Trend and causes of maternal death, stillbirth and neonatal death over seven decades in Hong Kong

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Summary

Background Reducing maternal and perinatal mortality is a global objective. Hong Kong is a city with low maternal and perinatal mortality but little is known about the trend and causes of these deaths in this high-income city. We analyzed the maternal death, stillbirth and neonatal death since 1946 in Hong Kong.

Methods Data were extracted from vital statistics, based on the number of registered deaths and births, provided by the Department of Health, the Government of the HKSAR. The annual change rate of mortality was evaluated by regression analysis. Contextual factors were collected to assess the association with mortality.

Findings Between 1946 and 2017, the stillbirth rate (per 1,000 total births) reduced from 21·5 to 2·4; early and late neonatal deaths (per 1,000 live births) reduced from 14·1 and 18·1 to 0·7 and 0·4 in 2017, respectively. The maternal mortality ratio (per 100,000 live births) declined from 125 to 1·8.
The causes of maternal and perinatal deaths were available since 1981 and 1980 respectively. The leading causes of death were thromboembolism (37·0%) and obstetric haemorrhage (30·4%) for maternal death; congenital problem (30·1%) and prematurity (29·0%) for neonatal death. No data on causes of stillbirth were available. No specific shift of pattern was observed in the causes of maternal and neonatal death with time. There were no cases of maternal death due to sepsis and only 2 cases (2·2%) of maternal deaths due to indirect cause.

Interpretation The maternal and perinatal death have reduced significantly in Hong Kong and maintained at the lowest level globally. Indirect maternal death and sepsis were unusual causes of maternal deaths. Use of ICD-PM stillbirth classification, setting up a maternal death confidential enquiry and adding pregnancy checkbox could be the next step to identify and categorize hidden burden.

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Introduction

From Millennium Development Goals to Sustainable Development Goals, the United Nations have identified reducing maternal and child mortality as a priority issue and aim a global reduction of maternal mortality ratio (MMR) to less than 70 per 100,000 live births, the neonatal mortality rate (NMR) to less than 12 per 1000 live births and under-five mortality rate to less than 23 per 1000 live births by 2030.[1] The Every Newborn Action Plan has further targeted reducing stillbirth rate to 12 per 1000 total births by 2030.[2] The catalytic effect from the ambitious unprecedented goal of Millennium Development Goals resulted in an estimated 43·9% decline in MMR (385 to 216 maternal death per 100,000 livebirth), 25·5% reduction of the stillbirth rate (24·7 to 18·4 stillbirth per 1000 total births) and 45·4% reduction in under-five mortality rate (77·8–42·5 per 1000 live births) from the 1990 to 2000 baseline respectively, which accounted for a total of 8·87 million deaths in 2015.[3–5] Accelerating growth with a strategic approach and national commitment is required to catch up with the uneven progress and meet 2030's global objectives.

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Research in context

Evidence before this study

Low- and middle-income countries (LMIC) contributed the majority of maternal and perinatal deaths. The causes of deaths differed among LMIC and high-income countries (HIC). Indirect causes, obstetric haemorrhage and thromboembolism were leading causes of maternal deaths among Spain, Japan and UK while preterm birth and congenital abnormalities were dominant causes of neonatal death in HIC. Although the mortality data of China were frequently reported in international studies, it was noted that the mortality data in Hong Kong was lower than the other parts of China and the perinatal and maternal mortality in Hong Kong remained the lowest globally. A very low-cost public service and free maternity care provided to ensure no one is denied medical care due to lack of means could have contributed to the low perinatal and maternal mortality in Hong Kong.

Added value of this study

We illustrated the rates and causes of perinatal and maternal mortality in Hong Kong. Hong Kong is able to maintain the lowest level of perinatal and maternal mortality. In contrast to other HIC, we found indirect cause of maternal death and sepsis are rare but thromboembolism, prematurity and congenital anomalies remain the major burden for maternal and neonatal death.

Implications of all the available evidence

Although the maternal and perinatal mortality remain low among HIC, the causes of deaths differed and under-reporting of maternal death is a common problem. Setting up a confidential enquiry and adding pregnancy checkbox could be the next step to identify missing cases and finetune health care programs. The use of ICD-PM stillbirth classification could facilitate correlation with maternal condition and standard reporting of the causes and timing of stillbirth, to allow international comparison. Low cost and well-organized healthcare structure are the keys to provide continuum of care to the women and the newborns. We call for comprehensive data collection and disaggregation to provide high-quality data and enable trend tracking in HIC. Research in interventions to prevent common themes of maternal and perinatal deaths are urgently needed.

Much global attention was drawn to the low-income countries (LIC) or middle-income countries (MIC) due to their significant contributions to these mortalities. Specific preventive interventions and programmatic frameworks to implement effective healthcare delivery were extensively studied in the literature, and successful mortality reductions after adopting these strategies in several countries were reported.[6–13] MMR was rising in United States in the past two decades.[14] Reporting the trend and cause of death in high-income countries (HIC) should not be overlooked. Despite the better quality of mortality data in the HIC, information on the causes and trend of maternal and perinatal mortality were relatively less,[15] thus losing the opportunity to explore the more common causes of death in HIC and their corresponding preventive measures.

Hong Kong is a unique city, once a British colony for 156 years and returned to its motherland on 1 July 1997. After the reunification, the British-style healthcare system was maintained and built its uniqueness in providing world-class advanced medical care.[16] The estimated MMR (per 100,000 livebirths) of China was 17·2 in 2013, stillbirth rate (per 1000 total birth) was 7·2 in 2015 and neonatal mortality rate (per 1000 live births) was 4·7 in 2017.[4,17,18] Variation of causes of death and mortality distribution among different populations exists within geographical regions.[19] Published international mortality report by either incorporating the data into China's or missing Hong Kong's may fail to capture the actual performance of this densely populated and highly developed city. In addition, these regional or national estimates were often driven by regions contributing the majority of data and, therefore, unable to reflect individual performance. An in-depth analysis of each locality would benefit tailored policy formulation and fine tune the healthcare structure using reliable epidemiological data. We reviewed the trend of maternal death, stillbirth, and neonatal death since 1946 and analysed the causes of these deaths in Hong Kong.

Methods

Death determination

The healthcare system and death determination in Hong Kong was described in detail in the appendix. The public service is provided by the Department of Health and Hospital Authority. The maternity and neonatal service, for example, antenatal examinations, neonatal checkups and vaccination are provided for free to Hong Kong citizens under public service to ensure no one is denied medical treatment due to lack of money.

Data collection and cause of death collation

The data were extracted from vital statistics, based on the number of registered deaths and births and the Certificate of stillbirth received by the Food and Environmental Hygiene Department, provided by the Department of Health, the Government of the Hong Kong Special Administrative Region, which included the numbers of maternal mortality, live birth, early neonatal death, late neonatal death, and post-neonatal death and the causes of these deaths categorized according to the international classification of diseases (ICD), where

possible since 1946–2017. Between the years 1960 and 2000, the classification of diseases and causes of death are based on the ICD 8th and 9th revision and changed to the ICD 10th revision from 2001 onwards. The ICD 9th codes were converted to ICD-10 codes by matching the closest diagnosis by the authors. The definitions of different terminologies were listed in appendix Table 1, which is similar to World Health Organization's recommendation.

Maternal causes of death were grouped into ectopic pregnancy, death related to abortion, hypertensive disorders, obstetric haemorrhage, pregnancy-related sepsis, thromboembolism, and others. The neonatal causes of death were classified into infection (including meningitis), pneumonia, malignancy, accident, congenital (including malformation and chromosomal abnormalities), sudden infant death syndrome, intrapartum complication, preterm birth, and others.

Several contextual factors were collected, gross domestic product [GDP, billion United States Dollar (USD)], total fertility rate, tertiary school enrollment rate (%), population density (number of people per kilometer) from World Bank; the possession of personal computer among female aged 15–44 years (%), the access to internet among female aged 15–44 years (%) from Census and Statistics Department, Hong Kong.[20,21]

Statistical analysis

Annual reports were not available in earlier years when data were recorded every five years before 1976. The annual change rate of mortality was estimated by the slope of the linear regression using 5-yearly data from 1946 to 1977, and using yearly data for 1978–1987, 1988–1997, 1998–2007, and 2008–2017. Vital statistics did not record the causes of stillbirth, but the causes of maternal and neonatal deaths were available after 1981 and 1980, respectively. The number of maternal death, stillbirths, and neonatal deaths was performed based on the actual number of each cause among 100,000 live births, 1000 total births, and 1000 live births respectively. The cause of deaths was also presented by the proportion of each cause in each year.

Data were presented with mean (standard deviation). Linear mixed effect model was used to investigate of the impact of socio-economic factors on mortalities. Log transformation was performed on both socio-economic factors, the QQ plots of residuals was approximately linear to support the normality assumption of the model, and the no correlation patterns were seen in the fitted vs. residual plots to support the constant variance assumption. The fixed effect of socio-economic factors was explored against neonatal and maternal death, and the year was used as random effect to minimize the impact of collinearity from time. To further explore the impact of socio-economic factors, multivariable linear mixed effect model was used. Some factors were available only after 2000; thus, the multivariable regression model was performed in two stages, between 1961 to 2017 and 2000 to 2017. Multivariable linear mixed effect model was used to explore the fixed effect of GDP, total fertility rate (birth per woman), tertiary school enrolment rate, population density (number of people per kilometre) after log transformation from 1961 to 2017, and using the year as random effect. The possession of personal computer among female aged 15–44 years (%), and the access to internet among female aged 15–44 years (%) were added into the multiple linear mixed effect model from 2000 to 2017. Missing data were common (Supplementary Table 2). For univariate regression, no imputation was made to fill the missing values. For the multivariable linear mixed model, sensitivity analysis was carried out to assess the impact of missing data imputation on the estimates of the model. The sensitivity analysis showed that the model was robust for the impact of missing data and had little impact on parameter estimation. Thus, no missing data handling was made in the multivariable models.

The descriptive analysis was conducted in R and the figures were produced using Microsoft Excel.[22] The linear mixed effect and multiple mixed effect models were performed using R with nlme.[23] A p-value <0.05 or a 95% CI beyond 0 was defined as statistical significance.

Results

The numbers of live births, maternal deaths, stillbirths, early and late neonatal deaths, and post-neonatal deaths were listed in appendix Table 3 and shown in Figure 1. The MMR (per 100,000 live births) declined from 125 in 1946 to 4·7 in 1980 and 1·8 in 2017. There was no maternal death in 2013 and 2016. The stillbirth rate (per 1000 total births) reduced from 21·5 in 1946 to 5·6 in 1980 and 2·4 in 2017. The lowest stillbirth rate was 1·6 in 2012. The early and late neonatal deaths (per 1000 live births) reduced from 14·1 and 18·1 in 1946 to 6·2 and 1·6 in 1980 and 0·7 and 0·4 in 2017, respectively. The lowest early and late neonatal deaths were 0·6 in 2011 and 0·2 in 2009, respectively. The post-neonatal deaths (per 1000 live births) reduced from 56·9 in 1946 to 4·0 in 1980 and 0·6 in 2017. The lowest was 0·4 in 2015.

The target of reducing maternal, neonatal mortality, and stillbirth, set by the United Nation and Every Newborn Action Plan, were persistently met since 1961, 1946, and 1971 respectively. The reduction rates between three epochs (1946 to 1980, 1980 to 2000 and 2000 to 2017) were 96%, 18% and 68% for maternal death; 75%, 78% and 36% for neonatal death; 74%, 0·5% and 56% for stillbirth.

Table 1 showed the annual change rate of maternal death, stillbirth, early and late neonatal death, and post-neonatal death. All deaths reduced significantly between

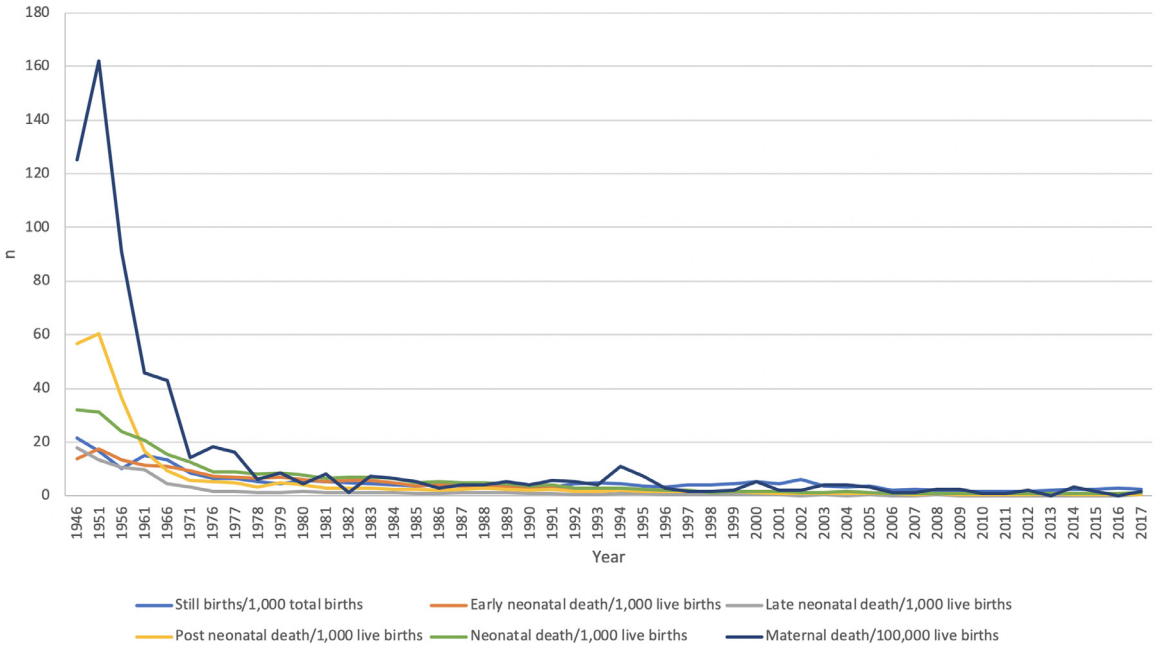

Figure 1. The numbers of maternal death, stillbirths, early and late neonatal deaths, and post-neonatal deaths from 1946 to 2017.

Year	1946–1977	1978–1987	1988–1997	1998–2007	2008–2017
Maternal death¶	-4·43 (-6·39, -2·47)	-0·33 (-0·90, 0·24)	-0·06 (-0·75, 0·64)	-0·06 (-0·43, 0·32)	-0·10 (-0·38, 0·17)
Stillbirth†	-0·41 (-0·62, -0·20)	-0·18 (-0·27, -0·08)	-0·03 (-0·18, 0·12)	-0·27 (-0·53, -0·02)	0·10 (0·02, 0·19)
Early neonatal death‡	-0·29 (-0·40, -0·16)	-0·36 (-0·46, -0·27)	-0·23 (-0·28, -0·19)	-0·04 (-0·08, 0)	0·01 (-0·01, 0·03)
Late neonatal death‡	-0·52 (-0·62, -0·42)	-0·04 (-0·07, -0·02)	-0·06 (-0·11, -0·02)	-0·04 (-0·03, 0·01)	0·01 (-0·01, 0·03)
Post neonatal death‡	-1·92 (-2·64, -1·19)	-0·20 (-0·32, -0·08)	-0·10 (-0·14, -0·05)	-0·11 (-0·14, -0·08)	-0·02 (-0·04, 0·01)
Neonatal death (early and late)‡	-0·80 (-0·91, -0·70)	-0·41 (-0·52, -0·30)	-0·30 (-0·37, -0·23)	-0·05 (-0·10, 0)	0·02 (-0·01, 0·04)

***Table 1*: The annual change rate (95% CIs) of maternal death, stillbirth, early and late neonatal death and post neonatal death.**
The annual change rate was estimated by the regression coefficient and 95% CIs from regression analysis.
¶ per 100,000 live births.
† per 1,000 total births.
‡ per 1,000 live births.

1946 and 1977. All other deaths, except maternal mortality, continued to decrease until 1987. Neonatal deaths and post-neonatal deaths continued to drop until 1997 and 2007, respectively. The annual change rate of stillbirth reduced between 1998–2007 and raised after 2008.

Table 2 and Figure 2 showed the numbers of maternal death per 100,000 livebirths and their percentages within the years of each cause of death between 1981 and 2017 (yearly breakdown in appendix Table 4). There was a total of 92 deaths, ranging from none to eight deaths in a year. The leading causes of maternal death in descending order were thromboembolism (34/92, 37·0%), obstetric haemorrhage (28/92, 30·4%), ectopic pregnancy and hypertensive disorders (8/92, 8·7%, respectively), others (8/92, 8·7%) and pregnancy with abortive outcome (6/92, 6·5%). There was no maternal death due to sepsis. One indirect maternal death happened in 1983 and 2001, respectively. No specific trend in the causes of maternal death with time was identified.

The numbers of neonatal death per 1,000 livebirths and their percentages within the years of each cause of death between 1980 and 2017 were shown in Table 3 and Figure 3 (yearly breakdown in appendix Table 5). There was a total of 7772 deaths, ranging from 52 to 667 per year. The leading causes of neonatal death in descending order were congenital (2339/7772, 30·1%), prematurity (2255/7772, 29·0%), others (1937/7772, 24·9%), intrapartum complication (850/7772, 10·9%), infection (252/7772, 3·2%), accident (57/7772, 0·7%), pneumonia (63/7772, 0·8%), sudden infant death syndrome (14/7772, 0·2%) and malignancy (5/7772,

	1981–1985	1986–1990	1991–1995	1996–2000	2001–2005	2006–2010	2011–2017	1981–2017
Ectopic pregnancy	0·77 (1·73)	0 (0)	0·57 (0·78)	0 (0)	0 (0)	0 (0)	0·39 (0·69)	0·26 (0·75)
Death related to abortion	0·49 (0·67)	0·56 (0·77)	0·29 (0·64)	0·37 (0·83)	0·35 (0·78)	0 (0)	0 (0)	0·28 (0·59)
Hypertensive disorders	1·70 (1·60)	0 (0)	0·29 (0·65)	0·37 (0·83)	0 (0)	0 (0)	0·25 (0·66)	0·37 (0·89)
Obstetric haemorrhage	1·47 (0·55)	1·40 (0·98)	1·40 (1·39)	1·01 (0·93)	0·77 (1·06)	0·74 (1·09)	0·31 (0·52)	0·98 (0·97)
Thromboembolism	0·70 (1·04)	2·24 (2·10)	3·67 (2·13)	1·08 (1.00)	0·82 (1·13)	1·07 (0·62)	0·23 (0·62)	1·34 (1·64)
Others	0·51 (0·69)	0 (0)	0·56 (0·76)	0 (0)	1·24 (1·13)	0 (0)	0·23 (0·62)	0·35 (0·70)
Total	5·64 (2·71)	4·20 (0·98)	6·78 (2·69)	2·84 (1·63)	3·18 (1·06)	1·81 (0·63)	1·41 (1·18)	3·57 (2·43)

***Table 2*: The average maternal mortality per 100,000 livebirths (standard deviation) by causes, between 1981 and 2017.**
The average maternal mortality rate was presented in mean (SD).

0·06%). There was no specific trend in the causes of neonatal death with time.

The regression coefficients of the fixed effect of social and economic factors on different types of mortality were shown in Table 4. Higher GDP, lower fertility rate, higher tertiary education enrolment rate, higher population density, and higher personal computer and internet access rate were significantly associated with lower mortality rates for nearly all mortalities. The effect of socio-economic factors was further explored with multivariable linear mixed model, the outcomes are shown in Table 5 and appendix Table 6 from 1961 to 2017, and 2000 to 2017, respectively. In multivariable analysis, higher neonatal mortalities were statistically significant associated with higher fertility rate and lower tertiary education enrollment rate between 1961-2017. Every increase of one unit log-transformed fertility rate (%) or tertiary education enrolment rate (%) was associated with 1·22 more log-transformed neonatal death per 1000 livebirths, 95% CI (0·66, 1·78) and 0·94 lower neonatal death per 1000 livebirths, 95% CI (-1·2, -0·68) respectively. No statistically significant association between the social and economic factors and maternal death was seen in multivariable analysis.

Discussion

Although a tremendous reduction of maternal death, stillbirth and neonatal death was observed in Hong Kong, the success was not brought up for international attention and often submerged among international figures.[24] Maternal death is rare in Hong Kong, and the MMR remains one of the lowest in the world. In 2017, the country-specific estimates of MMR ranged from 2 to 1150 per 100,000 live births. There were 13 out of 185 countries with MMR less than 5.[25] Globally, between 2003 and 2009, indirect death accounted for approximately 27% of all maternal deaths, while obstetric haemorrhage and hypertensive disorders were the most significant causes of direct death.[26] This is similar to another analysis carried out in sub-Saharan Africa and South Asia between 2012 and 2016.[27] In contrast, the estimates from Global Burden Disease analysis found indirect death only attributed 10·2% of all deaths in 2013, a slight increase from 9·1% in 1990.[18] Obstetric transition on major causes of death could occur with the reducing mortality rate in HIC.[28] Spain, Japan, and the UK were three countries with MMR of 4, 5, and 7 in 2017, respectively. The proportion of indirect death to all maternal death also differed among these countries with a rate of 10·2% in Spain, 25·5% in Japan, and 57·6% in the UK.[29–31] Cardiac disease was the major cause of indirect death. Obstetric haemorrhage remained the commonest cause of direct deaths in Japan (20·2%) and Spain (23·2%), while thromboembolism took the lead in the UK (13·8%). Our findings suggested maternal death due to sepsis and indirect death are rare, whereas thromboembolism became the leading cause of death in Hong Kong. The risk of thromboembolism was 3·6-fold higher in HIC than LIC, together with improved detection, safer abortion, and better obstetric management to other causes of maternal death could explain this observation.[32]

Neonatal death and stillbirth deserve wider attention since the reduction was slower than maternal and under five mortality. The proportion of neonatal death to under-five deaths raised significantly from 40% in 1990 to 47% in 2017.[17] 2% of global neonatal death occurred in HIC and its average NMR reduced by 55%, from 6·8 to 3 per 1000 livebirth between 1990 and 2017. The low NMR in Hong Kong is comparable to the lowest NMR found in Japan (0·9 per 1000 live births). The composition of neonatal death shifted from infection and diarrhoea in high mortality countries to preterm birth and congenital abnormalities in low mortality countries.[5,33] The average preterm birth rates in LIC and HIC were 12% and 9·3%, respectively.[34] The preterm birth rate <34 weeks among HIC ranged from 0·9 to 2·2%.[35] Prevention of preterm birth is far from ideal. Using existing preventive interventions could only achieve an estimated 5% relative rate reduction.[36] Indeed, the percentage change in the preterm birth rate between 2000 and 2014 varies among HIC, from a 46% reduction in Bahrain to a 159% increase in Belgium.[37] In Hong Kong, the preterm birth rate among

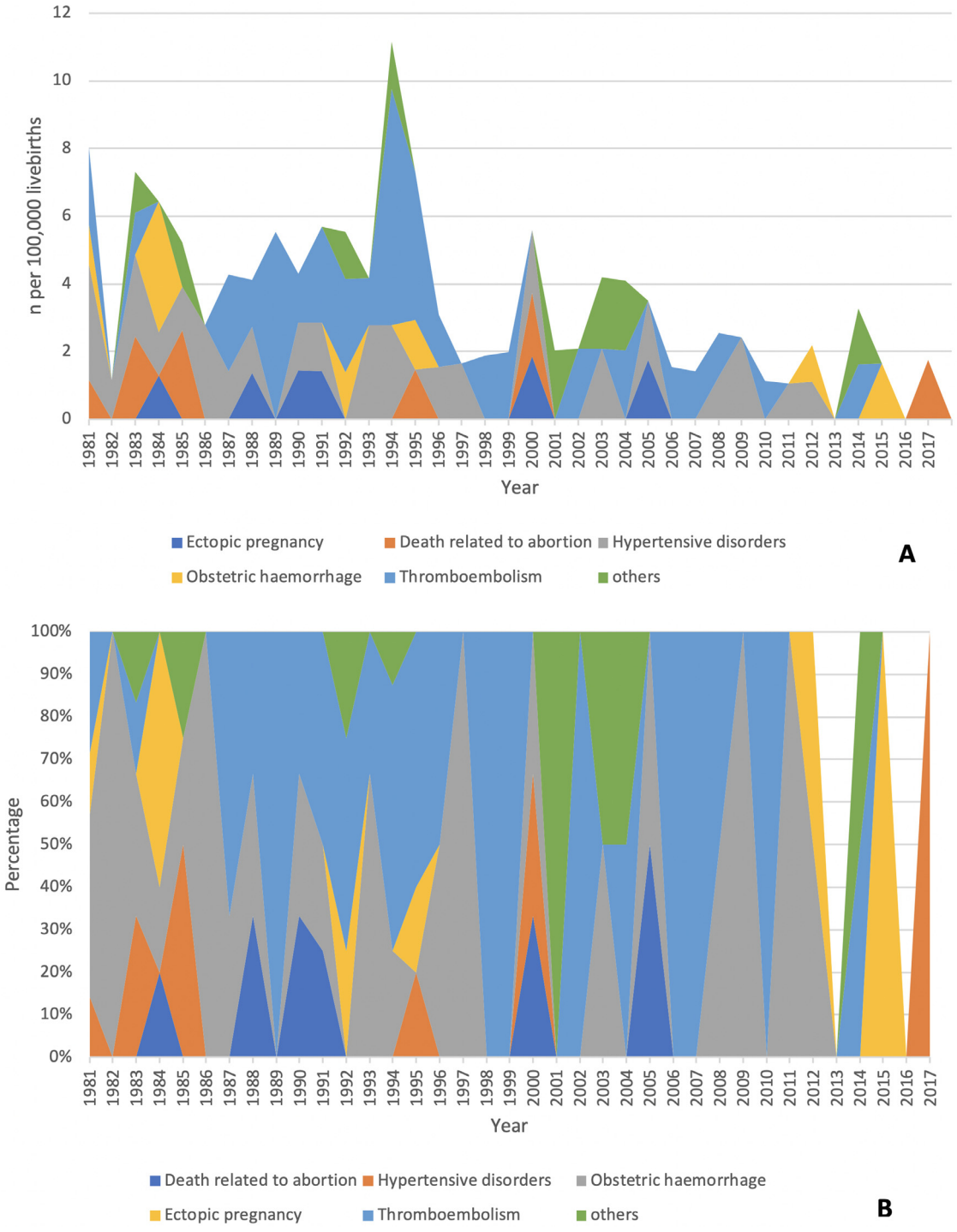

Figure 2. The number (A) and proportion (B) of maternal deaths according to different causes of death between 1981 and 2017.

singleton pregnancies was static from 1995 to 2011, with an overall preterm birth rate of 6·5%. Early preterm birth accounted for the highest perinatal mortality.[38] Although Kangaroo mother care, antenatal corticosteroid, magnesium sulphate, and intrapartum antibiotics coverage can reduce preterm birth complications, research should focus on the primary prevention of preterm birth in HIC. [39]

	1980–1985	1986–1990	1991–1995	1996–2000	2001–2005	2006–2010	2011–2017	1980–2017
Infection	0·17 (0·03)	0·11 (0·09)	0·08 (0·02)	0·04 (0·03)	0·08 (0·09)	0·07 (0·04)	0·08 (0·05)	0·09 (0·06)
Malignancy	0·004 (0·009)	0 (0)	0 (0)	0 (0)	0·004 (0·009)	0·003 (0·007)	0·002 (0·004)	0·002 (0·006)
Pneumonia	0·06 (0·03)	0·01 (0·01)	0·01 (0·01)	0·02 (0·02)	0·03 (0·02)	0·01 (0·01)	0·01 (0·01)	0·02 (0·03)
Accident	0·04 (0·02)	0·04 (0·02)	0·02 (0·02)	0·01 (0·02)	0·03 (0·02)	0·01 (0·01)	0·002 (0·01)	0·02 (0·02)
Congenital	1·72 (0·23)	1·63 (0·18)	1·08 (0·15)	0·67 (0·18)	0·45 (0·13)	0·31 (0·07)	0·21 (0·04)	0·86 (0·61)
Intrapartum complication	0·99 (0·23)	0·49 (0·08)	0·26 (0·11)	0·08 (0·04)	0·09 (0·06)	0·06 (0·04)	0·04 (0·02)	0·29 (0·35)
Prematurity	1·96 (0·36)	1·44 (0·22)	0·98 (0·24)	0·60 (0·16)	0·26 (0·12)	0·21 (0·05)	0·21 (0·05)	0·81 (0·69)
Sudden infant death syndrome	0·01 (0·01)	0·01 (0·02)	0·01 (0·01)	0·01 (0·02)	0 (0)	0·002 (0·005)	0 (0)	0·01 (0·01)
Others	1·68 (0·31)	0·89 (0·17)	0·58 (0·14)	0·38 (0·10)	0·51 (0·12)	0·36 (0·08)	0·43 (0·10)	0·70 (0·49)
Total	6·40 (0·83)	4·62 (0·57)	3·02 (0·59)	1·82 (0·32)	1·46 (0·19)	1·04 (0·06)	0·99 (0·13)	2·80 (2·11)

***Table 3*: The average neonatal mortality per 1000 livebirths (standard deviation) by causes, between 1981 and 2017.**
The average neonatal mortality rate was presented in mean (SD).

A strong correlation was seen among deaths of pregnant women, infants, and newborns.[27] Healthcare infrastructure improvement targeting common risk factors leading to maternal and perinatal death could result in a quadruple benefit of lower maternal death, stillbirth, neonatal death, and better child health.[40] Public health policies, strategies, and health care programs can optimize overall health within the population, such as improving nutrition and reproductive health, and modifying chronic diseases. The provision of antenatal care facilitates the engagement of pregnant women to health services. High-quality intrapartum care and timely intervention are crucial to prevent mortality as around 40% of foetuses, one-third of neonates, and one-fourth of mothers died on the day of birth.[17,18,41] Long-distance, poor transportation and communication, high disparity, lack of experienced birthing attendants and financial constraints, leading to delay attention and management, are often linked with increased adverse maternal and perinatal outcomes.[13] We could not evaluate any specific interventions or changes in health care practices leading to the tremendous reduction in mortalities, but multiple factors might partially explain the observation. Hong Kong is a densely populated city with well-developed transportation and communication. The government funds and supports health care services to ensure universal coverage and no one is denied medical management. Free compulsory universal primary and secondary education is provided to all children under public sector schools to secure educational attainment at the population level. Regarding pregnancy and perinatal care, an effective continuum of care is developed through antepartum, intrapartum, and postpartum care. Regular structured antenatal program care is provided freely by specialized obstetric units and maternal and child health centres. All deliveries, except unintended home birth, take place in hospitals where emergency facilities are accessible 24 hours, equipped with skilful birth attendants, and instrumental and Caesarean delivery are readily available. Standard neonatal and childhood immunization follows. Although HIC usually have similar fundamental functioning health systems to prevent easily avoidable deaths and move towards exploring and tackling specific diseases causing major local burdens, variation in the rate and causes of mortalities among HIC could be accounted by the difference in the characteristics of women and the infrastructure of the health care system. For example, in the UK, there was a four-fold and two-fold difference in maternal mortality amongst Black and Asian women respectively, when compared to white women.[29] This could be related to the limited accessibility of antenatal care in immigrant women secondary to language barriers, lack of awareness or understanding of the purpose of antenatal service and income barriers.[42] In the United State, neonatal mortality was highest in unintended/ unplanned home births.[43] Hong Kong is a very densely populated region with >7 million population in 1110km.[2] All eight public birthing hospitals are equipped with advanced neonatal intensive care units and are in close proximity to the population, together with the free and easily accessible tertiary maternity care, which allows antenatal care to reach out to the minority races and immigrant women and unintended home births seldom occurs.

Our vital statistics did not capture the gestational timing of maternal and perinatal deaths and the causes of stillbirth. Compared to LIC and MIC, where most stillbirths occur during the intrapartum period (e.g., 59·3% in South Asia), antepartum stillbirths were more common in HIC. A local analysis using International Classification of Diseases - Perinatal Mortality (ICD-PM) classification found that 97% of stillbirth occurs before labour and approximately 30% occurs before 28 weeks of gestation. Small for gestational age/intrauterine growth restriction is commonly associated with antepartum stillbirth in HIC and presented in 28·1% of stillbirth in Hong Kong.[44,45] The use of ICD-PM could

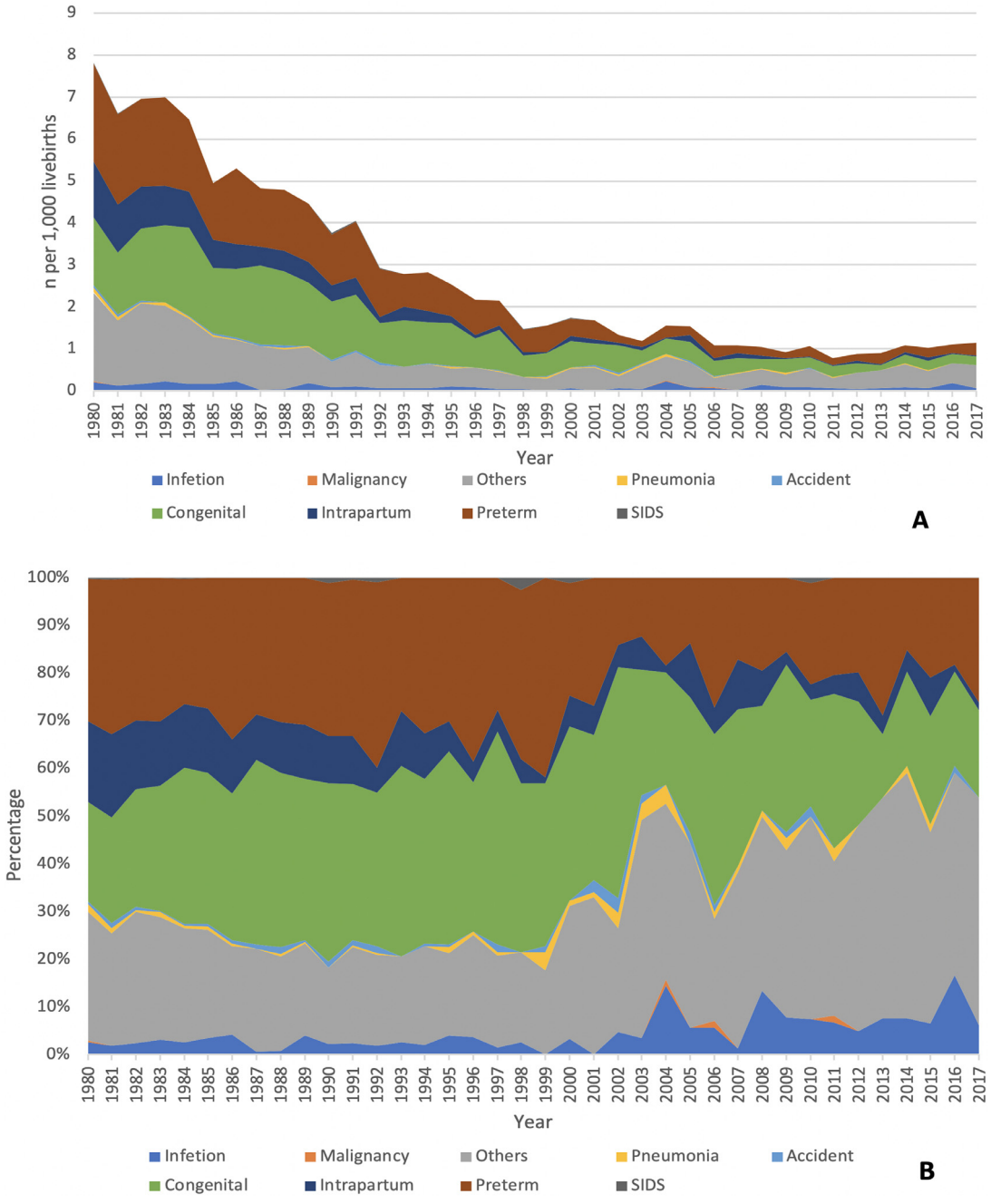

Figure 3. The number (A) and proportion (B) of neonatal deaths according to different causes of death between 1980 and 2017.

facilitate correlation with maternal condition and standard reporting on the timing and causes of stillbirth for international comparison. The stillbirth rate depends on the gestational threshold to define viability. One-third of stillbirths occurred before 28 weeks of gestation in HIC which could be missed using the World Health Organization's definition of stillbirth.[44] A lower viability threshold from 22 gestational weeks, due to increasing survival with advanced neonatal support, further amplify the stillbirth rate in HIC.

Another limitation of the study is the inability to explore the gestational timing of maternal death. There is a lack of a mechanism for confidential enquiry on maternal deaths in Hong Kong. Therefore, we cannot identify risk factors for these deaths and ascertain if maternal death is more common in antepartum,

	Stillbirth	Early neonatal death	Late neonatal death	Post neonatal death	Neonatal death	Maternal death
GDP (per 1 billion USD)	-0·3 (-0·36, -0·24) (1·17)***	-0·66 (-0·74, -0·58) (1·57)***	-0·63 (-0·7, -0·56) (1·04)***	-0·59 (-0·66, -0·52) (1·36)***	-0·66 (-0·73, -0·59) (1·69)***	-0·82 (-1·20, -0·44) (2·02)***
Fertility rate (births per woman)	0·88 (0·62, 1·13) (0·47)***	1·98 (1·6, 2·37) (0·02)***	1·93 (1·60, 2·26) (-0·45)***	1·77 (1·42, 2·11) (-0·02)***	1·99 (1·63, 2·34) (0·15)***	2·18 (0·83, 3·53) (0·14)**
Tertiary school enrollment (%)	-0·53 (-0·63, -0·43) (1·30)***	-1·2 (-1·34, -1·07) (1·97)***	-0·99 (-1·14, -0·84) (1·18)***	-1·03 (-1·13, -0·93) (1·62)***	-1·15 (-1·28, -1·02) (2·02)***	-1·65 (-2·69, -0·6) (2·69)**
Population density (per 1000 people per km^2)	-2·27 (-2·70, -1·84) (9·16)***	-4·68 (-5·38, -3·98) (17·91)***	-4·61 (-5·13, -4·09) (17·18)***	-4·36 (-4·85, -3·86) (16·62)***	-4·7 (-5·30, -4·09) (18·12)***	-6·12 (-8·89, -3·35) (23·49)***
Personal computer (15-44 years, %)	-2·2 (-3·01, -1·39) (4·71)***	-1·25 (-1·79, -0·71) (2·33)***	-1·23 (-2·20, -0·27) (1·88)*	-1·63 (-2·08, -1·17) (3·02)***	-1·23 (-1·68, -0·78) (2·44)***	-8·02 (-17·35, 1·32) (15·43)
Internet (15−44 years, %)	-1·33 (-1·87, -0·78) (3.00)***	-0·75 (-1·11, -0·39) (1·35)***	-0·74 (-1·36, -0·12) (0·92)*	-0·98 (-1·30, -0·65) (1·75)***	-0·74 (-1·04, -0·43) (1·48)***	-4·26 (-10·28, 1·75) (8·11)

***Table 4*: The effect of socio-economic factors on perinatal and maternal death (1961−2017).**
The analysis was performed by univariable linear mixed effect model after log transformation on socio-economic factors.
Data are presented as regression coefficient of the fixed effect (95% confident interval) (intercept) and significance level (***: <0·0001; **: <0·01; *: <0·05).

	Stillbirth	Early neonatal death	Late neonatal death	Post neonatal death	Neonatal death	Maternal death
Intercept[†]	14·69 (-1·63, 31)	-16·06 (-29·91, -2·21)	-10·91 (-31·3, 9·48)	6·85 (-5·64, 19·34)	-14·41 (-26·68, -2·15)	80·04 (-91·95, 252·04)
GDP (per 1 billion USD)[‡]	0·50 (-0·07, 1·07)	-0·42 (-0·91, 0·07)	-0·46 (-1·17, 0·26)	0·22 (-0·22, 0·65)	-0·43 (-0·86, 0)	1·53 (-4·50, 7·57)
Fertility rate (births per woman)[‡]	0·04 (-0·71, 0·78)	1·36 (0·73, 2.00)**	0·82 (-0·11, 1·75)	0·60 (0·03, 1·17)*	1·22 (0·66, 1·78)**	-4·07 (-11·92, 3·79)
Tertiary school enrollment (%)[‡]	-0·52 (-0·87, -0·17)**	-1·04 (-1·33, -0·74)***	-0·66 (-1·1, -0·23)**	-0·84 (-1·10, -0·57)***	-0·94 (-1·2, -0·68)***	-1·3 (-4·95, 2·35)
Population density (per 1000 people per km^2)[‡]	-3·81 (-8·40, 0·77)	4·88 (0·99, 8·77)*	3·29 (-2·44, 9·01)	-1·59 (-5·10, 1·92)	4·45 (1·01, 7·9)*	-21·27 (-69·61, 27·06)

***Table 5*: The fixed effect of socio-economic factors on neonatal and maternal death (1961−2017) using multivariable linear mixed model.**
The analysis was performed by multivariable linear mixed effect model after log transformation on socio-economic factors.
[†] Data for intercept are presented as intercept of the fixed effect (95% confident interval) and significance level (***: <0·0001; **: <0·01; *: <0·05).
[‡] Data for intercept are presented as regression coefficient of the fixed effect (95% confident interval) and significance level (***: <0·0001; **: <0·01; *: <0·05).

peripartum, or postpartum. It is also important to confirm sepsis and indirect death are rare causes of death in Hong Kong, since up to 81% of indirect death could be missed from mortality statistics.[46] More women died post-delivery than during the antepartum and intrapartum periods.[44] In the UK, almost half of maternal death happened between day one to six weeks after birth.[29] Prevention should also be condition/disease-specific once identified. Improving maternal mortality is possible even in regions with low MMR. 75% reduction of maternal death from haemorrhage was observed in Japan following serial education programs and recommendations to the management and emergency simulation programs.[31] On the other hand, MMR from thromboembolism remains static despite the increased awareness by national recommendations on its prevention.[29,47] Furthermore, vital registration could fail to record about 50% of maternal death.[3] In Hong Kong, suicide, or other causes, may have escaped from reporting to vital statistics due to omission, misclassification, or misinterpretation.[48] Adding a pregnancy checkbox may help to correct unidentified maternal death; however, under-reporting continues and errors from misuse or misclassification could falsely inflate the mortality rate.[49–51] Education on the correct use of the checkbox is essential.

Conclusion

The maternal and perinatal death have reduced significantly in Hong Kong and maintained at the lowest level globally. Thromboembolism, preterm birth and congenital malformations were the leading cause of maternal and neonatal deaths, respectively. Indirect maternal death and sepsis were unusual causes of maternal deaths.

The changing baseline demographics and advanced medical care may influence these mortalities in HIC. Delaying childbearing, a higher proportion of pregnancy with advanced maternal age, use of assisted reproductive technique and increasing incidence of multiple pregnancies,[52] more pregnant women with complex medical disorders contemplating pregnancy,[53] in-utero interventions for complex foetal anomalies [54–56] and lower gestational viability threshold are challenges to maintain the low mortality rate among HIC. Maternal and perinatal morbidities are critical issue to follow and address. We encourage HIC to continue reporting their maternal and perinatal mortality, with comprehensive data collection and disaggregation to provide high-quality data and enable trend tracking. Setting up confidential enquiry in maternal death and perinatal audit are cornerstone to identify gaps and finetune local policy targeting specific local burdens and strive for continuous improvement.[29,31,57–59] Then, HIC could become the pioneer to end preventable maternal and perinatal deaths and pave the road for LIC and MIC.

Contributors

KWC conceived the study, designed the protocol and literature search. KWC, MTYS, WW and CTN analysed the data. KWC wrote the first draft of the paper. All authors critically revised the drafts of the paper. All authors had full access to the data of the study, read and approved the final manuscript.

Data sharing statement

All data analysed are included in this paper and the appendix.

Declaration of interests

All authors declare no conflicts of interests.

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Supplementary materials

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References

1 UN Women. SDG 3. *Ensure healthy lives and promote well-being.* for all at all ages. https://www.unwomen.org/en/news/in-focus/women-and-the-sdgs/sdg-3-good-health-well-being.
2 WHO, UNICEF. *Every Newborn: An Action Plan to End Preventable Deaths.* Geneva: World Health Organization; 2014.
3 Alkema L, Chou D, Hogan D, et al. Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Maternal Mortality Estimation Inter-Agency Group. *Lancet.* 2016;387(10017):462–474.
4 Blencowe H, Cousens S, Jassir FB, et al. National, regional, and worldwide estimates of stillbirth rates in 2015, with trends from 2000: a systematic analysis. *Lancet Glob Health.* 2016;4(2):e98–e108.
5 Liu L, Oza S, Hogan D, et al. Global, regional, and national causes of under-5 mortality in 2000-15: an updated systematic analysis with implications for the sustainable development goals. *Lancet.* 2016;388(10063):3027–3035.
6 de Bernis L, Kinney MV, Stones W, et al. Stillbirths: ending preventable deaths by 2030. *Lancet.* 2016;387(10019):703–716.
7 Akseer N, Salehi AS, Hossain SM, et al. Achieving maternal and child health gains in Afghanistan: a Countdown to 2015 country case study. *Lancet Glob Health.* 2016;4(6):e395–e413.
8 Van Lerberghe W, Matthews Z, Achadi E, et al. Country experience with strengthening of health systems and deployment of midwives in countries with high maternal mortality. *Lancet.* 2014;384(9949):1215–1225.
9 Lawn JE, Blencowe H, Waiswa P, et al. Stillbirths: rates, risk factors, and acceleration towards 2030. *Lancet.* 2016;387(10018):587–603.
10 WHO. *Strategies Toward Ending Preventable Maternal Mortality (EPMM).* Geneva: World Health Organization; 2015.
11 UNICEF, WHO. *Every Newborn: An Action Plan to End Preventable Deaths.* 2014.
12 Michalow J, Chola L, McGee S, et al. Triple return on investment: the cost and impact of 13 interventions that could prevent stillbirths and save the lives of mothers and babies in South Africa. *BMC Pregnancy Childbirth.* 2015;15:39.

13 Kerber KJ, de Graft-Johnson JE, Bhutta ZA, Okong P, Starrs A, Lawn JE. Continuum of care for maternal, newborn, and child health: from slogan to service delivery. *Lancet*. 2007;370 (9595):1358–1369.
14 Joseph KS, Lisonkova S, Muraca GM, et al. Factors underlying the temporal increase in maternal mortality in the United States. *Obstet Gynecol*. 2017;129(1):91–100.
15 Flenady V, Wojcieszek AM, Middleton P, et al. Stillbirths: recall to action in high-income countries. *Lancet*. 2016;387(10019):691–702.
16 Kong X, Yang Y, Gao J, et al. Overview of the health care system in Hong Kong and its referential significance to mainland China. *J Chin Med Assoc*. 2015;78(10):569–573.
17 Hug L, Alexander M, You D, Alkema L. Estimation UNI-aGfCM. National, regional, and global levels and trends in neonatal mortality between 1990 and 2017, with scenario-based projections to 2030: a systematic analysis. *Lancet Glob Health*. 2019;7(6):e710–ee20.
18 Kassebaum NJ, Bertozzi-Villa A, Coggeshall MS, et al. Global, regional, and national levels and causes of maternal mortality during 1990-2013: a systematic analysis for the global burden of disease study 2013. *Lancet*. 2014;384(9947):980–1004.
19 Khan KS, Wojdyla D, Say L, Gulmezoglu AM, Van Look PF. WHO analysis of causes of maternal death: a systematic review. *Lancet*. 2006;367(9516):1066–1074.
20 The World Bank. Hong Kong SAR, China. https://data.worldbank.org/country/hong-kong-sar-china?view=chart.
21 Census and Statistics Department. The government of the Hong Kong SAR. Thematic Household Survery Report. https://www.censtatd.gov.hk/en/EIndexbySubject.html?pcode=B1130201&scode=453.
22 R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.
23 Pinheiro J, Bates D, DebRoy S, Sarkar D, R Core Team. *nlme: Linear and Nonlinear Mixed Effects Models. R Package Version 3.1-155*. 2022. https://CRAN.R-project.org/package=nlme.
24 Liang J, Li X, Kang C, et al. Maternal mortality ratios in 2852 Chinese counties, 1996-2015, and achievement of millennium development goal 5 in China: a subnational analysis of the global burden of disease study 2016. *Lancet*. 2019;393(10168):241–252.
25 WHO, UNICEF, UNFPA. *World Bank Group and the United Nations Population Division. Trends in Maternal Mortality, 2000–2017*. 2019. https://data.unicef.org/resources/trends-maternal-mortality-2000-2017/.
26 Say L, Chou D, Gemmill A, et al. Global causes of maternal death: a WHO systematic analysis. *Lancet Glob Health*. 2014;2 (6):e323–e333.
27 Alliance for Maternal and Newborn Health Improvement (AMANHI) mortality study group. Population-based rates, timing, and causes of maternal deaths, stillbirths, and neonatal deaths in south Asia and sub-Saharan Africa: a multi-country prospective cohort study. *Lancet Glob Health*. 2018;6(12):e1297–ee308.
28 Souza JP, Tuncalp O, Vogel JP, et al. Obstetric transition: the pathway towards ending preventable maternal deaths. *BJOG*. 2014;121 (Suppl 1):1–4.
29 Maternal, Newborn and Infant Clinical Outcome Review Programme. Saving Lives, Improving Mothers's Care. Lessons learned to inform maternity care from the UK and Ireland confidential enquiries into maternal deaths and morbidity 2016–18. 2020. https://www.npeu.ox.ac.uk/assets/downloads/mbrrace-uk/reports/maternal-report-2020/MBRRACEUK_Maternal_Report_Dec_2020_v10_ONLINE_VERSION_1404.pdf.
30 Blagoeva Atanasova V, Arevalo-Serrano J, Antolin Alvarado E, Garcia-Tizon Larroca S. Maternal mortality in Spain and its association with country of origin: cross-sectional study during the period 1999–2015. *BMC Public Health*. 2018;18(1):1171.
31 Hasegawa J, Katsuragi S, Tanaka H, et al. Decline in maternal death due to obstetric haemorrhage between 2010 and 2017 in Japan. *Sci Rep*. 2019;9(1):11026.
32 Siegal DM, Eikelboom JW, Lee SF, et al. Variations in incidence of venous thromboembolism in low-, middle-, and high-income countries. *Cardiovasc Res*. 2021;117(2):576–584.
33 Lehtonen L, Gimeno A, Parra-Llorca A, Vento M. Early neonatal death: a challenge worldwide. *Semin Fetal Neonatal Med*. 2017;22 (3):153–160.
34 Walani SR. Global burden of preterm birth. *Int J Gynaecol Obstet*. 2020;150(1):31–33.
35 Delnord M, Zeitlin J. Epidemiology of late preterm and early term births - an international perspective. *Semin Fetal Neonatal Med*. 2019;24(1):3–10.
36 Chang HH, Larson J, Blencowe H, et al. Preventing preterm births: analysis of trends and potential reductions with interventions in 39 countries with very high human development index. *Lancet*. 2013;381(9862):223–234.
37 Chawanpaiboon S, Vogel JP, Moller AB, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health*. 2019;7(1):e37–e46.
38 Hui AS, Lao TT, Leung TY, Schaaf JM, Sahota DS. Trends in preterm birth in singleton deliveries in a Hong Kong population. *Int J Gynaecol Obstet*. 2014;127(3):248–253.
39 World Health Organization. WHO recommendations on interventions to improve preterm birth outcomes. 2015. https://apps.who.int/iris/bitstream/handle/10665/183037/9789241508988_eng.pdf.
40 Bhutta ZA, Das JK, Bahl R, et al. Can available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? *Lancet*. 2014;384(9940):347–370.
41 Hug L, You D, Blencowe H, et al. Global, regional, and national estimates and trends in stillbirths from 2000 to 2019: a systematic assessment. *Lancet*. 2021;398(10302):772–785.
42 Higginbottom GMA, Evans C, Morgan M, Bharj KK, Eldridge J, Hussain B. Experience of and access to maternity care in the UK by immigrant women: a narrative synthesis systematic review. *BMJ Open*. 2019;9(12):e029478.
43 Grunebaum A, McCullough LB, Orosz B, Chervenak FA. Neonatal mortality in the United States is related to location of birth (hospital versus home) rather than the type of birth attendant. *Am J Obstet Gynecol*. 2020;223(2):254 e1-e8.
44 Flenady V, Koopmans L, Middleton P, et al. Major risk factors for stillbirth in high-income countries: a systematic review and meta-analysis. *Lancet*. 2011;377(9774):1331–1340.
45 Mok YK, Seto MTY, Lai THT, Wang W, Cheung KW. Pitfalls of international classification of diseases - perinatal mortality in analysing stillbirths. *Public Health*. 2021;201:12–18.
46 Karimian-Teherani D, Haidinger G, Waldhoer T, Beck A, Vutuc C. Under-reporting of direct and indirect obstetrical deaths in Austria, 1980-98. *Acta Obstet Gynecol Scand*. 2002;81(4):323–327.
47 Middleton P, Shepherd E, Gomersall JC. Venous thromboembolism prophylaxis for women at risk during pregnancy and the early postnatal period. *Cochrane Database Syst Rev*. 2021;3:CD001689.
48 Yip SK, Chung TK, Lee TS. Suicide and maternal mortality in Hong Kong. *Lancet*. 1997;350(9084):1103.
49 Catalano A, Davis NL, Petersen EE, et al. Pregnant? Validity of the pregnancy checkbox on death certificates in four states, and characteristics associated with pregnancy checkbox errors. *Am J Obstet Gynecol*. 2020;222(3):269.e1–e8.
50 Hoyert DL, Uddin SFG, Minino AM. Evaluation of the pregnancy status checkbox on the identification of maternal deaths. *Natl Vital Stat Rep*. 2020;69(1):1–25.
51 Creanga AA, Thoma M, MacDorman M. Value and disvalue of the pregnancy checkbox on death certificates in the United States-impact on newly released 2018 maternal mortality data. *Am J Obstet Gynecol*. 2020;223(3):393 e1-e4.
52 Monden C, Pison G, Smits J. Twin peaks: more twinning in humans than ever before. *Hum Reprod*. 2021;36(6):1666–1673.
53 Ramlakhan KP, Johnson MR, Roos-Hesselink JW. Pregnancy and cardiovascular disease. *Nat Rev Cardiol*. 2020;17(11):718–731.
54 Deprest JA, Nicolaides KH, Benachi A, et al. Randomized trial of foetal surgery for severe left diaphragmatic hernia. *N Engl J Med*. 2021;385(2):107–118.
55 Adzick NS, Thom EA, Spong CY, et al. A randomized trial of prenatal versus postnatal repair of myelomeningocele. *N Engl J Med*. 2011;364(11):993–1004.
56 Morris RK, Malin GL, Quinlan-Jones E, et al. Percutaneous vesicoamniotic shunting versus conservative management for foetal lower urinary tract obstruction (PLUTO): a randomised trial. *Lancet*. 2013;382(9903):1496–1506.
57 Flenady V, Wojcieszek AM, Middleton P, et al. Stillbirths: recall to action in high-income countries. *Lancet*. 2016;387(10019):691–702.
58 Willcox ML, Price J, Scott S, et al. Death audits and reviews for reducing maternal, perinatal and child mortality. *Cochrane Database Syst Rev*. 2020;3:CD012982.
59 Kilby MD, Gibson JL, Ville Y. Falling perinatal mortality in twins in the UK: organisational success or chance? *BJOG*. 2019;126(3):341–347.