, Luginaah I. Factors impacting antenatal care utilization: a systematic review of 37 fragile and conflict-affected situations. *Confl Health* 2022; **16:** 33.

46 Almeida LM, Caldas J, Ayres-de-Campos D, Salcedo-Barrientos D, Dias S. Maternal healthcare in migrants: a systematic review. *Matern Child Health J* 2013; **17:** 1346–54.

47 Heslehurst N, Brown H, Pemu A, Coleman H, Rankin J. Perinatal health outcomes and care among asylum seekers and refugees: a systematic review of systematic reviews. *BMC Med* 2018; **16:** 89.

48 Ganchimeg T, Ota E, Morisaki N, et al. Pregnancy and childbirth outcomes among adolescent mothers: a World Health Organization multicountry study. *BJOG* 2014; **121** (suppl 1): 40–48.

49 Laopaiboon M, Lumbiganon P, Intarut N, et al. Advanced maternal age and pregnancy outcomes: a multicountry assessment. *BJOG* 2014; **121** (suppl 1): 49–56.

50 Oteng-Ntim E, Meeks D, Seed PT, et al. Adverse maternal and perinatal outcomes in pregnant women with sickle cell disease: systematic review and meta-analysis. *Blood* 2015; **125:** 3316–25.

51 Early ML, Eke AC, Gemmill A, Lanzkron S, Pecker LH. Severe maternal morbidity and mortality in sickle cell disease in the national inpatient sample, 2012–2018. *JAMA Netw Open* 2023; **6:** e2254552.

52 Lesage N, Deneux Tharaux C, Saucedo M, et al. Maternal mortality among women with sickle-cell disease in France, 1996–2009. *Eur J Obstet Gynecol Reprod Biol* 2015; **194:** 183–88.

53 Kadir RA, Davies J, Winikoff R, et al. Pregnancy complications and obstetric care in women with inherited bleeding disorders. *Haemophilia* 2013; **19** (suppl 4): 1–10.

54 Han A, Stewart DE. Maternal and fetal outcomes of intimate partner violence associated with pregnancy in the Latin American and Caribbean region. *Int J Gynaecol Obstet* 2014; **124:** 6–11.

55 Howard LM, Oram S, Galley H, Trevillion K, Feder G. Domestic violence and perinatal mental disorders: a systematic review and meta-analysis. *PLoS Med* 2013; **10:** e1001452.

56 Van Parys AS, Verhamme A, Temmerman M, Verstraelen H. Intimate partner violence and pregnancy: a systematic review of interventions. *PLoS One* 2014; **9:** e85084.

57 Hill A, Pallitto C, McCleary-Sills J, Garcia-Moreno C. A systematic review and meta-analysis of intimate partner violence during pregnancy and selected birth outcomes. *Int J Gynaecol Obstet* 2016; **133:** 269–76.

58 Milman NT. Dietary iron intake in pregnant women in Europe: a review of 24 studies from 14 countries in the period 1991–2014. *J Nutr Metab* 2020; **2020:** 7102190.

59 Schoenaker DA, Soedamah-Muthu SS, Mishra GD. The association between dietary factors and gestational hypertension and pre-eclampsia: a systematic review and meta-analysis of observational studies. *BMC Med* 2014; **12:** 157.

60 Ladhani NNN, Shah PS, Murphy KE. Prenatal amphetamine exposure and birth outcomes: a systematic review and metaanalysis. *Am J Obstet Gynecol* 2011; **205:** 219.

61 Chomchai C, Na Manorom N, Watanarungsan P, Yossuck P, Chomchai S. Methamphetamine abuse during pregnancy and its health impact on neonates born at Siriraj Hospital, Bangkok, Thailand. *Southeast Asian J Trop Med Public Health* 2004; **35:** 228–31.

62 Marchand G, Masoud AT, Govindan M, et al. Birth outcomes of neonates exposed to marijuana in utero: a systematic review and meta-analysis. *JAMA Netw Open* 2022; **5:** e2145653.

63 Pineles BL, Hsu S, Park E, Samet JM. Systematic review and meta-analyses of perinatal death and maternal exposure to tobacco smoke during pregnancy. *Am J Epidemiol* 2016; **184:** 87–97.

64 Theuring S, Rubagumya K, Schumann H, Harms G, Rubaihayo J, Wanyenze R. Sexual risk behavior in HIV-uninfected pregnant women in western Uganda. *Arch Sex Behav* 2021; **50:** 3277–86.

65 Chersich MF, Pham MD, Areal A, et al. Associations between high temperatures in pregnancy and risk of preterm birth, low birth weight, and stillbirths: systematic review and meta-analysis. *BMJ* 2020; **371:** m3811.

66 Kuehn L, McCormick S. Heat exposure and maternal health in the face of climate change. *Int J Environ Res Public Health* 2017; **14:** 853.

67 Watt S, Chamberlain J. Water, climate change, and maternal and newborn health. *Curr Opin Environ Sustain* 2011; **3:** 491–96.

68 Curtis S, Fair A, Wistow J, Val DV, Oven K. Impact of extreme weather events and climate change for health and social care systems. *Environ Health* 2017; **16** (suppl 1)**:** 128.

69 Omer S, Zakar R, Zakar MZ, Fischer F. The influence of social and cultural practices on maternal mortality: a qualitative study from south Punjab, Pakistan. *Reprod Health* 2021; **18:** 97.

70 Lowe M, Chen DR, Huang SL. Social and cultural factors affecting maternal health in rural Gambia: an exploratory qualitative study. *PLoS One* 2016; **11:** e0163653.

71 Yao D, Chang Q, Wu QJ, et al. Relationship between maternal central obesity and the risk of gestational diabetes mellitus: a systematic review and meta-analysis of cohort studies. *J Diabetes Res* 2020; **2020:** 6303820.

72 Young MF, Oaks BM, Rogers HP, et al. Maternal low and high hemoglobin concentrations and associations with adverse maternal and infant health outcomes: an updated global systematic review and meta-analysis. *BMC Pregnancy Childbirth* 2023; **23:** 264.

73 Krieger N. Embodiment: a conceptual glossary for epidemiology. *J Epidemiol Community Health* 2005; **59:** 350–55.

74 Berwick DM. A user's manual for the IOM's 'Quality Chasm' report. *Health Aff* 2002; **21:** 80–90.

75 Bohren MA, Vogel JP, Hunter EC, et al. The mistreatment of women during childbirth in health facilities globally: a mixed-methods systematic review. *PLoS Med* 2015; **12:** e1001847.

76 Makary MA, Daniel M. Medical error—the third leading cause of death in the US. *BMJ* 2016; **353:** i2139.

77 Firoz T, Chou D, von Dadelszen P, et al. Maternal mortality and health care strategies. *Reprod Health* 2013; **10:** 1–7.

78 Souza JP, Gülmezoglu A, Lumbiganon P, et al. Caesarean section without medical indications is associated with an increased risk of adverse short-term maternal outcomes: the 2004–2008 WHO Global Survey on Maternal and Perinatal Health. *BMC Med* 2010; **8:** 71.

79 Betran AP, Torloni MR, Zhang JJ, Gülmezoglu AM. WHO statement on caesarean section rates. *BJOG* 2016; **123:** 667–70.

80 Jamoulle M. Quaternary prevention: a task of the general practitioner. *Br J Gen Pract* 2010; **60:** e343–45.

81 Loudon I. Maternal mortality in the past and its relevance to developing countries today. *Am J Clin Nutr* 1992; **56:** 524S–32S.

82 Pilkington H. Maternal mortality: a neglected tragedy. *Lancet* 2008; **372:** 1063–64.

83 Kirk D. Demographic transition theory. *Popul Stud* 1996; **50:** 361–87.

84 Omran AR. The epidemiologic transition: a theory of the epidemiology of population change. *Milbank Q* 2005; **83:** 731–57.

85 Popkin BM. Nutritional patterns and transitions. *Popul Dev Rev* 1993; **19:** 138–57.

86 Saucedo M, Deneux-Tharaux C, Pour le Comité National d'Experts sur la Mortalité Maternelle. Mortalité maternelle, fréquence, causes, profil des femmes et évitabilité des décès en France 2013–2015. *Gynecol Obstet Fertil Senol* 2021; **49:** 9–26 (in French).