

# Reproductive, maternal, newborn, and child health: key messages from *Disease Control Priorities 3rd Edition*



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As part of *Disease Control Priorities 3rd Edition*, the World Bank will publish a volume on *Reproductive, Maternal, Newborn, and Child Health* that identifies essential cost-effective health interventions that can be scaled up to reduce maternal, newborn, and child deaths, and stillbirths. This Review summarises the volume's key findings and estimates the effect and cost of expanded implementation of these interventions. Recognising that a continuum of care from the adolescent girl, woman, or mother to child is needed, the volume includes details of preventive and therapeutic health interventions in integrated packages: Maternal and Newborn Health and Child Health (along with folic acid supplementation, a key reproductive health intervention). Scaling up all interventions in these packages from coverage in 2015 to hypothetically immediately achieve 90% coverage would avert 149 000 maternal deaths, 849 000 stillbirths, 1 498 000 neonatal deaths, and 1 515 000 additional child deaths. In alternative calculations that consider only the effects of reducing the number of pregnancies by provision of contraceptive services as part of a Reproductive Health package, meeting 90% of the unmet need for contraception would reduce global births by almost 28 million and consequently avert deaths that could have occurred at 2015 rates of fertility and mortality. Thus, 67 000 maternal deaths, 440 000 neonatal deaths, 473 000 child deaths, and 564 000 stillbirths could be averted from avoided pregnancies. Particularly effective interventions in the Maternal and Newborn Health and Child Health packages would be management of labour and delivery, care of preterm births, and treatment of serious infectious diseases and acute malnutrition. Nearly all of these essential interventions can be delivered by health workers in the community or in primary health centres, which can increase population access to needed services. The annual incremental cost of immediately scaling up these essential interventions would be US\$6·2 billion in low-income countries, \$12·4 billion in lower-middle-income countries, and \$8·0 billion in upper-middle-income countries. With the additional funding, greater focus on high-effect integrated interventions and innovations in service delivery, such as task shifting to other groups of health workers and supply and demand incentives, can help rectify major gaps in accessibility and quality of care. In recent decades, reduction of avoidable maternal and child deaths has been a global priority. With continued priority and expansion of essential reproductive, maternal, newborn, and child health interventions to high coverage, equity, and quality, as well as interventions to address underlying problems such as women's low status in society and violence against women, these deaths and substantial morbidity can be largely eliminated in another generation.

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## Introduction

In September, 2000, 189 world leaders signed a declaration on eight Millennium Development Goals (MDGs) to improve the lives of women, men, and children in their respective countries.<sup>1</sup> Goal 4 called for a reduction in child mortality by 67% and Goal 5 for an improvement to maternal health, with target 5a referring to a reduction of maternal mortality by 75% between 1990 and 2015 and 5b to achievement of universal access to reproductive health.

For several decades, reproductive, maternal, newborn, and child health (RMNCH) has been a priority for most governments in low-income and middle-income countries (LMICs) and for donors and non-governmental agencies. For example, recent analyses by the Partnership for Maternal, Newborn and Child Health<sup>2,3</sup> showed that annual official development assistance for RMNCH to the 75 highest-burden countries increased from US\$3·5 billion in 2006 to \$8·7 billion in 2012. Since 1990, and notably after the MDG declaration, substantial progress has been made in improving RMNCH outcomes, with accelerated progress since 2005 that shows in particular the increased attention paid by the global community to improving the health of women and children. The UN Secretary General's Global Strategy for Women's and Children's Health, launched in 2010

and recast as the Global Strategy for Women's, Children's and Adolescents' Health in 2015, is an indication of the continued global commitment to the survival and wellbeing of women and children.<sup>4</sup>

However, a substantial burden of disease still remains in LMICs from unwanted pregnancies; high maternal, neonatal, and child mortality; prevalent malnutrition; frequent communicable and non-communicable diseases; and loss of human capacity to contribute to society. Cost-effective interventions that can be implemented widely in LMICs could greatly reduce these problems at an affordable cost, with substantial societal benefits.

RMNCH encompasses health concerns across the life course, from adolescent girls and women before and during pregnancy and delivery, to newborn babies (ie, in the first month of life) and to children. An important organisational framework is the continuum of care approach, which recognises the links from mother to child and the need for health services across the life course. This approach includes integrated preventive and therapeutic health interventions delivered through service platforms ranging from the community to the primary health centre (PHC) and to the hospital.

The RMNCH volume is part of the *Disease Control Priorities 3rd Edition* (DCP3), a nine-volume compendium

**Panel 1: Key messages**

- There have been large reductions in the annual number of maternal and child deaths in the past 25 years, yet for many countries the rate of reduction has been too slow to achieve Millennium Development Goals 4 and 5 by 2015.
- Progress could be accelerated by scaling up integrated packages of essential RMNCH interventions across the continuum of care. These interventions are highly cost-effective and result in benefits 8·7 times greater than the costs.
- The continuum of care approach recognises the links from mother to child and the need for health services across the stages of life. Interventions have been grouped into three packages—Reproductive Health, Maternal and Newborn Health, and Child Health—to examine their potential effect on deaths and costs.
- Scaling up all interventions in the packages of Maternal and Newborn Health, plus folic acid before pregnancy, and of Child Health from 2015 rates to 90% coverage would avert 149 000 maternal deaths, 849 000 stillbirths, 1 498 000 neonatal deaths, and 1 515 000 child deaths.
- The Reproductive Health package is particularly important for providing contraceptive services; addressing 90% of the 2015 unmet need could hypothetically reduce annual births by an estimated 28 million and could consequently prevent 67 000 maternal deaths, 440 000 neonatal deaths, 473 000 child deaths, and 564 000 stillbirths from avoided pregnancies.
- Individual interventions that have the highest effect on deaths are provision of contraception; management of labour and delivery; care of preterm births; treatment of severe infectious diseases including pneumonia, diarrhoea, malaria, and neonatal sepsis; and management of severe acute malnutrition.
- The three packages of RMNCH interventions have an annual incremental cost of US\$6·2 billion in low-income countries, \$12·4 billion in lower-middle-income countries, and \$8·0 billion in upper-middle-income countries. The mean per-capita cost of these three packages was \$6·7 in low-income, \$4·7 in lower-middle-income, and \$3·9 in upper-middle-income countries in 2015.
- These packages of interventions (exclusive of contraceptive services) are delivered through three key service platforms: community or health post, primary health centre, and community and referral hospitals. Community and primary health centre platforms could reduce 77% of maternal, newborn, and child deaths and stillbirths that are preventable by these essential interventions, with hospitals contributing the remaining averted deaths through more advanced management of complicated pregnancies and deliveries, severe infectious diseases, and malnutrition. Contraceptive services are almost entirely provided at the primary health centre level.
- Weaknesses in RMNCH delivery platforms, including limited access to care, poor quality of services, and shortages of health workers or drugs, are a major barrier to improvement of RMNCH outcomes. To overcome these weaknesses and expand access to RMNCH services, innovative delivery approaches are being used, such as task shifting to workers at a lower professional level, household visitation, community mobilisation and service delivery, financial incentives for households and health workers, supervision, and accreditation.

RMNCH=reproductive, maternal, newborn, and child health.

that details the most up-to-date evidence on intervention efficacy and programme effectiveness for the leading causes of global disease burden (panel 1). Other volumes in the DCP3 series also cover topics of importance to women and children, including disorders requiring surgery, cancer, mental disorders, HIV/AIDS and other sexually transmitted infections, tuberculosis, and malaria, as well as the health and development of children older than 5 years. The RMNCH volume and

this Review present the amount and trends of RMNCH indicators, proven interventions for prevention of mortality, the potential effects and costs of these interventions, and potential health service delivery platforms and system innovations in different World Bank regions and globally.

### Amount and trends in RMNCH indicators

#### Reproductive health

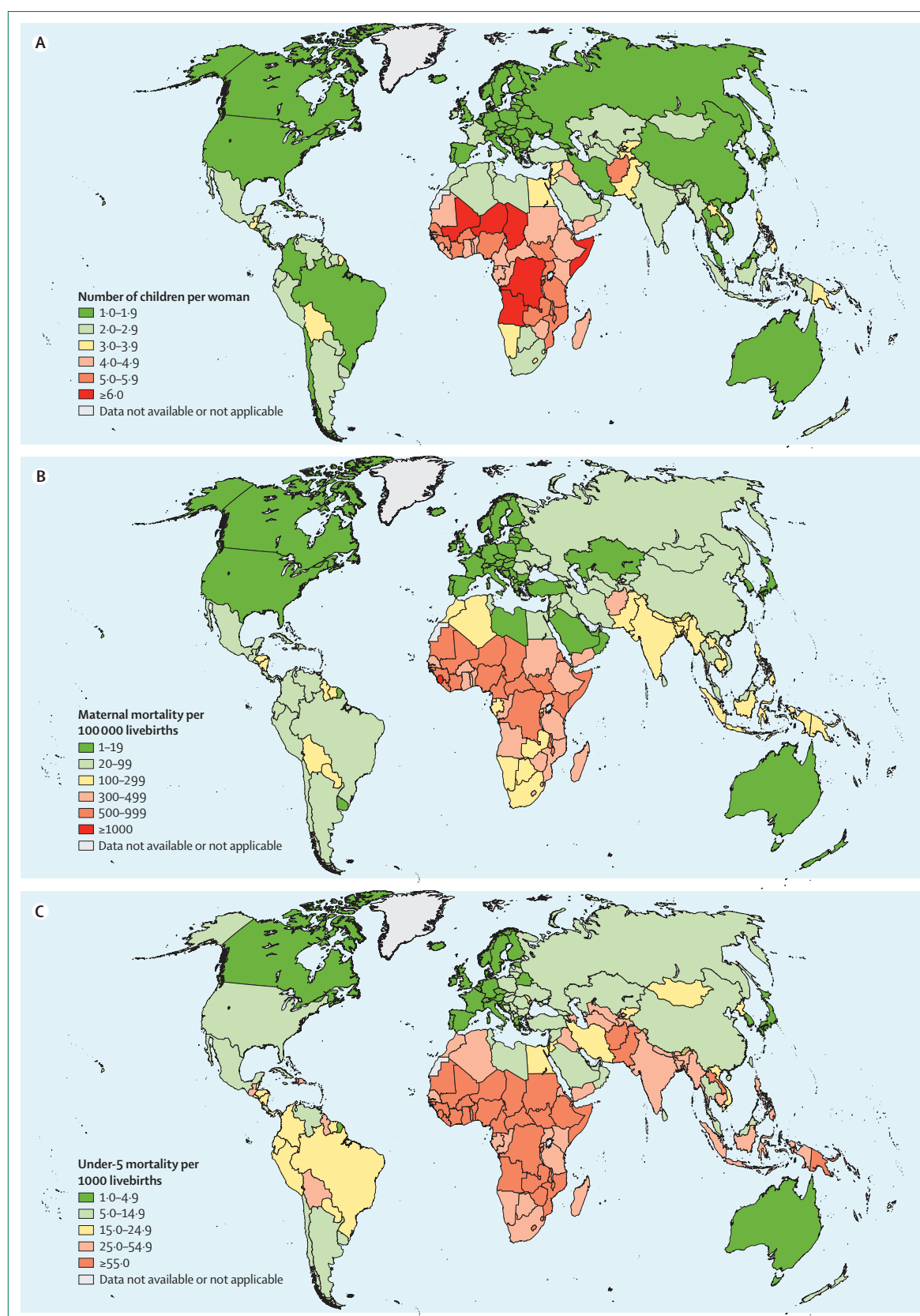
Poor reproductive health outcomes for women and their children are related to a broad spectrum of adverse circumstances and risk factors, such as unsafe sex leading to unwanted pregnancies and sexually transmitted infections, as well as violence against women and girls. Because these are sensitive matters and often associated with cultural and social context, measurement and quantification of the burden of these circumstances and risk factors remains a challenge. The DCP3 volume focuses on four circumstances and risk factors that have substantial public health effects on reproductive health: unwanted pregnancies, unsafe abortions, infertility, and violence against women.

Total fertility varies greatly around the world from around two children per woman in many high-income countries to more than six children elsewhere, with the highest rates occurring in sub-Saharan Africa (figure 1A). According to national survey data,<sup>5</sup> in 2015, 12% of married or in-union women of reproductive age worldwide wanted to delay or avoid pregnancy but were not using any method of contraception. In sub-Saharan Africa, 24% of women have an unmet need for family planning.<sup>5</sup>

In developing countries, an estimated 74 million unintended pregnancies occurred in 2012.<sup>6</sup> Some of these will have ended in unsafe abortion, a major cause of maternal morbidity and mortality.<sup>7</sup> About 8·5 million women annually worldwide have complications from unsafe abortion.<sup>8</sup> Regardless of legal status or abortion policies, prevention of unintended pregnancies can have a crucial role in reducing abortion. The large effects of reducing unwanted pregnancies on maternal, newborn, and child deaths and stillbirths are estimated in a later section of the paper.

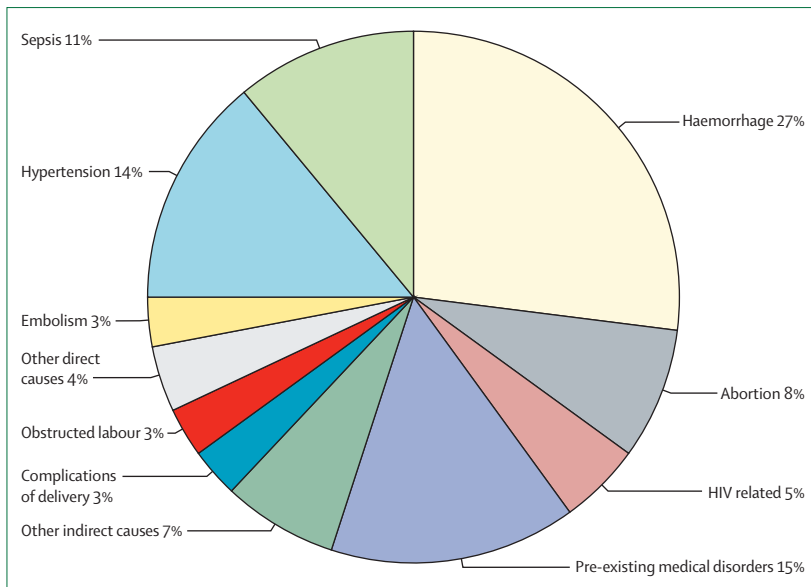
Another hidden burden of reproductive health is infertility. In 2010, an estimated 48·5 million women were involuntarily childless due to male or female infertility, or both. This issue is especially concerning in LMICs, where having children is highly valued, and as a result infertility can lead to severe stigmatisation, economic deprivation, denial of inheritance, divorce, and social isolation.<sup>9,10</sup>

As an extreme manifestation of social and gender inequality, violence against women and girls is often a hidden problem, with serious health consequences. Women exposed to intimate partner violence are more likely to have poor pregnancy outcomes; acquire HIV (in some regions), syphilis, chlamydia, or gonorrhoea; experience depression; and have alcohol misuse disorders.<sup>11</sup> In a 2010 study,<sup>12</sup> between 3% and 31% of women reported



For WHO HSIS see <http://www.who.int/healthinfo/en/>

**Figure 1: World maps showing total fertility, maternal mortality, and under-5 mortality** (A) Total fertility (children per woman) in 2010–15, (B) maternal mortality per 100 000 livebirths in 2015, and (C) under-5 mortality per 1000 livebirths in 2015. Data from Health Statistics and Information Systems (HSIS), WHO.



**Figure 2: Causes of maternal deaths in 2003-09**  
Data from Say and colleagues.<sup>15</sup>

	28 weeks gestation to birth*	Birth to 27 days*	28 days to 1 year*	1-5 years*	Birth to 5 years*	Maternal mortality 1990-2015
Low-income and middle-income countries	2.0	2.9	3.8	4.8	3.7	2.3
East Asia and the Pacific	3.4	5.4	4.6	7.1	5.5	3.9
Europe and central Asia	2.4	3.9	4.6	6.6	4.6	4.3
Latin America and the Caribbean	2.1	2.9	4.4	4.4	3.7	2.8
Middle East and north Africa	1.9	3.0	4.4	5.7	3.9	2.8
South Asia	2.2	2.8	4.1	5.2	3.6	4.5
Sub-Saharan African	1.4	2.2	4.1	5.1	3.9	2.4
High-income countries	1.6	2.8	2.7	3.0	2.8	1.9
World	2.0	2.9	3.7	4.8	3.7	2.3

Data are reduction in probability of dying per 1000 livebirths. \*Data from 2000 to 2013.

**Table 1: Annual reduction in probabilities of dying by World Bank region**

partner violence during pregnancy. Worldwide, 30% of women aged 15–49 years who are in a relationship experience physical or sexual violence, or both, by their intimate partner at some point in their lives.<sup>11</sup>

### Maternal mortality and morbidity

Globally, the total number of maternal deaths decreased by 43% from 532 000 in 1990 to 303 000 in 2015, and the global maternal mortality ratio reduced by 44%, from 385 maternal deaths per 100 000 livebirths in 1990 to 216 per 100 000 livebirths in 2015.<sup>13</sup> Thus, although substantial progress has been made, particularly in recent years, the goal of reducing maternal mortality by 75% by 2015 has not been met. Developing countries continue to account for over 99% (302 000 of 303 000)

of global maternal deaths.<sup>13</sup> The highest risks of maternal death are in countries in south Asia and sub-Saharan Africa (figure 1B).

The risk of maternal death has two components: the risk of getting pregnant, which is a risk related to fertility, and the obstetric risk of developing a complication and dying while pregnant, in labour, or post partum. The chapter of the DCP3 volume on maternal morbidity and mortality focuses on obstetric risks, which are highest at the time of delivery.<sup>14</sup>

The most important causes of maternal deaths are obstetric haemorrhage, hypertension, abortion, and sepsis; however, the proportion of deaths due to non-obstetric (ie, indirect) causes, including communicable and non-communicable diseases, is substantial (figure 2). The overall proportion of HIV-related maternal deaths is highest in sub-Saharan Africa (6.4%).<sup>15</sup> Most maternal deaths do not have a well-defined medical cause, and since many occur in the community rather than at medical facilities, establishing the cause is challenging. Deaths due to abortive outcomes (eg, ectopic pregnancy, induced abortion, or miscarriage), obstructed labour, and indirect causes are of substantial programmatic interest, but are particularly difficult to capture because of poor reporting owing to insufficient knowledge and substantial stigma associated with abortion. Despite the availability of proven interventions, the continued high proportion of deaths due to haemorrhage and hypertension are particularly concerning.

Regional variation exists in the common causes of maternal morbidity in the community; these include anaemia, pre-existing hypertension or diabetes, depression, and other mental health disorders. Prolonged and obstructed labour is associated with a high burden of morbidity and disability (eg, due to obstetric fistula). The true extent of maternal morbidity is not known because of difficulties in definition and measurement.

### Perinatal, neonatal, and child mortality

One of the most important and commonly used measures of the health of a population is under-5 mortality, that is, the probability of dying between a livebirth and the fifth birthday. In 2015, global under-5 mortality was 42.5 per 1000 livebirths, a decline from 90.4 per 1000 livebirths in 1990.<sup>16</sup> Under-5 mortality fell by at least half from 1990 to 2015 in all world regions. Despite this progress, the speed of decline in under-5 mortality was too slow for MDG 4 to be reached globally. The UN estimated that only 24 of 82 low-income or lower-middle-income countries achieved MDG 4.<sup>16</sup> However, compared with historical trends, there has been an acceleration in reduction of under-5 mortality from the year 2000 when the MDGs were approved.<sup>16</sup> The rapid declines in under-5 mortality have been largely explained by the increase in coverage of child survival interventions and changes in nutritional status.<sup>17,18</sup> Under-5 mortality remains high in many



countries in sub-Saharan Africa and some in south Asia (figure 1C).

With the recognition in the past decade that globally a large proportion (45% in 2015)<sup>19</sup> of these deaths in children occur in the first month of life, neonatal mortality has become more widely assessed. Additionally, estimates have also shown that a high proportion of viable fetuses die after 28 weeks of gestation, often at the time of delivery.<sup>20</sup> An estimated 2·6 million stillbirths occurred worldwide in 2015.<sup>21</sup>

The annual rates of reduction (ARRs) in deaths in children aged 1–59 months from 2000 to 2015 would have been sufficient to achieve MDG 4 in nearly all regions if obtained from 1990.<sup>16</sup> Table 1 shows ARRs in stillbirths and maternal, neonatal, and child deaths. Neonatal deaths have been reducing at a much slower pace than those in older children (1–59 months). Likewise, the reductions in stillbirths have been slower than those for neonates and older children in all regions.<sup>21</sup> The regional disparity in ARRs in these two age groups (stillbirths and neonates) is also more salient than that among older children, with an ARR in east Asia and the Pacific 2·3–2·4 times higher than that in sub-Saharan Africa for stillbirths and neonatal deaths compared with 1·1–1·4 times difference between regions among older age groups.

In 2015, 5·9 million deaths occurred after a livebirth before age 5 years.<sup>16</sup> The leading cause of child deaths was complications from preterm birth, followed by pneumonia and intrapartum-related complications, formerly known as birth asphyxia (figure 3).

If the current regional trends in child mortality continue to 2030, global child deaths will fall to 4·4 million.<sup>22</sup> 24·9% of global livebirths occur in sub-Saharan Africa.<sup>22</sup> This proportion is projected to increase to 32·6% by 2030 because of the region's high fertility rate compared with other regions. Thus, the proportion of child deaths globally that will occur in this region is expected to increase from 49·6% to 59·8% by 2030. During the next 15 years, with current health interventions further implemented, infectious causes of death are anticipated to decline more quickly than non-infectious causes.<sup>22</sup> Accelerated implementation of interventions to reduce deaths from infectious diseases could cause a reduction in the anticipated increase in proportion of global child deaths that occur in sub-Saharan Africa, where these causes are especially important.

### Maternal, fetal, and child malnutrition and early childhood development

Malnutrition in women and in children under age 5 years includes both undernutrition and the increasing problem of overweight. One important measure of malnutrition in women of reproductive age (20–49 years) is body-mass index (BMI). A BMI of less than 18·5 kg/m<sup>2</sup> is defined as undernutrition or excessive thinness and a BMI of at least 25 kg/m<sup>2</sup> is classed as overweight. In 1980, the

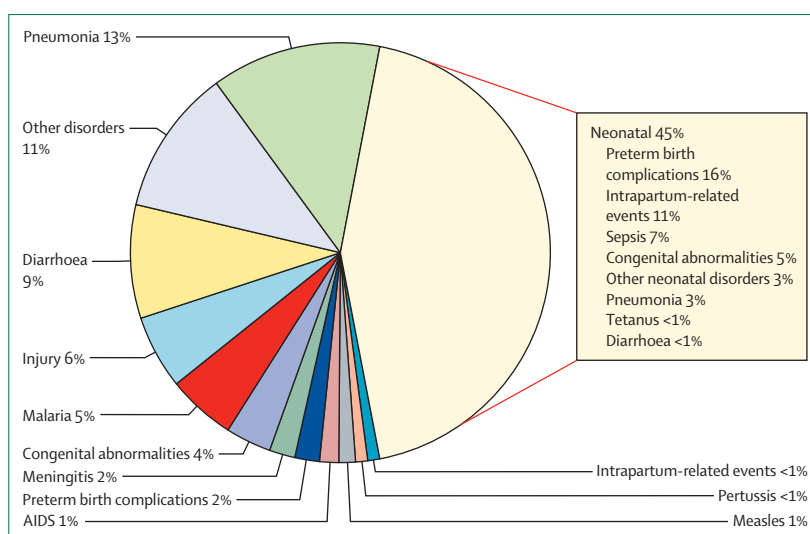


Figure 3: Causes of childhood (<5 years) deaths in 2015

Data from Liu and colleagues.<sup>19</sup>

prevalence of maternal undernutrition was almost 20% in Asia and Africa, but it has fallen since then.<sup>23</sup> Nevertheless, prevalence remains higher than 10% in these regions. During the same period, the prevalence of overweight in women steadily increased in all world regions, reaching more than 50% in the UN-defined regions of the Americas and Oceania, 30% in Africa, and 20% in Asia.<sup>23</sup> Maternal deficiencies of essential vitamins and minerals are also prevalent, with folate, iodine, calcium, zinc, and iron deficiencies having particular relevance to maternal and fetal health.

Fetal growth restriction, assessed by the newborn baby being small for gestational age, is a consequence of maternal nutrition and other morbidity, infection, and toxic in-utero exposures.<sup>24</sup> When a US birthweight reference was used for comparison, more than a quarter of all livebirths in LMICs (32·4 million babies) were born small for gestational age.<sup>23</sup> A new international birthweight standard was published subsequently.<sup>25</sup> Comparison with this standard is likely to result in a reduction of about a quarter in the estimated global prevalence of babies born small for gestational age.<sup>26</sup> During the neonatal period and infancy, these babies have an increased risk of mortality, which is similar with either the US reference or the new international standard,<sup>26</sup> and of stunted linear growth.<sup>23,27</sup> The risk of mortality with babies born small for gestational age increases if they are also premature.

Childhood nutritional status is best assessed by comparison of the child's height or weight with an international growth standard. Although mortality increases progressively for height-for-age SDs (Z scores) below –1 compared with the international standard in children in low-income countries, the usual threshold for defining stunted linear growth is a Z score of less than –2.<sup>23</sup> In 2011, an estimated 165 million (26%) of 641 million children

Community or health post*	Primary health centre†	First-level and referral hospitals‡
Information and education		
1 Sexuality education		
2 Nutritional education or food supplementation		
3 Promotion of care seeking for ANC and delivery		
4 Prevention of sexual and reproductive tract infections	1 Detection and treatment of sexual and reproductive tract infections	
5 Prevention of FGM (for daughters of women of reproductive age)	2 Management of complications after FGM	
6 Prevention of GBV	3 Care after GBV (prevention of STIs or HIV, provision of emergency contraception, and support and counselling)	
7 Information about cervical cancer and screening	4 Screening and treatment of precancerous lesions, and referral of patients with cancer	1 Management of cervical cancer
Service delivery		
8 Folic acid supplementation§		
9 Immunisation (HPV, hepatitis B)		
10 Contraception: provision of condoms and hormonal contraceptives§	5 Tubal ligation, vasectomy, and insertion and removal of long-lasting contraceptives§	2 Management of complicated contraceptive procedures

**Figure 4: Essential interventions for Reproductive Health, by delivery platform**

All interventions listed for lower level platforms can be provided at higher levels. Similarly, each facility level represents a spectrum and diversity of capabilities. The column in which an intervention is listed is the lowest level of the health system in which it would usually be provided. Red type denotes urgent care, blue continuing care, and black routine care. ANC=antenatal care. FGM=female genital mutilation. GBV=gender-based violence. HPV=human papillomavirus. STI=sexually transmitted infection. \*A trained and supported health worker based in or near communities working from home or a fixed health post. †A health facility staffed by a physician or clinical officer and often a midwife to provide basic medical care, minor surgery, family planning and pregnancy services, and safe childbirth for uncomplicated deliveries. ‡Provide full supportive care for complicated neonatal and medical disorders, deliveries, and surgeries. §Intervention effect was included in the Lives Saved Tool.

under age 5 years globally had stunted linear growth.<sup>23</sup> In LMICs, the prevalence of stunting has decreased since 1990, with declines being more rapid in Asia and Latin America and slower in Africa; prevalence of stunting has declined at a similar pace in rural and urban areas, but remains higher in the former.<sup>28</sup> Since 1990, overweight (Z scores >2 compared with the growth standard) has steadily increased by more than 50% to 7%, affecting 43 million children. Children with a weight-for-height of less than -2 Z scores are judged to have wasting; those with a Z score less than -3 have severe wasting. Severe wasting, which is estimated to affect 3%, or 19 million, of 641 million children worldwide, requires urgent intervention with therapeutic feeding and treatment of concurrent infections.<sup>29</sup> Of the micronutrient deficiencies, vitamin A and zinc deficiencies are associated with increased risk of morbidity and mortality caused by infectious diseases.<sup>23,24</sup>

Nutritional disorders, including fetal growth restriction, suboptimum breastfeeding, stunting, wasting, and deficiencies of vitamin A and zinc, are important underlying causes of neonatal and child deaths, often in synergy with infectious diseases. 45% of under-5 deaths have been attributed to these nutritional disorders.<sup>23</sup>

Estimates suggest that as many as 39% of the world's surviving children do not reach their developmental

potential, based on the prevalence of stunting and poverty.<sup>30</sup> There are various causes of poor development, including antenatal and postnatal nutrition, exposure to violence, brain injuries or infections, and environments with insufficient stimulation.<sup>31</sup> The fetal period and the first 2 years of life are crucial periods for development, because this is when the brain matures fastest and when it can be most influenced by favourable or unfavourable conditions. Micronutrient deficiencies before and during pregnancy have important consequences, such as compromised mental development with iodine deficiency and neural tube defects with folic acid deficiency.<sup>23</sup> Inadequate diets and a high number of infectious diseases in the first 2 years of life lead to short stature (ie, stunting) and permanent deficits in cognitive and social development. One of the most important determinants of development in children is the amount and quality of household psychosocial stimulation,<sup>32</sup> which is itself associated with poverty and maternal illness, including depression.<sup>33</sup>

### Interventions to reduce maternal and child morbidity and mortality

The RMNCH volume identifies essential interventions, based on their efficacy and appropriateness to address important health conditions. In figures 4–6, these

Community or health post*	Primary health centre†	First-level and referral hospitals‡
Pregnancy		
1 Preparation for safe birth and newborn care; emergency planning		
2 Micronutrient supplementation§		
3 Nutrition education§		
4 Intermittent preventive treatment in pregnancy§		
5 Food supplementation§		
6 Education about family planning	1 Management of unintended pregnancy§	
7 Promotion of HIV testing	2 Screening and treatment for HIV and syphilis§	
	3 Management of miscarriage or incomplete abortion and care after abortion§	
	4 Antibiotics for preterm premature rupture of membranes§	
	5 Management of chronic medical disorders (eg, hypertension, diabetes mellitus)	
	6 Tetanus toxoid§	
	7 Screening for complications of pregnancy§	
	8 Start antenatal steroids (as long as clinical criteria and standards are met)§	1 Antenatal steroids§
	9 Start magnesium sulphate (loading dose)§	2 Magnesium sulphate§
	10 Detection of sepsis§	3 Treatment of sepsis§
		4 Induction of labour beyond term§
		5 Management of ectopic pregnancy§
		6 Detection and management of fetal growth restriction§
Delivery in woman		
8 Management of labour and delivery in low-risk women by skilled attendant§	11 Management of labour and delivery in low-risk women (basic emergency obstetric care), including initial treatment of obstetric and delivery complications before transfer§	7 Management of labour and delivery in high-risk women, including operative delivery (comprehensive emergency obstetric care)§
Post partum in woman		
9 Promotion of breastfeeding§		
Postnatal in neonate		
10 Thermal care for preterm newborn babies§	12 Kangaroo mother care for preterm newborn babies (ie, newborn baby is held with skin-to-skin contact with an adult)§	8 Full supportive care for preterm newborn babies§
11 Neonatal resuscitation§		
12 Oral antibiotics for pneumonia§	13 Injectable and oral antibiotics for sepsis, pneumonia, and meningitis§	9 Treatment of complications, meningitis, and other very serious infections§
	14 Management of jaundice §	

**Figure 5: Essential interventions for Maternal and Newborn Health, by delivery platform**

All interventions listed for lower level platforms are frequently provided at higher levels. Similarly, each facility level represents a spectrum and diversity of capabilities. The column in which an intervention is listed is the lowest level of the health system in which it would usually be provided. Red type denotes urgent care, blue continuing care, and black routine care. \*A trained and supported health worker based in or near communities working from home or a fixed health post. †A health facility staffed by a physician or clinical officer and often a midwife to provide basic medical care, minor surgery, family planning and pregnancy services, and safe childbirth for uncomplicated deliveries. ‡Provide full supportive care for complicated neonatal and medical disorders, deliveries, and surgeries. §Included in the Lives Saved Tool.

Community or health post*	Primary health centre†	First-level and referral hospitals‡
1 Promote breastfeeding or complementary feeding§		
2 Provide vitamin A, zinc, and food supplementation§		
3 Immunisations¶		
4 Co-trimoxazole for HIV-positive children§	1 ART for HIV-positive children§	
5 Education on safe disposal of children's stools and handwashing§		
6 Distribute and promote use of ITNs or IRS, or both§		
7 Detect and refer children with severe acute malnutrition§	2 Treat severe acute malnutrition§	1 Treat severe acute malnutrition associated with serious infection§
8 Detect and treat serious infections without danger signs (iCCM  ); refer if danger signs appear§	3 Detect and treat serious infections with danger signs (IMCI**)§	2 Detect and treat serious infections with danger signs with full supportive care§

**Figure 6: Essential interventions for Child Health, by delivery platform**

All interventions listed for lower level platforms are frequently provided at higher levels. Similarly, each facility level represents a spectrum and diversity of capabilities. The column in which an intervention is listed is the lowest level of the health system in which it would usually be provided. Red type denotes urgent care, blue continuing care, and black routine care. ART=antiretroviral therapy. iCCM=integrated community case management. IMCI=integrated management of childhood illness. IRS=indoor residual spraying. ITN=insecticide-treated net. \*A trained and supported health worker based in or near communities working from home or a fixed health post. †A health facility staffed by a physician or clinical officer and often a midwife to provide basic medical care, minor surgery, family planning and pregnancy services, and safe childbirth for uncomplicated deliveries. ‡Provide full supportive care for complicated neonatal and medical conditions, deliveries and surgeries. §Included in Lives Saved Tool. ¶Immunisations included in the standard package are those for diphtheria, pertussis, and tetanus; polio; BCG; measles; hepatitis B; *Haemophilus influenzae* type b; pneumococcus; and rotavirus. ||Components are treatments for diarrhoea, pneumonia, and malaria. \*\*Components are treatments of diarrhoea, pneumonia, malaria, AIDS, other infections, and severe acute malnutrition.

interventions are listed according to the least advanced service platform where their delivery is possible. The three platforms represent services that can be provided by (1) community health workers or health posts, (2) PHCs, or (3) hospitals, both community and referral. The interventions are grouped by which stage they are needed in the continuum of care, and are referred to as (1) Reproductive Health (figure 4), (2) Maternal and Newborn Health (figure 5), and (3) Child Health (figure 6). Additionally, we consider the nature of their provision (urgent, continuing care, or routine care), which has important implications for the responsibilities of the health system. The interventions identified have important effects on mortality, morbidity, disability, and developmental outcomes. In the analytical work to follow, we focus on the mortality effect of interventions because this has received the greatest policy attention, for example, in the MDGs, and because interventions that avert death will also prevent non-fatal adverse effects.

### Effect of essential interventions on stillbirths and maternal, neonatal, and child deaths

In this analysis, we estimated the deaths averted by essential interventions individually and grouped into three packages: (1) Reproductive Health, (2) Maternal and Newborn Health, and (3) Child (1–59 months) Health. We report the estimated effect on maternal, newborn, and child deaths and stillbirths in 75 countries in which over 95% of the world's maternal and child deaths occur.<sup>34</sup> Estimates are derived using the Lives Saved Tool (LiST; panel 2)<sup>35–44</sup> by increasing the coverage of each intervention

to 90% from the current coverage in each of these 75 countries.<sup>34</sup> In figures 4–6, the interventions included in the LiST are shown. We estimated the immediate effect on deaths of the individual interventions and their combined effects if implemented together in the Maternal and Newborn Health and Child Health packages. For presentation, the effects of folic acid supplementation in the Reproductive Health package are combined with the Maternal and Newborn Health package effects.

An analysis of the effects of provision of contraceptives, the key intervention in the Reproductive Health package, was done in which the intervention was scaled up to cover 90% of unmet need.<sup>44</sup> Other interventions in the Reproductive Health package are primarily educational and were not deemed to have a direct effect on mortality. Estimates of the effects of other interventions, such as human papillomavirus vaccination or the targeted health-care approach for adolescents, are discussed in other volumes (eg, Cancer, and Child and Adolescent Development).

We also investigated the effects of interventions provided by each of three platforms for health services (figures 4–6). The community platform includes all interventions that can be delivered by a community-based health worker with appropriate training and support or by outreach services, such as child health days delivering immunisations, vitamin A, and other interventions. For ill children, the integrated community case management approach is assumed to include diagnosis and treatment of pneumonia, diarrhoea, and malaria cases without danger signs that suggest the need for referral.<sup>45,46</sup> The



PHC platform is defined as a facility with a doctor or a nurse midwife, or both, nurses, and support staff, as well as basic diagnostic and treatment capabilities. The PHC provides facility-based services such as contraceptive services, including long-acting reversible contraceptive surgical sterilisation (vasectomy or tubal ligation); care during pregnancy and delivery for uncomplicated pregnancies; provision of medical care for adults and children, such as injectable antibiotics, that cannot be done in the community; and training and supervision of community-based workers. For the LiST modelling, the effects of meeting the unmet need for contraceptives are considered to be delivered by the PHC platform. For young infants and children, the Integrated Management of Childhood Illness approach is assumed to be used at the PHC level.<sup>47</sup> The hospital platform, consisting of both community and referral hospitals, includes more advanced services for management of labour and delivery in high-risk women or those with complications, including operative delivery; full supportive care for preterm newborn babies; and management of children with severe infection or severe acute malnutrition with infection.

The largest effect of the Reproductive Health package was estimated to be from contraception services that prevent unintended pregnancies. Meeting 90% of current unmet need for contraceptives would prevent an estimated just under 28 million births in 2015, which, in turn, would reduce maternal deaths by 67 000, neonatal deaths by 440 000, child deaths by 473 000, and stillbirths by 564 000. Because about half of unwanted pregnancies are aborted, prevention of these pregnancies would also reduce millions of abortions, more than half of which would have been unsafe.<sup>48</sup> Additionally, delayed age of first pregnancy and avoidance of short intervals between pregnancies would reduce adverse birth outcomes such as preterm delivery. These potential deaths averted by prevention of unplanned pregnancies cannot be added to the potential lives saved by the Maternal and Newborn Health (plus folic acid supplementation) and Child Health packages, which are estimated at 2015 rates of fertility and mortality.

The Maternal and Newborn Health package provides many interventions, resulting in large potential effects on all of the mortality outcomes. An estimated 2 574 000 deaths would be averted: 849 000 stillbirths, 149 000 maternal deaths, 1498 000 neonatal deaths, and 78 000 child deaths (figure 7). 180 837 (21%) of 849 621 stillbirths could be averted with the community platform, 381 523 (45%) with the PHC platform, and an additional 287 261 (34%) in hospitals. For maternal deaths, 106 456 (71%) of 149 428 could be averted with the PHC platform and most of the remaining avertable deaths (24 090 [16%]) with hospital care. For neonatal deaths, the effects on level of services were different: 738 951 (49%) of 1 497 714 could be averted with the community platform, 173 161 (12%) with the PHC platform, and 585 602 (39%) with hospital care. The

### Panel 2: Lives Saved Tool

The LiST has been developed over the past 12 years. The initial version of the software was developed as part of the work for the Child Survival Series in *The Lancet* in 2003.<sup>35</sup> The purpose of the programme was to estimate the effect that scaling up community-based interventions would have on under-5 mortality.<sup>36</sup> The Bill & Melinda Gates Foundation provided support to the further development and maintenance of the software as part of the work of the CHERG. At that point, the software was shifted into the free and publicly available Spectrum software package, to take advantage of the demographic capabilities of that software and to provide links to other models for family planning and AIDS.<sup>37</sup> Since that time, the LiST has expanded its scope to investigate the effect of interventions on birth outcomes and stillbirths,<sup>38</sup> maternal mortality, and incidence of pneumonia and diarrhoea,<sup>39</sup> as well as neonatal and child mortality.

The LiST has been characterised as a linear, mathematical model that is deterministic.<sup>40</sup> It describes fixed relations between inputs and outputs that will produce the same outputs each time one runs the model. In the LiST, the primary inputs are coverage of interventions with the condition that the quality of that intervention is sufficient to be effective, what is commonly referred to as effective coverage. The outputs are changes in population level of risk factors (eg, wasting or stunting rates, or birth outcomes such as prematurity or size at birth) and cause-specific mortality (neonatal mortality, child [1–59 months] mortality, maternal mortality, and stillbirths). The relation between an input (change in intervention coverage) with one or more outputs is specified in terms of the effectiveness of the intervention at reducing the probability of that outcome. The outcome can be cause-specific mortality or a risk factor. The overarching assumption in the LiST is that mortality rates and cause of death structure will not change except in response to changes in coverage of interventions.

The 66 separate interventions within the LiST (figures 4–6) target stillbirths, neonatal mortality, mortality in children aged 1–59 months, maternal mortality, or risk factors such as stunting and wasting within the model. In the LiST, interventions can be linked to many outcomes, with some interventions linked to several causes of death and risk factors. The LiST allows one to assess the effect of scaling up coverage of several interventions simultaneously.

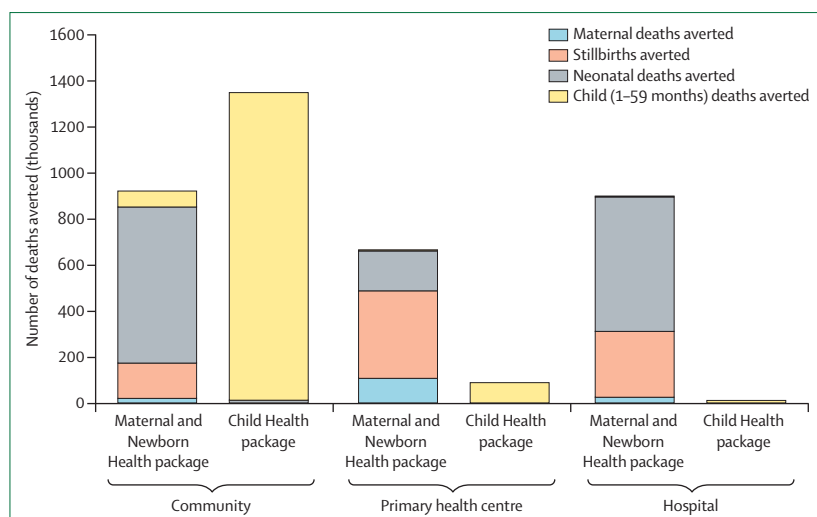
The development of the LiST has been under the guidance of the CHERG. The CHERG, along with its institutional sponsors, has developed rules of evidence to decide what interventions should be included in the model as well as how to develop the estimates of efficacy and effectiveness used in the model.<sup>41</sup> Although the assumptions used within the LiST are from various sources, most of the assumptions about efficacy and effectiveness of interventions come from a series of journal supplements.<sup>42–44</sup> The set of assumptions and their sources can be found on the LiST website.

CHERG=Child Health and Epidemiology Reference Group. LiST=Lives Saved Tool.

interventions with the largest effects were labour and delivery management, care of preterm births, and treatment of neonatal sepsis and pneumonia (appendix). Some deaths could be averted through provision of folic acid before conception, which prevents fetal neural tube defects, resulting in a reduction of stillbirths by 26 000 and neonatal deaths by 48 000 at 2015 rates of fertility.

The Child Health package has essential interventions across all three service platforms, and together these could avert over 1 437 000 child deaths. The largest effect (1 339 202 [93%] of 1 437 130 avertable child deaths) can be achieved by interventions in the community platform (figure 7), especially through immunisations and treatment

See Online for appendix



**Figure 7: Deaths averted by health-care packages through three service platforms**  
From analyses using the Lives Saved Tool.

of infectious diseases (appendix). The PHC platform could also reduce child deaths, primarily through treatment of infectious diseases and severe acute malnutrition, which is categorised at this level because of the need for initial assessment and possibly stabilisation in a health facility and careful monitoring of cases even though therapeutic feeding can be largely provided in the community and from the hospital platform with full supportive care for severe infectious diseases and malnutrition.

Scaling up all interventions in the Maternal and Newborn Health and Child Health packages would avert 149 000 maternal deaths, 849 000 stillbirths, 1498 000 neonatal deaths, and 1515 000 child deaths, a total of 4 011 000 deaths averted. These reductions are about half of the 303 000 global maternal deaths<sup>13</sup> and also about half of the 5·9 million newborn and child deaths.<sup>16</sup> However, they would only result in a reduction of about a third of the 2·6 million global stillbirths.<sup>21</sup> Well-functioning community and PHC platforms could reduce 77% of maternal, newborn, and child deaths and stillbirths that are preventable by these essential interventions, with hospitals contributing the remaining averted deaths through more advanced management of complicated pregnancies and deliveries and newborn and child disorders.

An additional consideration for the organisation of health services is whether the interventions can be scheduled routine care (shown as black in figures 4–6) or provided as continuing care such as for chronic disorders (shown as blue), or if the service needs to be available at all times to offer urgent care (shown as red). Because of the unpredictable nature of most life-threatening conditions in maternal, newborn, and child health, such as complications of labour and delivery or acute illnesses, most of the essential interventions must be available for urgent care at all times of the day.

## Cost of scaling up essential interventions for RMNCH

The cost-effectiveness of individual RMNCH interventions, summarised in panel 3, is well established.<sup>49</sup> In the RMNCH volume, we have estimated the cost of scaling up the Reproductive Health (family planning only), Maternal and Newborn Health, and Child Health packages in 74 of the 75 countries (Sudan excluded because of absence of data) that account for more than 95% of the world's maternal and child deaths. The estimated annual incremental costs are based on per-capita costs from an investment case.<sup>54</sup> Using population estimates for 2015 associated with the estimated effect of the interventions on mortality (figure 7), the annual incremental costs are US\$6·2 billion in low-income, \$12·4 billion in lower-middle-income, and \$8·0 billion in upper-middle-income countries, respectively (table 2). Considering a longer time horizon, to 2035, the costs increase slightly depending on the country income group, reflecting population increases.<sup>55</sup> These estimates include costs of health system strengthening.

The Child Health package includes a wide range of commodities and services related to prevention and treatment of childhood illness, including malaria and HIV. The cost to scale up the Child Health package to 2035 is an additional US\$22·1 billion per year. Scaling up the Maternal and Newborn Health package requires an additional \$6·7 billion per year.

The cost of scaling up contraceptive services in the Reproductive Health package is low at US\$0·2 per capita per year and an annual incremental cost of only \$1·4 billion. Because the model scales up progressively to 2035, it estimates the cost of adding a mean of 104 million new users during the period. We also examined the cost of eliminating all unmet needs for women who do not use effective contraceptive methods. This requires serving 209 million additional users of contraception at a cost of \$13·9 per new user (\$15·8 in low-income, \$10·0 in lower-middle-income, and \$24·4 in upper-middle-income country groups), for which an additional total annual cost of \$2·9 billion would be needed.

Results from the RMNCH investment case are complemented by new evidence on health interventions regarding reproduction and in mothers, neonates, and children, which are also presented in the RMNCH volume. Although information on empirical costs has grown substantially in the past decade, it remains imperfect and does not include up-to-date information on established interventions such as vitamin A capsule distribution and family planning, for which modern contraceptive coverage is low despite high expressed unmet need. Additionally, in emerging areas such as maternal depression and intimate partner violence, few studies have been published from which data can be used. However, the published work does support trends in costs across the essential packages and provides an abundance of information, especially for child illness and for various platforms. For example, mean unit

costs (cost per beneficiary) are lower for family planning interventions, antenatal care visits, and normal deliveries at home or at health centres with trained birth attendants. Costs per beneficiary tend to increase with the complexity of the service (ie, treatment of obstetric or abortion complications, treatment of severely acute malnourished children, and a range of community-based nutrition interventions). For instance, breastfeeding support and prevention of micronutrient deficiencies are inexpensive compared with facility-based treatment of severe acute malnutrition. Within packages, costs are also likely to vary depending on the context and condition; for example, the prevention and treatment of malaria and diarrhoeal disease are less expensive per child (US\$20–100) than treatment of pneumonia and meningitis, which more often need inpatient admission (\$150 per visit or \$800 per child treated for pneumonia; \$300–500 for inpatient care).

### Role of health-care delivery mechanisms

Many gaps exist in access to services, resulting in essential interventions not reaching the high coverage and quality needed to prevent more deaths. To help address these gaps, there has been great interest in task shifting, an innovative approach to delivery of more RMNCH services through reassignment of part or all of some tasks to other groups of workers. Lay community health workers (eg, health extension workers in Ethiopia) are being increasingly used to classify and treat childhood infectious diseases, such as pneumonia, diarrhoea, and malaria, and approaches such as integrated community case management for their care are expanding widely.<sup>45</sup> A WHO guidance panel recently examined the evidence on task shifting and made more than 100 recommendations for tasks related to maternal and newborn health that could be done by lay health workers who have received adequate training and support (eg, promotion of appropriate care-seeking behaviour and antenatal care during pregnancy, administration of misoprostol to prevent post-partum haemorrhage, and promotion and support of breastfeeding), auxiliary nurses (eg, administration of injectable contraceptives), auxiliary nurse midwives (eg, neonatal resuscitation and insertion and removal of intrauterine devices), nurses (eg, administration of a loading dose of magnesium sulphate to prevent or treat eclampsia), midwives (eg, vacuum extraction during childbirth), and associate clinicians (eg, manual removal of the placenta).<sup>56</sup>

Coverage with essential RMNCH interventions can also be increased using the following innovative demand-side interventions. First, findings from a recent meta-analysis of pregnant women's participatory learning and action groups showed that community participation groups could potentially reduce maternal mortality by 37% and newborn mortality by 23%.<sup>57</sup> Second, removal of user fees can result in increased use of the targeted RMNCH service, sometimes by a large margin.<sup>58,59</sup> Third, findings from a 2009 Cochrane review showed that conditional cash transfers were

### Panel 3: Economic and social returns from investment in the continuum of care

The immunisation programmes for BCG; diphtheria, pertussis, and tetanus; measles; polio; and hepatitis B remain cost-effective, whether delivered through outreach or facility-based services. New life-saving vaccines against rotavirus and pneumococcal infections are cost-effective in low-income countries, at less than US\$100 per death averted when assessing their costs and benefits using the GAVI-negotiated prices of \$5 per vaccine dose. Figure 8 provides costs per death averted obtained from a systematic review.<sup>49</sup> Home-based management of maternal and neonatal care, including interventions to train traditional birth attendants for safer births,<sup>50</sup> is cost-effective, with lower end estimates of cost-effectiveness under US\$1000 per death averted. Scaling up midwifery services, integrated with obstetrics, and including family planning costs US\$2200 per death averted.<sup>51</sup>

Well-targeted investments along the continuum of care can bring many benefits, including financial risk protection, improved and more equitable access to RMNCH services (a crucial strategy for achieving universal health coverage), strengthening of health systems, and greater service integration. Using extended cost-effectiveness analysis,<sup>52</sup> taking into consideration financial risk protection in addition to health benefits, investing in the provision of universal public finance for pneumonia treatment and for combined treatment and pneumococcal conjugate vaccination provide substantially higher financial risk protection and save more lives for poor segments of the population in Ethiopia than the current policies.

Investments that increase the supply and demand for RMNCH interventions can have long-lasting effects; for example, the benefits of investments in nutrition can go beyond the immediate improvement in nutritional status by also improving cognitive development, school performance, and future earnings.<sup>33,53</sup>

The economic and social benefits of a set of integrated RMNCH interventions include health and fertility effects.<sup>54,55</sup> Some of these benefits are strictly economic, reflected in higher GDP from increased workforce participation and higher productivity. Other benefits, denoted as social benefits, are not reflected in conventional GDP measures. For example, the value of a child's life saved does not depend only on his or her participation in the labour force when an adult. When taking into consideration the full income approach that goes beyond GDP to also capture these social benefits, including from reducing morbidity and controlling fertility, the benefit:cost ratios suggest high returns on increased investment in RMNCH in most countries, especially when benefits beyond the intervention period are included. For all low-income and middle-income countries considered as a group, benefits are 8.7 times greater than the costs for the intervention period to 2035, for which the future costs and benefits are discounted by 3% per year.<sup>54</sup>

GDP=gross domestic product. RMNCH=reproductive, maternal, newborn, and child health.

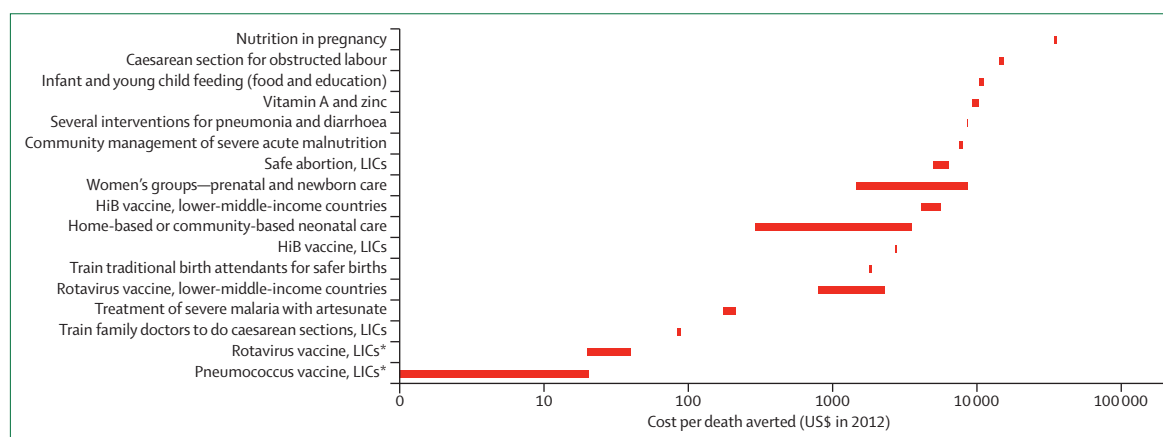
associated with higher service use and might be an effective approach to promote use of frequently undervalued preventive interventions, such as immunisation.<sup>60</sup> Fourth, although few rigorous assessments have been done, vouchers have been linked to increases in use of facility delivery and family planning.<sup>61,62</sup>

On the supply side, there has been growing interest in use of pay for performance, which rewards providers or health-care organisations for achieving coverage or quality targets. In one study in Rwanda,<sup>63</sup> a 23% increase in facility delivery and larger increases in preventive care visits by young children were reported in facilities enrolled in a payment plan compared with randomly selected controls. However, the investigators of a 2012

	Low-income countries		Lower-middle-income countries		Upper-middle-income countries		Total cost per package	
	2015	2035	2015	2035	2015	2035	2015	2035
<b>Reproductive Health package</b>								
Cost in millions*	\$562	\$603	\$520	\$630	\$151	\$164	\$1233	\$1397
Cost per capita	\$0.6	\$0.5	\$0.2	\$0.2	\$0.1	\$0.1	\$0.2	\$0.2
<b>Maternal and Newborn Health package</b>								
Cost in millions*	\$1183	\$1268	\$2922	\$3542	\$1768	\$1923	\$5872	\$6733
Cost per capita	\$1.3	\$1.0	\$1.1	\$1.1	\$0.9	\$0.9	\$1.0	\$1.0
<b>Child Health package</b>								
Cost in millions*	\$4484	\$4810	\$8838	\$10712	\$6060	\$6591	\$19382	\$22113
Cost per capita	\$4.8	\$3.9	\$3.4	\$3.3	\$2.9	\$2.9	\$3.5	\$3.3
<b>Total package</b>								
Cost in millions	\$6229	\$6681	\$12 406	\$14 884	\$7979	\$8679	\$26 487	\$30 243
Cost per capita	\$6.7	\$5.4	\$4.7	\$4.6	\$3.9	\$3.9	\$4.7	\$4.5

Annual incremental costs of essential health packages by country income groups for 2015 and 2035. Estimates have been inflated to US\$ 2012 using the US Consumer Price Index data (World Bank World Development Indicators). \*Costs include commodities, front-line health workers, and additional health system strengthening costs for scaling up services.

**Table 2: Costs of essential Reproductive Health, Maternal and Newborn Health, and Child Health services by package**



**Figure 8: Cost-effectiveness ranges of interventions for reproductive, maternal, newborn, and child health**

If country group is not specified, results refer to low-income and lower-middle-income countries combined. LIC=low-income country. HiB=Haemophilus influenzae B.

\*Cost-effectiveness of vaccines is sensitive to vaccine price. Rotavirus and pneumococcus vaccine costs to LICs are a fraction (eg, 5%) of the price paid by GAVI to procure the vaccines, and GAVI, in turn, receives prices that are more favourable than upper-middle-income countries pay (eg, because of volume discounts).

Cochrane review<sup>64</sup> suggested that the quality of evidence is too poor to draw general conclusions about the effectiveness of pay for performance and noted that several studies arrived at contradictory results.

Two other approaches to improvement of the quality of RMNCH services are (1) supportive supervision for front-line health workers, which is associated with small benefits for provider practice and knowledge;<sup>65</sup> and (2) surgical safety and intrapartum care checklists, which are aimed at reducing human error in care delivery.

## Conclusions

Despite sizable recent reductions in child and maternal mortality, the speed of reduction in mortality has been too slow to achieve MDGs 4 and 5 globally. Particular world regions, especially sub-Saharan Africa, have high

prevalence of fertility, maternal mortality, and under-5 mortality, providing a compelling case for accelerated implementation of integrated RMNCH interventions.

Most deaths from RMNCH conditions could be greatly reduced by scaling up packages of integrated interventions across the continuum of care. Many of these interventions, especially family planning, labour and delivery management, promotion of breastfeeding, immunisations, improved childhood nutrition, and treatment of severe infectious diseases, are among the most cost-effective of all health interventions. Nevertheless, implementation research is still needed to adapt these interventions to the local health service context and achieve the greatest effects. The benefits of scaling up packages extend beyond health to also include substantial economic and social outcomes. Improved access and



quality of care around childbirth can generate a quadruple return on investment by saving maternal and newborn lives and preventing stillbirths and disability. Furthermore, these benefits can extend beyond survival; for example, investing in early childhood nutrition and stimulation can reduce damage to cognitive development and adult capacity. Strengthening health systems and improving data for decision making are, among others, key strategies to drive improvement, equity, and accountability.

The 2015 UN Global Strategy for Women's, Children's and Adolescents' Health builds on evidence presented in this volume, as well as the need to focus on crucial population groups such as adolescents and those living in economically impoverished and conflict settings, build the resilience of health systems, improve the quality of health services and equity in their coverage, and work with health-enhancing sectors on issues such as women's empowerment, education, nutrition, water, sanitation, and hygiene. The objectives of universal health coverage, including public health interventions as well as preventive and curative services,<sup>66</sup> and ensuring financial security and health equity are key to realising the health goal of Sustainable Development Goals beyond 2015. As the world begins efforts to achieve the targets of this health goal, there is a need for articulation of a clear vision and commitment to realise good health and human rights of all women, adolescents, and children.

#### Contributors

REB, NW, and MT developed the plan for this DCP volume and manuscript and did the LiST analyses. CL wrote the panel on cost:benefit and provided the costing estimates. DC and LL provided data and text for the manuscript. All authors, including the Authors Group, contributed to editing and approved the final draft. REB had responsibility for submitting for publication.

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