The folly of forgetting history: how lessons from the early 20th c successes in reducing infant mortality in the U.S. can help reorient & restructure current initiatives in low and middle-income countries.

Amiya Bhatia, MPH
Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, 677 Huntington Ave, Boston, MA
amb803@mail.harvard.edu
857-260-9432

Nancy Krieger, PhD
Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health

S.V. Subramanian, PhD
Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health

Acknowledgements: This project was supported by the Harvard/Robert Wood Johnson Foundation Health & Society Scholars seed grant program, based at the Harvard Center for Population and Development Studies.

Number of pages of text: 31 pages

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Abstract

Context: Between 1915 and 1950, the infant mortality rate (IMR) in the United States declined from 100 to fewer than 30 per 1000 live births, prior to the widespread use of medical technologies and vaccination. We contrast the role of public health institutions and interventions for IMR reduction in past versus present efforts to reduce infant mortality in low and middle-income countries (LMICs) to critically examine the current evidence base for reducing infant mortality, and to propose ways in which lessons from history can inform efforts to address the current burden of infant mortality.

Methods: We searched the peer-reviewed and grey literature on the causes and explanations behind the decline in infant mortality in the United States between 1850 and 1950, and in LMICs after 2000. We included historical analyses, empirical research, policy documents, and global strategies. For each key source, we assessed the factors considered to be salient in reducing infant mortality.

Findings: Public health programs that played a central role in the decline in infant mortality in the United States in the early 1900s emphasized large structural interventions like filtering and chlorinating water supplies, building sanitation systems, developing the birth and death registration area, pasteurizing milk, and also educating mothers on infant care and hygiene. The creation of new institutions and policies for infant health additionally provided technical expertise, mobilized resources, and engaged women's groups and public health professionals. In contrast, contemporary literature and global policy documents on reducing infant mortality in LMICs have primarily focused on interventions at the individual, household, and health facility level, and on the widespread adoption of cheap, ostensibly accessible and simple technologies, often at the cost of leaving the structural conditions that determine child survival largely untouched.

Conclusions: Current discourses on infant mortality are not informed by lessons from history. Although structural interventions were central to the decline in infant mortality in the United States, current interventions in LMICs which receive the most global endorsement do not address these structural determinants of infant mortality. Using a historical lens to examine the continued problem of infant mortality in LIMCs suggests that structural interventions, especially regarding sanitation and civil registration, should again become core to a public health approach to addressing infant mortality.

Keywords: Infant mortality [MeSH], history [MeSH], sanitation [MeSH], low and middle income countries, CRVS

Policy points

- Current efforts to reduce infant mortality and improve infant health in low and middle-income countries can benefit from awareness of the history of successful early 20th c initiatives to reduce infant mortality in high income countries which occurred before widespread use of vaccination and medical technologies
- Improvements in sanitation, civil registration, milk purification, and institutional structures to monitor and reduce infant mortality played a crucial role in the decline in infant mortality seen in the United States in the early 1900s
- The commitment to sanitation and civil registration has not been fulfilled in many low and middle-income countries. Structural investments in sanitation and water purification as well as in civil registration systems should be central, not peripheral, to the goal of infant mortality reduction in low and middle-income countries

Introduction

The infant mortality rate (IMR) has long been a measure of whether societies' social, political, economic structures and health systems enable a child to complete their first year of life.[1,2] In the United States, the IMR declined from 100 deaths per 1000 live births in 1915 to fewer than 10 deaths per 1000 live births by 1990, with the sharpest decline occurring between 1915 and 1960, before widespread use of medical technologies and vaccines.[2] Although other high income countries also made similar progress in the early 20th century, such a sharp decline did not take place in many low and middle income countries (LMICs) until after the end of the Second World War, and is yet to take place in some countries.[3] For example, in 2015, the IMR in LMICs was 53.2 deaths per 1000 live births (comparable to the United States in 1935 when the IMR was 55.7 deaths per 1000 live births), and globally ranged from a maximum of 96 deaths per 1000 live births in Angola to a minimum of 1.5 deaths per 1000 live births in Luxemburg.[4]

Partly in response to persistent inequities in the IMR across and within countries i.e., differences in rates across groups that are unnecessary, unjust, and in principle preventable,[5–9] there has been a marked increase in global commitments to child and neonatal survival, through a growing number of partnerships and policies,[10–16] combined with an increase in Official Development Assistance (ODA). For example, one study found that the total aid disbursed to four sectors (health, education, water and sanitation, and food and humanitarian assistance) for child survival in 134 countries more than doubled between 2000 and 2014, rising from US$ 22.62 billion to US$ 59.29 billion. This increase in aid was noted in all income groups and regions, with Sub-Saharan Africa receiving the largest amount of disbursements.[17]

In this context, the new Sustainable Development Goal (SDG) 3 for 2030 seeks to 'end preventable deaths of newborns and children under 5 years of age, with all countries aiming to

reduce neonatal mortality to at least 12 per 1,000 live births, and under-5 mortality to at least as 25 per 1,000 live births'.[18] Notably, this SDG goal has been articulated following the global failure to achieve Millennium Development Goal (MDG) 4, set in 2000, which had aimed to reduce the mortality rate among children under-five by two thirds between 1990 and 2015. Although the child mortality rate (CMR) declined and the global IMR declined from 62.8 in 1990 to 31.7 deaths per 1000 births in 2015,[4] MDG 4 was not achieved. Worryingly, in 2015 the UN Inter-agency Group for Child Mortality Estimation concluded that to meet the new SDG 3 target, 63 countries would need marked acceleration of their current rates of reduction.[19]

Critical work accordingly is needed to understand and address reasons for the gap between recent and projected goals to reduce the IMR in LMICs – and we believe useful guidance can be gleaned from a deeper look into the early 20th century history of the reduction of IMR in high income countries. Specifically, we examine the historical evidence base of the IMR decline in the United States in the early 1900s and the role of public health institutions and structural interventions in enabling this decline. We then use the key themes that emerge from this historical analysis to assess current efforts in LMICs, which emphasize individual-level biomedical interventions for infant mortality. As the historical record clarifies, current approaches are not inevitabilities: in the early 1900s, policymakers, public health experts and practitioners made – and funded – a set of different choices that effectively lowered infant mortality.[20–27]

There are compelling arguments for why history should inform global public health discourses [5,28–33] and our historically-informed analysis not surprisingly engages with longstanding tensions between structural and individualist approaches to improving population health and reducing health inequities.[5,6,8] In offering such an analysis, we do not assume a

contextual, political or economic equivalency between the turn of the 20th century in the U.S. and turn of the 21st century globally. Rather, as Randall Packard observed in his 2016 book *A History of Global Health*, "we need to understand these forces and how they have defined and limited global-health interventions. We also need to acknowledge the limitations and consequences of the choices that have been made." [6] In this vein, this paper seeks to contribute to the paucity of literature connecting historical and current efforts to reduce infant mortality in order to critique and inform current policies and interventions to improve child survival and reduce health inequities.

Methods

To understand the key milestones in policy, governance, law, and public health which contributed to reducing infant mortality, we searched for literature on the causes and explanations behind the decline in infant mortality in the United States between 1850 and 1950. Key words used included "United States, infant mortality, 1850-1950, causes, determinants", and specific search terms for key themes in the literature (e.g. sanitation, medicine, water, registration, hygiene, breast feeding, education). We included secondary literature from history, economics, social sciences and public health, which examined the decline in infant mortality. Our goal was not to review primary sources or to disentangle the precise, and relative effects of the range of causal factors that decreased infant mortality, especially given that data on IMR were initially absent and only began to be compiled during the time period of interest.[34] Given fragmentary, limited, and not easily comparable federal, state, and local funding data, we did not attempt to examine the financial commitments from public and private organizations to address infant mortality during this time period. Rather, our intent is to summarize arguments for the

decline, as offered both by historical contemporaries and by contemporary historians, and examine whether structural interventions were central or peripheral to the reduction of infant mortality.

We conducted a similar search of peer-reviewed and grey literature to examine contemporary research on the causes and determinants of infant and neonatal mortality in LMICs, as well as efforts made by donors, the United Nations, and other global health institutions to address infant mortality between 2000 and 2015. Although, this time period does not represent the totality of activities in LMICs, it reflects global efforts made in the 21st century, the MDG and SDG periods, activities supported by the large increase in ODA synonymous with this period,[17,35] and the increase in global attention towards child survival.[13,14] We used key words for "infant mortality" combined with search terms for low and middle-income countries (e.g. developing, resource poor, LMIC) and we conducted our searches by using PubMed, Google Scholar, and the institutional websites of WHO and UNICEF and other institutions with a mandate to address infant mortality to conduct the search.

To capture the conceptual frameworks and recommendations employed regarding IMR reduction, our search additionally encompassed global targets, policy documents, resolutions of the United Nations, strategies, toolkits, operational frameworks, technologies, and interventions to address infant mortality, including infant pneumonia, diarrhea, and non-immunization. We deliberately focused on the explicitly stated goals and aims of policies to reduce IMR that have been developed by donors, Western aid agencies and other global organizations, so as to understand what these global health institutions value and fund. It was therefore outside the scope of our review to evaluate the implementation of programs or address policies and initiatives: (a) not expressly designed to reduce IMR (e.g., sanitation projects with no explicit

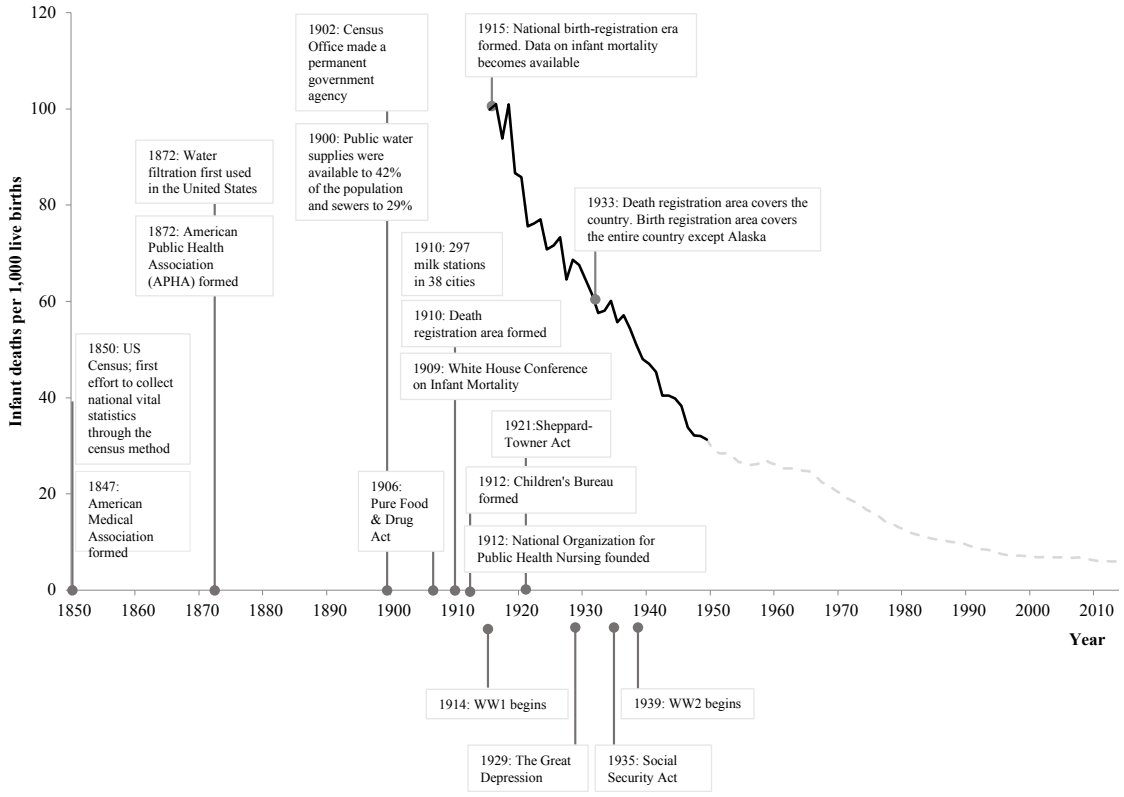
IMR reduction target), and (b) independently implemented by specific LMIC governments (i.e., not explicitly tied to global initiatives). This focus enabled us to examine common and divergent themes between two moments in work to reduce IMR: public health policy in the United States at the turn of the 20th century and global health policy at the turn of the 21st century.

Infant mortality trends in the United States and low and middle-income countries

Although the current definition of the IMR - the number of deaths before 1 year of age per 1000 live births - was not commonly accepted until the 1880s, estimates suggest that in 1860, infant mortality was 197 deaths per 1000 live births for the whole American population and 350 deaths per 1000 live births for enslaved populations.[36] Efforts to gather national data on birth and death rates included the white and black population, albeit at an unequal pace: in 1900 the death registration area included 26 percent of the total population, but only 4.4 percent of the black population.[37] In 1916, as national data became available, the mortality rate was 101 deaths per 1000 live births (white: 99.0/1000; black: 184.3/1000).[38] By 1940, the infant mortality had decreased to 47 deaths per 1000 live births (white: 43.2/1000; black: 72.9/1000),[38] and by 1950, the IMR was 29.2 per 1000 live births. Figure 1 charts this decline along with the coinciding development of public health polices in the late 19th and early 20th century, including the efforts to improve sanitation, expand birth registration, and create institutions to address infant health, all of which played a role in addressing the leading causes of infant and child mortality and decreasing the burden of infectious disease. In the late 1800s, infants most often died from diarrheal diseases, diphtheria, measles, pneumonia and influenza, scarlet fever, tuberculosis, typhoid and paratyphoid fevers, and whooping cough.[39] However, by 1920 these deaths had greatly diminished, and between 1900 and 1998, the percentage of child deaths attributable to

infectious diseases declined from 61.6% to 2%.[21,39] In addition, there was a dramatic reduction in water and food-borne diseases (typhoid, cholera, dysentery, and non-respiratory tuberculosis) -- from an overall mortality rate of 214 per 100,000 in 1848-54 to virtual elimination by 1970.[22]

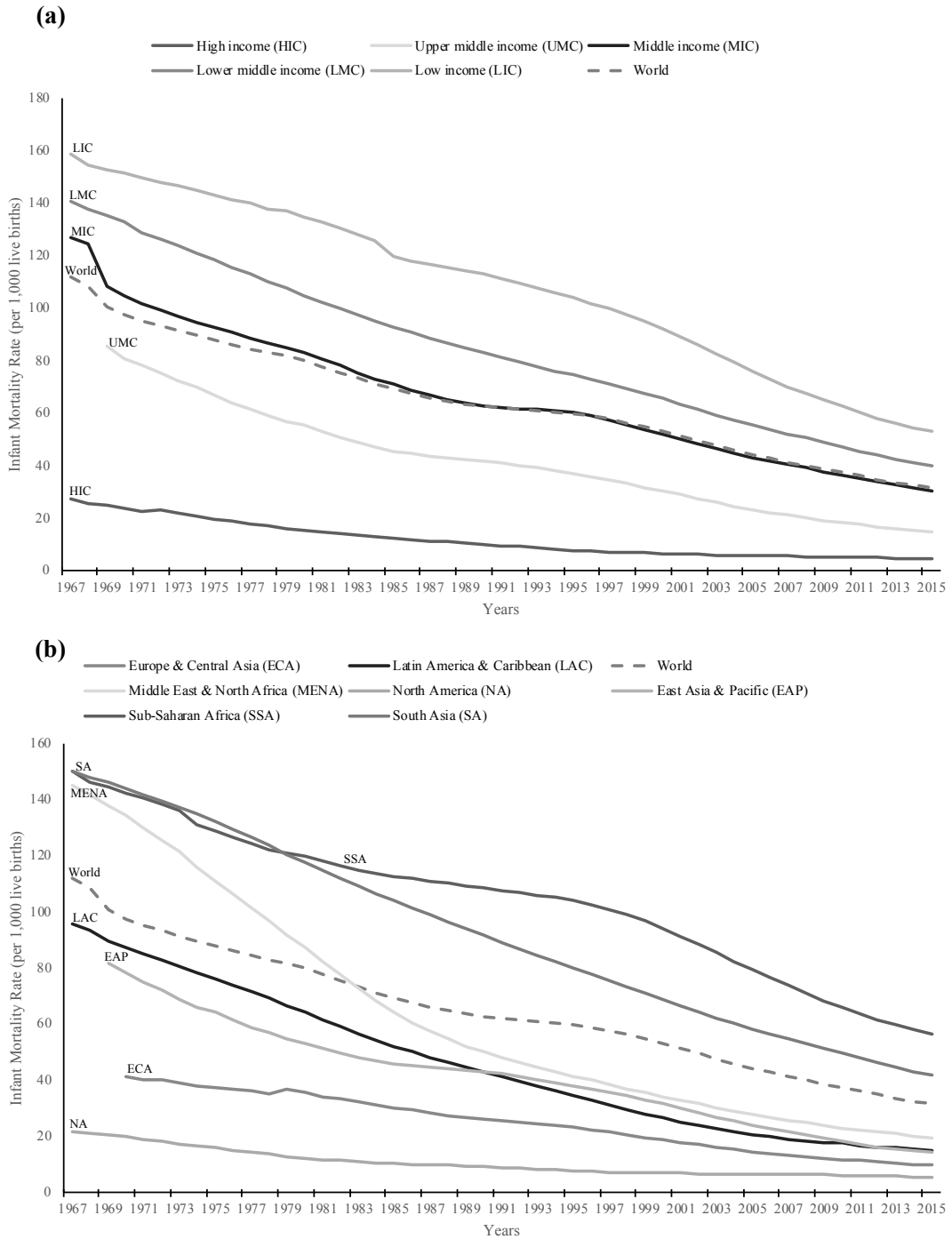
Figure 1 – The infant mortality rate in the United States (1915-2013) and key milestones



The infant mortality rate is the number of deaths among infants under 1 year, excluding fetal deaths; rates per 1,000 registered live births.
Sources for events and milestones:[26,27,65,66,71,72,77,136,36,39,55,57,60–63]
Data sources: U.S. Census Bureau (1900-1970),[137] National Center for Health Statistics(2000-2011 and 2013)[138,139]

To contextualize the earth 20th century decline in infant mortality in the United States, Figure 2 shows the average IMR in World Bank income groups (2a) and regions (2b) between 1967 and 2015.[4] By 1967 - when World Bank IMR data became available - high income-countries, North America and Europe had completed their largest declines. Between 1967 and 2015, infant mortality declined by 22.6 among high-income countries and by over 100 deaths per 1000 live births in LMICs. During the same period, the IMR declined by 16.4 deaths per 1000 live births in North America and by 31.7 deaths per 1000 live births in Europe & Central Asia. In contrast, the IMR declined by 125.5 in the Middle East and North Africa, followed by 108.4 deaths per 1000 live births in South Asia.

Figure 2 - Infant mortality rates for countries, stratified by income group (a) and region (b) (1967-2015)



Source: World Bank Data, 2015[4]

Notes: In 2015 the IMR in LMICs was 53.2 deaths per 1000 live births, which is comparable to the United States in 1935 when IMR was 55.7 deaths per 1000 live births. The IMR ranged from a maximum of 96 deaths per 1000 live births in Angola to a minimum of 1.5 deaths per 1000 live births in Luxemburg.[4]

Factors contributing to the decline in infant mortality in the United States in the early 1900s

In the early 1900s, high infant mortality became one of the targets of social reform movements in the United States, galvanizing public health and policy interventions at the state and national level that focused on reducing poverty and improving conditions of the poor. Table 1 outlines the literature we identified to understand the decline in infant mortality, and the factors mentioned by each author as contributing to this decline. There was consensus among public health professionals in that era, shared by contemporary scholars, that public health programs like filtering and chlorinating water supplies, building sanitation systems, expanding the birth registration area, pasteurizing milk, and subsequent efforts to educate mothers on infant care and hygiene played a central role in the decline in infant mortality.[20–27]

In reports to the Census Bureau in 1900, local health authorities clearly considered structural public health measures to be the major reason for IMR declines.[23] Writing in 1926, Woodbury attributed the decrease of the infant mortality rate by one-fifth between 1915 and 1921 to increased public interest in infant health which galvanized infant-welfare work, the establishment of child-hygiene divisions in 36 states, the improvement of standards for milk distribution, and the training of physicians.[40] More contemporary accounts of infant mortality decline in the early 1900s tell a similar story. In 1999, the CDC described sanitation, water purification, the Children's Bureau, and milk purification as the major public health achievements behind the decline in infant mortality in the early 1900s.[26] In a 2004 historical analysis of the primary literature, Condran described how 20th c debates on the mortality transition have variously argued the determinants were: (1) allegedly inevitable effects of economic variables on the health of populations, such that mortality declines were viewed as a largely unanticipated, consequence of structural change, vs. (2) deliberate policy-directed efforts

of individuals, governments, and the medical community to lower mortality levels.[20] Rejecting this dichotomy, Condran by contrast concluded that the evidence suggests that no single factor can explain the improvements in infant health by the last quarter of the 19th century.[20] In 1990, Ewbank and Preston suggested that changes in health practices in homes related to infant feeding and hygiene were an important contributing factor[41] and in 1994, Condran and Preston also emphasized the importance of maternal behavior change.[42] Although the emphasis on salient factors did vary across the sources we reviewed, the literature cited in Table 1 indicates that public health professionals and other scholars, past and present, have primarily argued that the marked decline in infant mortality was due more to social and environmental changes than to advances in clinical and medicine.[18,20,21,23–27,31,34,38,43–69]

Arguing against overemphasizing the contribution of the medical establishment, the historians Gaspari and Woolf in 1985 observed that 'while sanitary engineers were making some headway in decreasing mortality rates, physicians seemed to be having the opposite impact', in part due to the poor quality of medical training and care in the early 1900s.[24] As they and other historians have recounted, the decline in IMR began prior to the use of drugs or childhood vaccines and, before the development of pediatric surgery or intensive care technologies.[23–25,27,42,59,60,66] Notably, in the early 1900s, few births occurred in hospitals,[30] and no medical treatments could cure either diarrheal disease and pneumonia, which were the two leading causes of infant death in the early decades of the twentieth century.[34] The diphtheria antitoxin was the only effective chemotherapy , and physicians instead chiefly relied on drugs they had used since the 19th century, including digitalis, quinine, and opium derivatives.[70] It was not until the 1940s that the widespread use of antibiotics, fluid and electrolyte therapy, and safe blood transfusion became possible – and these clinical remedies were only available to infants who could access

hospitals.[25,26,30]Although physicians took a far more prominent and active role in the children's health movement after 1880,[27] the American Association of Pediatrics was not formed until 1930, much later than earlier institutional efforts to improve child health like the 1912 Children's Bureau. The net implication is that US initiatives in the early 20th c designed to address infant mortality relied chiefly on public health, not biomedical interventions – and notably reduced the IMR.[66]

Further motivating these social interventions was a growing awareness of socioeconomic and racial/ethnic inequalities in infant mortality. In 1926, Woodbury drew on studies of infant mortality in eight cities carried out by the U.S. Children's Bureau among 22,422 live born infants between 1911 and 1915, to show that the IMR among 'colored' infants (154.4 deaths per 10000 live births) was nearly 1.5 times higher than white infants (111.2), and the IMR among infants of foreign-born mothers (127.0) was higher than infants of native white mothers (93.8).[40] Contemporary analyses, based on more comprehensive data, also provide evidence of socioeconomic gradients in infant mortality during the early 20th century: as reported by Preston and Haines in 1991, literate mothers had better child survival than illiterate ones, and higher infant mortality rates among working mothers were concentrated among black and the foreign born mothers.[21] Their analyses also indicate that a contributing factor to the early 20th c racial/ethnic inequities in the IMR was that the bulk of the U.S. black population resided in rural areas, which did not benefit from the urban gains in infant mortality reduction, brought about by urban initiatives to improve water supplies, sewage, and food and milk quality.[2] Reflecting these geographic disparities, in 1933 the infant mortality rate among black infants was almost 2 times that of white infants (91.3 compared to 52.8 deaths per 1000 live births).[71]

The context within which this public health response occurred is of note. Between 1865 and 1920, there was considerable industrial output devoted to providing infrastructure and materials to house, transport and deliver public services for the shift towards cities[36] combined with improvements in national transportation, agricultural technology, living conditions, electricity and refrigeration.[25] Germ theory emerged as a way to understand disease, which marked a shift away from theories of contagion and miasma.[5,29,34,72] The Progressive moment towards the turn of the century stressed the need to systematize and expand public health beyond the level of individual cities, and advocated for universal standards of public hygiene administered by a system of public health organization.[5,66,72] Women's suffrage between 1869 and 1920 led to women gaining the right to vote in 1921, and women's groups played a central role in social activism and public health efforts, including the formation and implementation of the Children's Bureau, and increases in local public health spending.[73,74]

These efforts, however, intersected with U.S. racial politics of white supremacy. During the 1880s and 1890s, the system of legal racial discrimination ("Jim Crow"), upheld by the government force and extrajudicial violence and terror (e.g., by the Klu Klux Klan (KKK)), was established in the U.S. South, as part of the white backlash to post-Civil War economic and civil rights gains of the freed, previously enslaved black population,[75] with the 1920s marking the "second coming of the KKK" throughout the U.S.[76] Related, as Stern & Merkel noted in 2002, central to the progressive movement and intervention into poor, foreign-born, or black neighborhoods was an ethnocentrism that held white middle-class values as the ideal.[27] As they recount, these tensions were evident in all three waves of infant mortality campaigns — environmental sanitation, milk purification, and maternal education—which together led to large reductions, albeit unevenly by race/ethnicity, in infant mortality by 1950.[27]

With this history in mind, we now turn to analysis of the key factors listed in Table 1 that contributed to the decline in infant mortality in the United States. Our intent is both to examine the development of institutions, policies, and interventions, and also to set the basis for critiquing the assumptions and approaches to contemporary efforts in LMIC to reduce the IMR.

Table 1 – Overview of the literature on the factors which contributed to the decline in infant mortality in the United States in the early 20th century

Source			Factors mentioned as contributing to the decline in infant mortality					
Year	Author(s)	Title	Governance and new institutions	Sanitation	Health education for mothers	Civil and vital registration	Breast Feeding and milk purification	Medical care
1923	**Abbott G**[55]	Ten Years' Work for Children	X		X	X	X	
1926	**Woodbury**[40]	Infant mortality and its causes: with an appendix on the trend of maternal mortality rates in the United States	X	X	X	X	X	X
1933	**Tisdale ES**[56]	TheWork of the State Sanitary Engineer	X	X			X	
1950	**Hetzel A**[62]	U.S. Vital Statistics System				X		
1950	**Shapiro S**[57]	Development of Birth Registration and Birth Statistics in the United States	X			X		
1978	**Condran GA, Crimmins-gardner, E**[23]	Public health measures and mortality in U.S. cities in the late nineteenth century		X				
1985	**Gaspari K., Woolf A.**[24]	Income, public works, and mortality in early twentieth-century American cities		X				
1988	**Combs-Orme T**[58]	Infant Mortality and Social Work: Legacy of Success			X	X	X	
1990	**Meckel R**[59]	"Save the Babies": American Public Health Reform and the Prevention of Infant Mortality, 1850-1929		X	X		X	
1990	**Ewbank D, Preston S**[41]	Personal health behavior and the decline in infant and child mortality; The United States, 1900–1930			X		X	X
1991	**Preston SH, Haines MR**[21]	Fatal Years: Child Mortality in Late Nineteenth-Century America	X	X	X		X	
1994	**Fee E in Porter D**[60]	Public Health and the State: The United States	X	X	X			
1994	**Condran, GA Preston, SH**[42]	Child mortality difference, personal health care practices, and medical technology: The United States, 1900 – 1930			X		X	X
1995	**Lindenmeyer, K**[77]	The U.S. Children's Bureau and Infant Mortality in the Progressive Era	X		X			X
1996	**Preston SH**[61]	American Longevity: Past Present, and Future	X		X		X	
1999	**Brosco JP**[63]	The early history of the infant mortality rate in America: "A reflection upon the past and a prophecy of the future"			X		X	
1999	**CDC**[26]	Achievements in Public Health, 1900-1999: Healthier Mothers and Babies	X	X			X	

Source			Factors mentioned as contributing to the decline in infant mortality					
Year	Author(s)	Title	Governance and new institutions	Sanitation	Health education for mothers	Civil and vital registration	Breast Feeding and milk purification	Medical care
2000	**Almgren G, Kemp SP, Alison E**[34]	The Legacy of Hull House and the Children's Bureau in the American Mortality Transition	X		X			
2001	**Fishback P V, Haines MR, Kantor S**[38]	The Impact of the New Deal on Black and White Infant Mortality in the South	X			X		
2002	**Stern A, Markel H**[27]	Formative Years: Children's Health in the United States, 1880-2000	X	X	X		X	X
2003	**Wolf JH**[64]	Low Breastfeeding Rates and Public Health in the United States			X		X	
2004	**Markel H, Golden J**[31]	Children's public health policy in the United States: How the past can inform the future	X	X	X		X	X
2004	**Condran, GA.**[20]	Early Death: Mortality among Young Children in New York, Chicago, and New Orleans		X	X		X	
2005	**Cutler DM, Miller G**[65]	The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States		X				
2007	**Nathanson, CA**[66]	Disease Prevention as Social Change: The State, Society, and Public Health in the United States, France, Great Britain, and Canada	X	X			X	
2007	**Lee, Kwang-Sun**[67]	Infant mortality decline in the late 19th and early 20th centuries: the role of market milk					X	
2008	**Miller, G**[73]	Women's Suffrage, Political Responsiveness, and Child Survival in American History	X		X		X	
2012	**Thompson ME, Keeling AA**[78]	Nurses' role in the prevention of infant mortality in 1884-1925: Health disparities then and now			X			
2013	**Stoll BJ**[25]	American Pediatric Society 2013 presidential address: 125th anniversary of the American Pediatric Society–lessons from the past to guide the future		X			X	
2014	**Moehling CM, Thomasson MA**[79]	Saving Babies: The Impact of Public Education Programs on Infant Mortality	X		X			
2015	**Alsan M, Goldin C**[69]	Watersheds in Infant Mortality: The Role of Effective Water and Sewerage Infrastructure, 1880 to 1915.		X				
Total			16	14	19	6	20	6

Notes:
Governance and new institutions includes the role of the Child's Bureau, State/National Health Board(s), policy change, new laws and regulations, the role of sanitary engineers
Sanitation includes water purification, sewers, sewage treatment
Health education for mothers includes the delivery of information in the form of pamphlets, home visits, media by social workers, volunteers, advocates, nurses on breastfeeding, registration, infant care, home hygiene
Civil and vital registration includes creating the birth and death registration area, promoting registration, and the laws to enable registration
Breast feeding and milk purification includes de-contaminating milk, encouraging mothers to breastfeed, milk stations, pasteurization laws
Medical care includes the role of dispensaries, pediatricians, and vaccinations

Governance and new institutions for infant and child health

The creation of new institutions and policies to advocate for infant health, provided technical expertise, mobilized resources, and engaged women's groups, sanitarians, and public health professionals to improve infant health. In the mid-to-late 1800s, Boards of Health were established in cities; the first Board was established in Louisiana in 1855, and served as a quarantine authority, and the first effective State Board was established in Massachusetts in 1869.[72,80,81] Their mandate was to conduct inspections on sanitary conditions, public drainage, food, milk and quarantine.[72,80] By 1900, the need for coordination across cities led to the establishment of State Boards of Health,[72] and by 1906, a group of Progressive intellectuals within the American Association for the Advancement of Science began a campaign to establish a federal health department. By 1912 the federal government had made a substantial commitment to public health by turning the Marine Hospital Service into the United States Public Health Service and authorizing it to investigate the causes and spread of diseases, study the problems of sewage, sanitation and water pollution, and publish health information for the general public.[60]

There were concurrent efforts to create institutions focused on infant and child health. In 1909 the White House Conferences were initiated and brought experts and activists together to address the needs of children.[31] The same year the American Association for Study and Prevention of Infant Mortality was created to bring the IMR to national attention.[63] Several years later, President Roosevelt and President Taft recommended the establishment of the Children's Bureau to Congress. In 1912, the Children's Bureau was created with an appropriation of $25,640. Julia Lathrop was the first woman to head a federal agency, and the Bureau was the first public agency in the world with a mission to consider the problems of childhood in an integrated way, and chose infant mortality is its first, and central, issue.[55,77,82] Almgren and others, in 2000, described this as a strategic, popular, and non-controversial choice, as well as a

compelling issue for the thousands of women who had supported the development of the bureau.[34,74,77]As noted by several of the sources cited in Table 1, the Children's Bureau made several crucial contributions to infant mortality reduction. First, Lathrop premised the Bureau's efforts on the argument that poverty rather than ignorance was the cause of infant mortality, and chose to address the social conditions that affected infant mortality.[77,83,84] Second, the Bureau strengthened state and national institutions: state child-hygiene or child-welfare agencies were established in 1912, and by 1920 there were 34 in operation. Although they were typically divisions of state departments of public health, their organization and scope of activities were based on the Children's Bureau's 'Minimum Standards for Public Protection of the Health of Mothers and Children'.[34] Third, the Bureau conducted research: 10 community studies of infant mortality between 1913 and 1923 were commissioned which described the social gradient in infant mortality, highlighted efforts to reduce infant mortality, and assessed the care available to women and children.[55,74] Conferences were scheduled in eight cities to disseminate findings.[58] To benefit from lessons from other countries in reducing the IMR, Lathrop and others examined programs and policies in New Zealand,[40,55] which at the time had the lowest national rates of child deaths (but not taking into account the much higher rates of IMR among the indigenous Māori vs New Zealand residents of European ancestry)[85] and used Great Britain as an example to argue for greater national and state cooperation to reduce maternal and child deaths.[55] Fourth, the Bureau ran campaigns, and developed programs. Notable examples included: a 20-year-long national birth registration campaign; maternal education activities between 1912 and 1922 on prenatal, infant and child care; engagement of women's groups to advocate for improvements in health, welfare and rights for women and children;[34,55] the opening of milk centers for working mothers who relied on cow's milk for infants staffed by nurses who discussed infant care and

feeding.[58] However, as Lindenmeyer wrote in 1995, by 1920 the Bureau began to focus less on poverty as a cause of infant death and more on motherhood education, individual family responsibility, and began promoting physician-directed medical care.[77]

One of the Bureau's most significant contributions was the Sheppard-Towner Act: the bill was introduced in 1918, passed in November 1921 (one year after women's suffrage) and implemented a year later.[34,73,79] The law appropriated seven million dollars in federal money for states to promote maternal and infant health and welfare. Funds were used to establish public health clinics, implement classes for midwives, infant-care classes, prenatal care, or pay public health nurses to visit new and expectant mothers.[79] By 1930 the legislation led to the expansion of the birth and death registration area, to the establishment of state child-hygiene bureaus and divisions, permanent state health centers for mothers and children, and an increase in state appropriations for infant and maternal health.[38] Even though the Sheppard–Towner legislation was repealed in 1929, public health infrastructure supported by this legislation was already in place by the late 1920s which included: the purification of water, improvements in the disposal of sewage, health education, milk pasteurization, visiting nurses, and maternal education.[34,38,79]

Civil registration

Between 1850 and 1950, the vital statistics system transformed the measurement of births, deaths, and the calculation of mortality rates by providing timely information on births and deaths. The system made the problem of infant deaths visible, including differences between black and white children, and urban and rural children. Although the United States lagged far behind the United Kingdom and several other countries in the quality of its national vital registration data,[21,40,60,62,72,80] vital statistics emerged in the early/mid 19th century as a local then state function and grew in response to local and state needs, allowing it the support that might be lacking if the system were primarily national.[62]

Within the U.S., the 1850 census marked the first effort to collect national vital statistics on deaths and births. Although emphasis was placed on obtaining mortality statistics, tabulations were also prepared showing the number of enumerated children who were under one year of age as of census date, in order to compute infant mortality rates.[57] National efforts to improve civil registration of births began to gain momentum; the newly formed American Medical Association advocated for improving registration and for registration laws, which led to six states enacting such laws by 1851. Several years later, the AMA "RESOLVED, That a committee of one from each State be appointed to report upon a uniform system of registration of marriages, births, and deaths".[62] In 1880, the U.S. census (which then was in charge of vital statistics) established a death registration area to measure deaths which initially comprised of two states and several cities but expanded to include the entire county by 1933.[62,84]

Two decades later, the 1900 census sample filled many gaps in American demographic history, and converted the U.S. from the industrialized country with the poorest mortality data at the turn of the century to the country with perhaps the richest and most detailed data on infants and children.[57] In 1902, The US Bureau of the Census also became a permanent agency of the federal government, authorized to obtain, annually, copies of death records filed in the vital statistics offices of those states and cities having adequate death registration systems and to publish data from these records.[39,62] The presence of a permanent agency to lead the collection of vital statistics was a crucial turning point in efforts to measure infant mortality.

By 1903 when Congress adopted a resolution on the importance of a complete and uniform system of registration throughout the country, there were several key institutions supporting these efforts – the Census Bureau, the AMA, the American Public Health Association and other organizations drafted a Model Law, which states could use to improve registration. In

1907 the American Public Health Association established a Vital Statistics Section to aid the adoption of uniform registration methods and publication of statistical.[62] In 1915, the US Census and Children's Bureau worked together to create the US birth registration area, which initially encompassed 31.1 percent of the population and 10 states and included over 70% of the population by the early 1920s.[55] By 1933 all states were registering live births and deaths with acceptable coverage and providing the required data to the Census Bureau for the production of national birth and death statistics.[39] As birth record data became more available, the birth certificate began to increase in value and, in some places, became the primary document for verifying age in entering school and in obtaining work permits.[57] When Federal and State Governments began to enact welfare legislation in the 1920s and 1930s, a birth certificate was used as the legal document to prove the age of recipients.[62] After 1946, responsibility for vital statistics shifted from the US census to the Public Health Service,[84] and as health departments employed officers with public health training, records were used for statistical analysis.[62]

In a 1950 analysis of the development of US vital statistics, Hetzel quoted the following excerpt from a report of the National Resources Committee to describe the process of improving registration:

> *"The long, hard, often discouraging campaign which was fought to bring States, one by one, into the fold constitutes one of the proudest chapters in the history of the Bureau of the Census....in some States, the boards of health had to be educated to the need, before the citizens of that State could approach the legislature. In others, the legislatures were apathetic, in spite of strong pressures…Each State had to educate its physicians and undertakers as to their duties, as well as an army of local registrars." (p.53).*[62]

As this quote attests, those involved in the work of vital registration had the "long view" clearly in mind, and saw that these data were truly vital, not only to track mortality, including infant mortality, but also to understand the health and well-being of the nation.[39]

Sanitation

From 1850 to 1880, infant mortality was viewed as an urban problem that could be best combated through purifying the water supply and building sewage systems.[27] As Duffy wrote, the 'sanitary revolution' was in full swing during the last two decades of the 19th c.[81] By 1890 sewage systems were fairly widespread -- of the 96 cities with a population of 10,000 and greater, 73% had sewers and only 26 had no sewers at all – and by 1907, nearly every city in the United States had sewers.[86] By 1910, public water supplies were available to 42% of the population and sewers to 29%.[36] During this time, the role of Sanitary Engineer was created in every state health department. In 1933 Tisdale, the Director of the Division of Sanitary Engineering in the Charleston, West Virginia State Department of Health described how inoculation was a stop-gap, and instead emphasized the importance of state-wide sanitation control. Sanitary Engineers had 'a close and vital connection with every water works engineer', and played a role drafting new laws to meet the growing sanitation demands of the state, and functioned as the state technical advisor on questions pertaining to water, milk, sanitation, sewage, malaria, industrial hygiene and waste disposal.[56] He warned against reducing resources towards sanitation: 'carefully consider the conservation of human life and your natural resources before you apply the pruning knife to this branch of state government'.[56]

In a 2005 study of clean water technologies in large American cities in the early 20th century Cutler and Miller suggested these were "likely the most important public health intervention of the 20th Century".[65] They estimated that the introduction of water filtration and chlorination systems could explain nearly half the overall reduction in mortality between 1900 and 1936, three quarters of the decline in infant mortality, nearly two thirds of the decline in child mortality, and the near-eradication of typhoid fever.[65] They emphasized that although water systems were expensive, their benefits appear to be substantially greater than the costs. An

earlier 1978 analysis by Condran et al. likewise suggested that the provision of central water supplies and sewage systems were central to the 'public health movement' in the late 1800s.[23] Using data from 1880-1915 in Massachusetts, Alsan and Goldin in 2015 showed that appropriate sewerage systems and safe potable water for homes caused a sharp and persistent decrease in infant mortality.[69] It is important to note that there are debates about the relative importance of clean water and sewage systems. Some scholars have suggested that filtration of water supplies had a much more clear-cut effect on mortality reduction[23] while others have argued that removing waste through covered sewers best served the health of urban popluations.[24] Others have pointed to the role of campaigns (discussed below) that focused on unclean milk (a source of typhoid), which was largely outside the purview of structural efforts to improve sanitation[24] and also on the role of women's suffrage in increasing public spending for health and sanitation through hygiene campaigns.[73]

Breastfeeding and milk purification

In contrast to recognition of the dangers of unclean water in the mid-19th century, milk began to attract the attention of public health officials in the mid-1870s when reformers began to focus on the quality of urban milk supplies.[59] Several public health campaigns were initiated. At first, the focus was on improving the compositional integrity of milk, and preventing adulteration, dilution and spoilage. Later, in the 1890s, informed by germ theory and the new science of bacteriology, public health efforts were also directed towards preventing the microbial contamination of milk and cleaning milk supplies.[41,42,59] This included pasteurizing milk, sealing milk in bottles and transporting it in refrigerated rail-road cars.[64]

In the last quarter of the 19th c, as working-class women increasingly entered the industrialized workforce, and with many working while still also caring for infants, breastfeeding

declined. Working mothers in particular began to supplement their own milk with cow's milk, and wean babies before they were three months of age[64] which meant the unpasteurized market milk supplies contaminated with tuberculosis, typhoid, scarlet fever, diphtheria, and streptococcal germs had a direct effect on infant health.[41] Scientists documented, at the beginning of the 20th century, that bacterial counts in the market milk supply in six U.S. cities were similar to counts in sewage at that time.[67]

Public health interventions varied in scope and level. First, dairies and milk suppliers were inspected,[87] and milk stations were created to provide free or subsidized milk to poor mothers. The first stations were opened in 1893 in New York City. Funded by philanthropist Nathan Straus, these milk depots were the first building blocks of an at least partially state-supported administrative and clinical infrastructure devoted to infant health.[66,81,87] By 1910 there were 297 stations in 38 cities, funded by a wide range of charitable agencies including settlement houses, women's clubs, and children's aid societies.[66]

The second intervention was pasteurization.[20,42,67] Milk reformers conceded that milk stations supplied a very small population, and structural change was needed to remove poor quality milk from the urban milk supply.[67] In 1912 the New York City Health Department mandated the pasteurization of all milk coming into the city, well in advance of similar measures in the rest of the world.[66] Following this, legislation in the 1920s made the pasteurization of milk mandatory which led to the most dramatic changes in the milk supply.[20] In a 2007 analysis, Lee reported that the decline in infant mortality was inversely correlated with the cleaning of the market milk supply between 1840 and 1940, a period which also exhibited a decline in breastfeeding and no medical treatment for infantile diarrhea, lending support to the thesis that pasteurization contributed to the IMR decline.[67]

Thirdly, and finally, local public health officials designed interventions to urge mothers to breastfeed for as long as possible. For example, in Chicago, nurses were sent neighborhoods with the highest death rates in 1908 to discuss infant feeding with mothers. However, since health department officials believed the non-acculturation of immigrants was at the root of infant mortality, nurses were sent only into immigrant neighborhoods.[64] In Minneapolis, led by Julie Sedgwick, chief of the department of pediatrics in the University of Minnesota, public health workers met with every new mother immediately after the birth of her baby, and in the nine months following delivery, to address any lactation-related problems.[64]

Several historians have noted that although many of the interventions to improve milk quality were structural, nevertheless physicians at the time typically disagreed on whether the problem was due to poverty or maternal behavior. Brosco, in 1999, characterized this as a debate between reformers and physicians who 'called for legislation to prohibit the sale of commercial baby foods and to sanction mothers who did not nurse their children'[63] and who 'argued that in-sufficient family income rather than laziness or ignorance led mothers to stop breastfeeding'.[63] Similarly, in 2007, Nathanson observed, 'the construction of infant mortality as a problem of bad milk was attractive to public health officials…it promised a simple prophylactic against infant deaths, obviating the need for the fundamental environmental and behavioral reforms that had proved so difficult to accomplish'.[66]

Health education for mothers

The emphasis on breastfeeding as a maternal issue was indicative of the remaining strand of efforts to reduce infant mortality, which viewed the key problem as being that women were ignorant of how to care for their children. This approach became more prominent in the early 20th century, because, as the historian Meckel concisely observed in his 1990 classic analysis of

late 19th and early 20th c U.S. public health efforts to "save the babies," once key structural interventions were implemented, e.g., involving sanitation and milk pasteurization, the focus of infant welfare activity shifted from 'milk reform to maternal reform'.[59]

Thus, mothers became the 'first line of defense against childhood disease'.[41] Health information centered on infant feeding, home hygiene, and maternal responsibility.[41,42] Mothers were taught about protecting the infant from diseases carried by flies, conveyed by their dirty hands, and transmitted through impure milk. Information was delivered by a variety of means: the Children's Bureau published pamphlets called Infant Care and Prenatal Care on how to look after children, and widely disseminated information on proper clothing, frequent bathing, and good ventilation. Public health literature, Baby Weeks (which were supplemented by a Children's Year in 1918-19),[74] "better baby" campaigns and newspapers, which featured columns on infant care, formed part of the campaign. "Little Mothers" classes were begun in many cities to teach young girls the proper methods of infant care before they had children".[41,63,82,87] Nurses and community health workers were relied upon to provide information on home hygiene and infant feeding in door to door campaigns, at milk stations, and at health centers.[73,78,87] Information was also delivered in oral or written form at clinics or dispensaries, infant feeding stations or milk depots, and hospitals.[41,42,87] These efforts were coordinated through a range of institutions, the most essential of which was the national network of women's clubs, and also included state child-hygiene or child-welfare agencies.[34] It is important to note that upper class families were more able to take advantages of these messages. Given inequities in access to education and literacy, health-related information delivered via pamphlets, newspapers, and schools would have been inaccessible for many African-American families and low-income families.[30,41]

Several contemporary historians have suggested efforts directed at shaping maternal behavior did contribute to reductions in infant mortality.[34,41] Yet, consonant with the dominance of eugenics in the 1920s in U.S. academia, public health, and politics,[74,88–90] along with surging anti-immigrant populism and policies (epitomized by the 1924 and 1927 Immigration Restriction Acts),[76,91,92] many public health professionals and child welfare advocates embraced eugenic positions, and their treatment of African-American and foreign-born infants were shaped by racist and anti-immigrant views.[63,74] Efforts to develop culturally sophisticated public health campaigns sought to explain American ideals of personal hygiene, disease avoidance, parenting, and personal conduct to immigrant communities.[27,74] Even so, as noted by Brosco in 1999, noteworthy debates occurred between those who believed mortality rates could be attributed to ignorance and poor parenting and those who argued that income, working long hours, poverty and inequity as the primary causes of high child mortality. The former advocated for health education and parenting classes, while the latter for better labor standards, and improved maternal nutrition.[63] The implication is that even with the rise of individually oriented and often victim-blaming approaches, advocates for structural interventions to reduce IMR continued to maintain a presence.

Then and Now: A comparison of efforts to address infant mortality in the United States (1850-1950) with donor funded efforts to address IMR in low and middle-income countries (2000-2015)

In contrast to the early 20th c history in the U.S. of efforts to reduce IMR, our review of the contemporary literature on reducing infant mortality in LMICs indicates the field is far less focused on structural interventions and far more focused on interventions at the individual, household, and health facility level. The evidence that routinely receives the most attention highlights the relationship between infant mortality and: (a) individual-level maternal factors,

including maternal mortality, maternal education, breastfeeding, birth spacing, and medical care before, during and after pregnancy, and (b) individual-and household-level child factors, including household sanitation, child nutrition and medical care at/after birth, vaccination, and household socioeconomic factors. In both cases, there is an emphasis on curative interventions for specific diseases.[19,93–100] Discussions about the health impacts of large-scale sanitation projects, institutional change, civil registration and public policy efforts to improve breastfeeding, whether past or present, are largely missing from this literature.

The contrast between the approaches advocated is captured by Table 2, which summarizes key factors in the United States' effort to reduce infant mortality and juxtaposes these to the approaches endorsed and recommended in global policy documents, and the mainstream evidence base for early childhood interventions to prevent neonatal and infant mortality and improve infant health in LMICs.

Table 2 – Efforts to address infant mortality in the United States (1850-1950) and in low and middle-income countries (2000-2015)

Intervention area	Lessons from History: United States, 1850-1950		Donor funded efforts to address IMR in low and middle-income countries, 2000-2015	
	Structural	Individual/household	Structural	Individual/household
Sanitation	• Sewage systems • Sanitary conventions • Sanitary engineers as designated positions • Filtration • Chlorination	• Education about infant hygiene	• Boreholes or pumps	• Stand-alone toilets • Education on the safe disposal of child feces and how to purify water at home • Hand washing • Subsidies to build latrines • Direct provision of toilets to schools or households • Provision of Oral Rehydration Therapy • Soap distribution
Civil and Vital Registration	• Birth registration area created and expanded • Congress resolution on birth registration • Birth registration prioritized by Children's bureau • State and national registration system	• Parents receive information about birth registration	• Biometric identification • Technical assistance and interventions to improve Civil Registration and Vital Statistics systems	• National surveys as a replacement for poor national data

Breastfeeding and milk purification	• Inspection and testing of milk • Pasteurization of milk • Milk stations	• Education about breastfeeding	None	• Initiation of early breastfeeding (within the first hour) • Education on: exclusive breastfeeding for 6 months, and continued breastfeeding and complementary feeding from 6 months • Home pasteurization of milk
Medical care	• Improvements in obstetric care • Shift from miasma to germ theory of disease • Improvements in medical education and the growth of pediatrics		• Training of skilled birth attendants • Strengthening of pre and post-natal care • Shaping global and local markets for life-saving commodities	• Simplified antibiotic therapy for neonatal infections • 13 life-saving commodities* • Immediate thermal care (to keep the baby warm) • Hygienic cord and skin care • Neonatal resuscitation with bag and mask • Kangaroo mother care for preterm (premature) and for less than 2000g babies • Case management of childhood pneumonia, diarrhea, respiratory distress syndrome, sepsis, meningitis • Postnatal contact with a skilled health-care provider • Care for children with developmental delays
Vaccination	• Pertussis and Diphtheria vaccination introduced but not widespread		• Vaccine delivery infrastructure, including cold chain	• Vaccine campaigns • Routine immunization plus *H.influenzae*, meningococcal, pneumococcal and rotavirus vaccines • Incentives for vaccination
Health behavior	None	• Children's Bureau messaging to change health behavior • Maternal education about infant hygiene and feeding	None	• Hand-washing interventions • Chlorine tablets • Maternal education • Incentives to deliver in hospitals
Other	None	None	• Girls education	• Birth spacing • Insecticide-treated bed nets and quality assured artemisinin-based combination therapies • Management of severe acute malnutrition: ready to use therapeutic foods, micronutrient supplements, vitamin A capsules, antibiotics, therapeutic food formulations.
New institutions and policies	• Children's Bureau • American Medical Association • American Public Health Association • Sheppard-Towner Act • State level health boards National Health Board		*Global* • MDGs and SDGs • 2016-2020 Global Strategy for Women's and Children's Health • United Nations Commission on Life-Saving Commodities • Every Newborn: an action plan to end preventable deaths • Ending Preventable Child Deaths from Pneumonia and Diarrhoea by 2025 The integrated Global Action Plan for Pneumonia and Diarrhoea (GAPPD) *National* • Health Ministry • Ministry of Woman and Child Development or equivalent	

	• Ministries overseeing sanitation infrastructure • Registrar General

Notes:
Sources [15,18,20,21,23–27,31,34,38,43–69,87,100]
*13 commodities: Oxytocin (post-partum hemorrhage); Misoprostol (post-partum hemorrhage); Magnesium sulfate (eclampsia and severe pre-eclampsia); Injectable antibiotics (newborn sepsis); Antenatal corticosteroids (ANCs) (preterm respiratory distress syndrome); Chlorhexidine (newborn cord care); Resuscitation devices (newborn asphyxia); Amoxicillin (pneumonia); Oral rehydration salts (diarrhea); Zinc (diarrhea); Female condoms; contraceptive implants; emergency contraception.

As Table 2 clarifies, many of the contemporary interventions that receive the most global endorsement for addressing infant mortality do not address root causes and do not include sanitation and birth registration as central to the goal of reducing the IMR. Several recent global documents illustrate these problems. The Global Action Plan for Pneumonia and Diarrheoa does not include the terms 'sewage' and 'sewer', and the term 'infrastructure' is used solely to describe strengthening the infrastructure to deliver vaccines.[51] The emphasis instead is primarily on individual and household level interventions, with the plan advocating chiefly for exclusive breastfeeding with appropriate complementary feeding, vaccination, Oral Rehydration Therapy (ORT), and demand creation for behavior change, and improvements in the access to - and use of - safe drinking-water and sanitation – without, however, discussion of what it will take to put in place appropriate sanitation and water systems.[51] The 2016-2020 Global Strategy for Women's and Children's Health likewise presets, as examples of interventions with high returns on investments in children's health, solely high quality of care at child birth, immunization, breastfeeding, and early childhood development. Although the strategy acknowledged that around fifty per cent of the gains in the health of women, children and adolescents resulted from investments outside of the health sector and that interventions beyond the health sector should be core to infant health, nevertheless water and sanitation, education, air pollution, and birth registration were not included in the core list of interventions and instead were only mentioned as 'multi-sector enablers'.[44]

The same problems affect the prioritization and framing of the interventions listed in a 2014 global review of the key interventions related to reproductive, maternal, newborn and child health (RMNCH),[101] which drew on global policy and peer-reviewed literature, including the Child and Neonatal Lancet Series (2003 and 2005) to review 142 RMNCH interventions suitable for delivery through the health sector in LMICs.[47] In this document, issues pertaining to infrastructure development, governance, and social development, along with recommendations for reducing inequality, ensuring fair working conditions, safe and affordable drinking water, and adequate sanitation were relegated to a separate policy guide and not included in the primary document.[101] In 2012, the United Nations Commission on Life-Saving Commodities defined the barriers to the distribution and use of 13 low-cost, high-impact commodities solely at the individual level, with the key obstacles described as: 'poor compliance by health workers', 'poor understanding of products by mothers/caregivers' and 'limited awareness and demand'.[45] Similarly, the 2014 Lancet Every Newborn Series examined progress on preventing neonatal deaths since 2005 with no discussion of the wider history of such efforts. Although the importance of birth registration was discussed,[102] the series advanced a commitment to scaling up a package of services at both facility and community levels[15,103] and listed skilled birth attendants, antenatal care visits, female literacy rates and total fertility rates as contextual factors.[16] The priorities of the Every Newborn Action Plan (ENAP), developed as part of the Lancet Series referred primarily to several packages of interventions for both woman and baby delivered along the continuum of care and argued that such an approach will have 'the highest impact on saving lives and improving health outcomes'.[52] Although improving birth and death registration is a strategic goal, the plan refers peripherally to sanitation to an 'intersectoral goal'.[52]

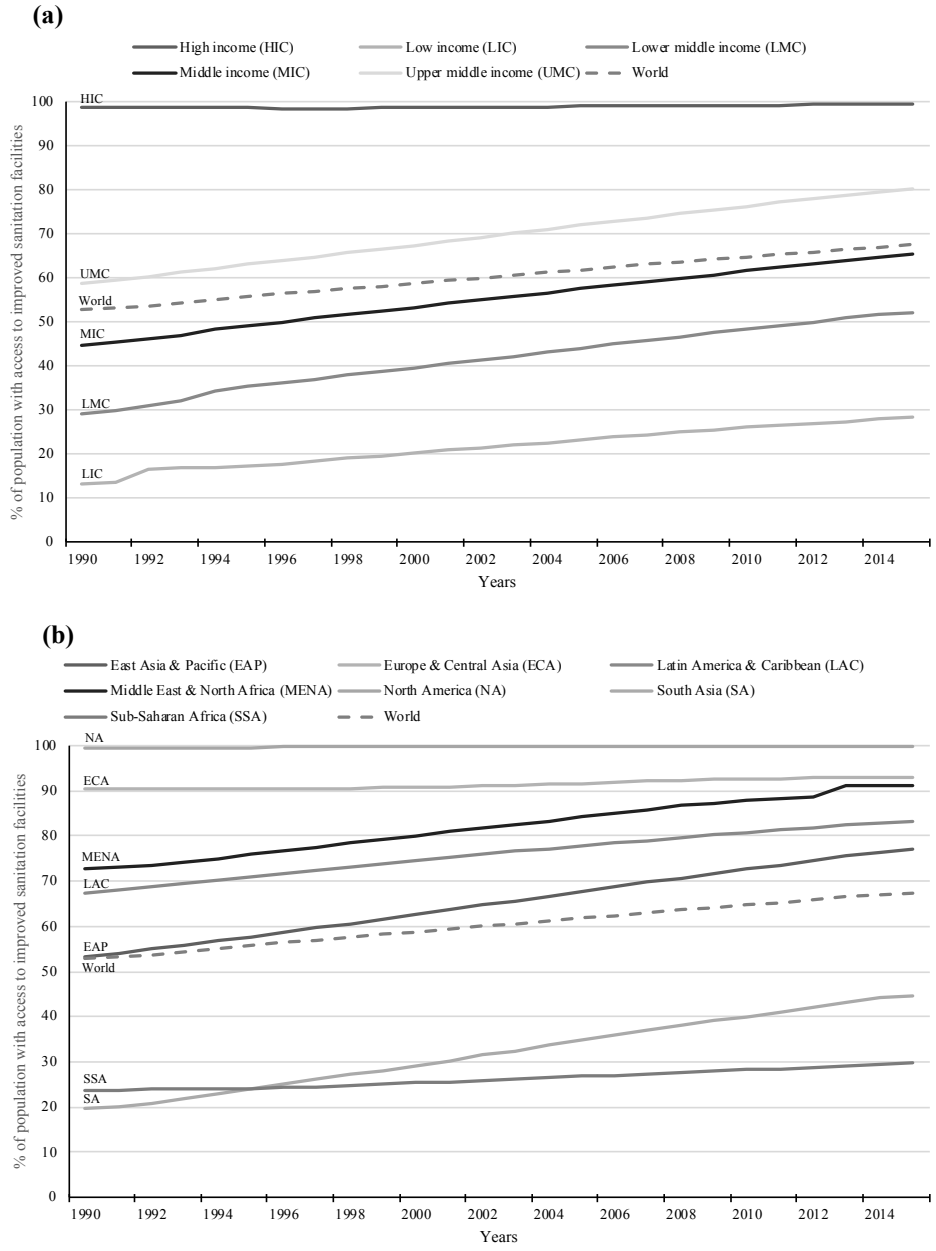
Strikingly, most global targets, policy documents and declarations are ahistorical and do not engage with the history of past era's successes in reducing infant mortality. Attesting to the lack of historical grounding, scant analysis exists that compares the costs of investing in behavior change, medical technology and vaccination in perpetuity to investments in improving the infrastructure to register births, clean water and improve access to primary care. Moreover, estimates of infant and child mortality in many countries remain elusive: notably, the Institute of Health Metrics and Evaluation (IHME) and the Maternal and Child Epidemiology Estimation group differ on their estimates for the causes child death, especially for malaria and AIDS,[104–106] making it challenging to monitor infant mortality and rely on a single set of estimates to guide policy and planning.[104] We now turn to whether tensions between individual and structural interventions exist in the context of global policies and programs specifically for sanitation, civil registration and breastfeeding to address infant mortality in LMICs.

Sanitation

In the case of sanitation, the most recent UN estimates suggest 2.3 billion people lack a basic sanitation service (defined as improved facilities that are not shared with other households) and 844 million people are unable to access a basic drinking water service (defined as drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip, including queuing).[107] Exemplifying the problem, an analysis for Sub-Saharan Africa of the coverage of the SDG sanitation target (defined as improved water with a collection time of under 30 minutes, plus sanitation and a hand washing facility with soap) estimated that basic SDG coverage was only 4% and 921 million people lacked access.[108] By 1990, however, North America, and Europe and Central Asia had achieved almost complete access to improved sanitation (Figure 3). Although South Asia had the largest gain in access to sanitation between

1990 and 2015, nevertheless 44.8% of the population did not have access to improved sanitation in 2015. Both South Asia and Sub-Saharan Africa remained below the global average of 67.5%.[4]

Figure 3 – Access to improved sanitation facilities in countries, stratified by (a) income group and (b) region (1990-2015)



*Improved sanitation facilities: Access to improved sanitation facilities refers to the percentage of the population using improved sanitation facilities. Improved sanitation facilities are likely to ensure hygienic separation of human excreta from human contact. They include flush/pour flush (to piped sewer system, septic tank, pit latrine), ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet.
Source: World Bank Data, 2015[4]

The role of public health professionals and institutions in building large sewage or water filtration systems is very different in the current global health context compared to the United States at the turn of the 20th century. Although there is agreement that access to good sanitation and clean water can prevent infant mortality, undernutrition and diarrhea[94,109–112] (Table 2), structural sanitation and hygiene interventions are not central to current mainstream public health interventions designed to avert infant mortality in LMICs.

Studies have found that even though piped water and connected toilets are initially much more expensive than low-tech sanitation technologies, the average cost per life-year saved turns out to be roughly the same due to the longer durability and superior health impact associated with the higher-end technologies.[110] For example, in a 2011 analysis of 171 household surveys, Fink and Hill found strongly protective effects of high quality toilet facilities for the risk of mortality, episodes of diarrhea and stunting. They demonstrated that the average mortality reduction achievable by investment in water and sanitation infrastructure was 25 deaths per 1,000 children born across countries, and full household coverage with water and sanitation infrastructure could lead to a total reduction of 2.2 million child deaths per year in the developing world.[110]

Nevertheless, even efforts to promote the adoption of effective, low-cost improvements to water quality and sanitation have been largely unsuccessful[109] and a greater focus has been placed on addressing diarrhea and stunting directly (Table 2). For example, in 1978, an editorial in The Lancet called ORT "potentially the most important medical advance of the 20th century" and since that time approximately a million lives per year have been saved by ORT.[25] However, a status quo where ORT is an acceptable substitute for clean water and sanitation systems has become acceptable,[113] and the interventions currently used in LIMCs to improve sanitation

described in Table 2 operate largely at the individual level, or household level, concerned with the provision of commodities, and with education and behavior change. Exemplifying this orientation, the MDG target did not include any consideration of the need for sanitation in schools, workplaces and public places.[36] Suggesting also that many of the global targets are inadequate, even if the WHO sanitation target was met, 1.6 billion people would still lack even a simple '*improved'* latrine at home (defined as flush/pour flush to: piped sewer system, septic tank, pit (latrine); ventilated improved pit latrine; pit latrine with slab; composting toilet).[36] Similarly, even if the WHO drinking water target had been reached in 2015, 800 million people would have been living in homes where water is collected from distant or unprotected sources.[114]

Civil registration

Major problems likewise remain with regard to adequate civil registration, including of births, which is vital to ensure good data for allocating resources to reduce the IMR. Instead, the attention of governments in many LIMCs is being directed towards creating biometric identity systems (Table 2). Conservative estimations suggest that 80 countries have biometric identification programs, and over 1 billion people in LMICs have had their biometrics recorded, and this number is growing.[115] Most recently, the 2016 World Development Report advocated for identification systems as a way to address the significant number of children and adults without any form of identification document.[116] However, the purpose of biometric identification systems is to authenticate individual identity and they do not to confer rights and privileges associated with birth registration,[117] nor are they mandated to be connected to CRVS systems.

Investments in digital identification systems without improving CRVS cost governments the ability to monitor and act upon important public health data, including the infant mortality rate. This is taking place even though the benefits of birth registration are well described, and

both the Universal Declaration of Human Rights and the Convention of the Rights of the Child as well as the Commission on Information and Accountability for Women's and Children's Health[118] underscore the importance of legal identity and civil registration and vital statistics systems. Additionally, the SDGs aim to improve the "proportion of children under five years of age whose births have been registered with a civil authority" (SDG 16.9).[18]

However, pointing to large gaps in civil registration, in 2015, using data from 198 economies, the World Bank estimated that around 1.80 billion people lacked legal identity, with the largest number in South Asia. Slightly less than half of these people are children.[119] A study using data from 94 countries between 2000-2014, showed that birth registration remained lowest in Eastern and Southern Africa, West and Central Africa and South Asia.[120] As discussed by two Lancet series on civil registration in 2007 and 2015,[121,122] weak vital registration systems in LMICs deny children and adults the benefits associated with registration (e.g. accessing government programs, travel, opening a bank account, and proving family relationship) and also undermine capacity to generate the local data needed to guide public policy and resource allocation (a data need that cannot be met by surveillance based solely on national surveys or sentinel sites).[123] Interventions to improve birth registration include registration campaigns in communities, improving access to registration for children born in health facilities, using mobile technology and digitizing birth records.

Breastfeeding

Also striking is that despite the proliferation of global and national agencies with targets focused on reducing IMR[19,44,45,51,52,124,125] (Table 2), the scope of the proposed initiatives remains primarily focused on changing the behavior of individuals, especially mothers, as exemplified by the case of current interventions focused on breast feeding and milk purification. In brief, many studies describe the benefits of breastfeeding for infant and maternal health, and attribute

breastfeeding a role in decreasing infant mortality.[51,97,126] A Lancet series concluded that breastfeeding was one of the top interventions for reducing under-5 mortality, and suggested that the modest changes in breastfeeding rates since 2000 contributed to the fact that most LMICs did not reach the MDG infant mortality targets. However, current global discourses on breastfeeding overwhelmingly recommend education for mothers in health facilities, and during post-natal visits, and few laws are in place to enable and protect the employment and work conditions that allow women to breastfeed. Although some countries have enacted policies on milk purification, implementation of the International Code on Marketing of Breast Milk Substitutes is not a substitute for structural interventions addressing economic obstacles to women breastfeeding.[126]

Why history matters in current efforts to address infant mortality

As should be apparent, current approaches to reducing infant mortality endorsed by global policy documents and public health research are not informed by relevant historical evidence. Perhaps the current focus in LMICs on individual behavior would be understandable if research demonstrated that the relevant structural interventions have already been implemented or else that structural interventions would not be as effective as the interventions oriented toward individual behavior. This would be analogous to what occurred in the US, starting in the 1910s, once structural reforms involving sanitation, milk pasteurization, and civil registration were either completed or well-underway. However, the current literature does not support such an interpretation and instead makes clear that structural reforms to address infant mortality were never the priority of global polices or interventions.

The historical context of the current commitment in LMICs to an IMR reduction strategy focused on smaller scale interventions targeted primarily at individuals, households, and health facilities, is important. Table 3 contextualizes the evidence base and policy goals underpinning

global health efforts to address infant mortality and provides a broad chronology of the creation of global institutions to address infant mortality following the Second World War, which is characterized by a shift away from a commitment to more comprehensive, broadly based community health programs towards more narrowly defined technological interventions.[8,127]

Table 3: Summary of key milestones and shifts in global health priorities pertaining to the reduction of infant mortality

Year	Milestone
1944	UN Monetary and Financial Conference in Bretton Woods establishes the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (World Bank)
1945	United Nations established
1946	UNICEF founded
1946	First meeting of the Board of the World Bank
1948	WHOs constitution ratified by the first World Health Assembly
1959	World Health Assembly commits to a global smallpox eradication program
1974	WHO creates the Expanded Programme on Immunizations
1974	Alma-Ata Declaration which articulated the goal of primary heath care (PHC) and of achieving health for all by 2020
1969	World Health Assembly declares it was not feasible to eradicate malaria
1977	Eradication of smallpox
1980s	World Bank Structural Adjustment Programs
1982	UNICEF launches child survival agenda which focused initially on four interventions: growth monitoring, oral rehydration, breastfeeding, and immunizations (GOBI)
1984	Bellagio conference. Acceptance of Jim Grant's goal of immunizing 80 percent of the world's children against six major diseases by 1990.
1990	World Summit for Children, New York. Nations committed to a target of 70 deaths per 1000 live births for children under five
1995	Integrated Management of Childhood Illness (IMCI) programme created
2000	GAVI Alliance created
2000	Save the Children launches its Saving Newborn Lives programme funded by the Bill and Melinda Gates Foundation
2000	Millennium Development Goals
2005	The Partnership for Maternal, Newborn and Child Health (PMNCH) is founded
2005	Lancet Neonatal Survival Series published
2005	Countdown to 2015
2010	United Nations Millennium Development Goals Summit UN Secretary-General Ban Ki-moon launches Every Woman Every Child
2012	World Health Assembly endorses Global Vaccine Action Plan (GVAP)
2014	WHO develops the Every Newborn Action Plan WHO and UNICEF develop the integrated Global Action Plan for Pneumonia and Diarrheoa (GAPPD)
2015	Sustainable Development Goals
2016	2016-2020 Global Strategy for Women's and Children's Health

Sources: [3,6,8,13,51,52,93,125,127–131]

Evidence indicates this shift away from community development towards technological "fixes" has led to substitution effects in morbidity and mortality, e.g., children were saved from measles and diarrhea only to die from causes not covered by these interventions.[3] Although the elements of GOBI dramatically reduced child mortality across the LMICs world by 1990, this was at the expense of efforts either to strengthen health services, to address a wide range of health issues that could not be eliminated through immunizations, and of improving water and sanitation.[6] In the 1990s and early 2000s, the Integrated Management of Childhood Illness (IMCI) programme delivered narrowly focused vertical interventions, which did not consider contextual factors.[93,128] There are more recent efforts to strengthen health systems[132] and build a continuum of care that functions effectively to meet the needs of women and children.[52,104,128] The 2008 WHO Commission on the Social Determinants of Health led by Sir Michael Marmot[7] deepened global awareness of and commitment to the importance of changing contexts and structures and underpins the renewed thrust of WHO work on health in all policies and the Sustainable Development Goals relating to health.

Shiffman draws on social constructivism to suggest that issues and claims considered important are related to the 'effectiveness of global health policy communities in portraying and communicating severity, neglect, tractability and benefit in ways that appeal to political leaders' social values and concepts of reality'.[133] We show (Table 2 and 3) that the growing financial, political and programmatic commitment to child survival[13,14,17] has entrenched an emphasis on the widespread adoption of a small number of cheap, ostensibly accessible and simple technologies, often at the cost of leaving the wider conditions that determine child survival largely untouched.

The urgency of bringing an historical and structural lens to the continued problem of IMR in LIMCs is underscored by the continued gross inequities and stalled progress in reducing IMR within many countries. We contend that delivering individual and household level interventions to prevent infant mortality without corresponding investments in infrastructure is neither sustainable nor effective, and urge that structural interventions, especially regarding sanitation and civil registration, should again become core to a public health approach to addressing infant mortality. Based on the literature we have reviewed, we believe our findings are relevant for the allocation of funds and government resources to address infant mortality, for the design and delivery of public health programs, and for a reconsideration of the importance of water, sanitation and birth registration, which have been called the 'forgotten foundations of health'.[114]

There are a number of limitations to our analysis. First, we relied heavily on secondary sources, not primary sources, for material from the late 1800s and early 1900s. We are therefore, not able to offer national, state or local estimates of the cost of reducing IMR during this period. Although our reliance on the research and interpretation of professional historians can perhaps raise questions about the selectivity of historical records and approaches taken to their analysis, any such concerns are, we believe, mitigated by the agreement across the different sources and diverse scholars whose work we consulted. Second, many of the analyses of historical and contemporary IMR data we identified all contended with examining trends in infant mortality in a context where vital statistics were either limited or absent, with the only aggregated data typically available. Third, although, the actions which enabled infant mortality declines in specific LMICs are instructive, it was beyond the focus of this paper to discuss the unique circumstances of each LMIC, and we instead focused on trends by region and income group, and on global recommendations and funding priorities. Further work could fruitfully develop

historical and contemporary case studies focused on how specific LMICs addressed infant mortality, including via the financing and implementation of large scale investments in their own public health systems, so as to illuminate the ways in which they have and have not addressed structural causes of child morbidity and mortality.

Fourth, we are mindful of problems inherent in analyses that seek to map the past onto the present. Rather, we consider the historical record to demonstrate that current evidence-based global policy emerges out of a specific context, and is neither inevitable nor the only way to design solutions to the problem of infant mortality and IMR inequities. The historical example from the late 19th/early 20th century U.S. indicates that reductions in infant mortality and IMR inequities were not possible without investments in improved nutrition, clean water, sewage systems, sanitation programs, registration systems and other structural programs, i.e., precisely the types of interventions that have been abandoned or remain under-funded in low-income countries. Although awareness of historical precedents may not necessarily help avoid repeating the mistakes of the past,[28] ignorance of this history can be dangerous and can lead to uncritical acceptance of the status quo, including what is taken for granted as evidence, and without any recognition of what has been lost.

The history we have reviewed may also be instructive for contemporary U.S. domestic policy, especially since in 2010 the U.S. sank to 26th among the 29 Organisation for Economic Co-operation and Development (OECD) countries for infant mortality in 2010.[134] Cognizant of the late 20th century poor standing of the U.S. for IMR rankings, in 2004, the historians Markel and Golden suggested that the past should inform the future of child health policy.[31] In 2007, they went further, and argued that many of the problems facing infants and children in the U.S. today require environmental responses similar to those applied a century or more ago when child

health was the centerpiece of public policy in the U.S – and they called for the creation of a U.S. Department of Children's Affairs to provide leadership akin to the Children's Bureau.[135]

In conclusion, it is folly to forget history. As we have shown, public health emerged as for the 'public' – sewage pipes, registration systems, milk purification, and government investment in child health emerged prior to, then alongside, changes in medical care and vaccination, which were not the mainstay of why infant mortality decreased. Our findings suggest that structural interventions have been largely erased from the contemporary evidence base of infant mortality reduction. Public health recognition in the late 19th and early 20th c that structural interventions were the most effective way to address infant mortality has been replaced by a new set of priorities focused on technological and educational interventions targeted at mothers and households. Given the plethora of countries that decreased IMR prior to mass vaccination, low and middle-income countries and development partners working to address IMR should contend with the fact that this history could be instructive. We do not argue that investments in vaccination programs or critical medical care should wane, but that there is an urgent need to attend to sanitation, clean water, vital registration, and to the state institutions which provide resources to child health. To decrease infant mortality and improve lives, the pillars of a public health system need to be built, not replaced or undermined, and history could offer some crucial lessons.

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Appendix

Table 1- Timeline of factors which contributed to the decline in infant mortality in the United States (1840-1990)

Year	Event/milestone	Label
1841	Massachusetts passed what has been termed the first State registration law of modern type	Civil and vital registration
1842	Massachusetts begins state-wide civil vital registration	Civil and vital registration
1847	AMA formed and appointed a committee to study ways and means of improving the registration of births, deaths and marriages. Several years later, the Association formally urged physicians throughout the country to request their States to establish offices for the collection of vital statistics	Governance and new institutions
1848	AMA examines conditions of other cities and releases a report showing death rates are higher in American cities than European cities	Civil and vital registration
1850	Shattuck report	Civil and vital registration
1850	US Census; showed that using census for vital events was not practical, but this was not discontinued until 1910	Civil and vital registration
1850	First effort to collect national vital statistics through the census method	Civil and vital registration
1850	US Census	Civil and vital registration
1854	John Snow identifies water source as the origin of the cholera outbreak, making water and sewage disposal important	Medical care
1855	First State Board established in Louisiana, mostly focused on quarantine	Governance and new institutions
1857	Wilson Jewell and others organized the National Quarantine and Sanitary Convention. Annual meetings held until 1861	Sanitation
1858	Eight states establish registration systems	Civil and vital registration
1866	State of New York establishes a sanitary bureau which was responsible for the surveillance and control of communicable diseases which dealt with sanitary inspections, contagious diseases, public drainage and food inspection and the inspection of offensive trades. Laboratories were also established in both the city and state departments	Sanitation
1869	State Board established in Massachusetts, which became a model for many other states	Governance and new institutions
1870	First city health authority was established in San Francisco	Governance and new institutions
1872	APHA founded by wartime sanitary commissions with a focus on sanitary reform with vital statistics as a principal component. Establishes a standing committee to promote uniformity in registration	Governance and new institutions
1872	Water filtration first used in the United States in Poughkeepsie, New York, in 1872	Sanitation
1879	Congress creates national board of health (following yellow fever epidemic)	Governance and new institutions
1879	National health board begins receiving annual mortality or weekly reports for the full year from 24 cities	Civil and vital registration
1880	30,000 people in urban areas had filtered water	Sanitation
1880	National Health Board begins to receive weekly mortality reports from 90 cities. Board calls a meeting of state and local registrars to discuss the best ways to collect and publish vital statistics	Civil and vital registration
1882	Koch identifies TB and in 1883, cholera vibrio	Medical care
1885	Rabies vaccine	Medical care
1889	Bond issue to fund and create the Chicago Sanitary District was approved in 1889 by a vote of 70,958 to 242	Sanitation
1893	Milk stations providing free or subsidized milk to poor mothers were inaugurated in the United States in New York City on the Lower East Side, funded by a philanthropist Nathan Straus	Breast feeding and milk purification
1897	Mandatory vaccination of school children in NYC	Medical care
1897	Plague vaccine	Medical care
1900	Public water supplies were available to 42% of the population and sewers to 29%	Sanitation
1900	Death registration area formed (10 states and District of Columbia)	Civil and vital registration
1900	APHA adopts principles of a model law for the registration of births and deaths	Civil and vital registration
1900	US Census, including a count of mortality and shift towards using death certificates	Civil and vital registration
1902	Census Office (which was one disbanded between each census) made permanent and a full-time government agency and named ‘Bureau of the Census’	Civil and vital registration
1902	Marine Hospital Service becomes largest single agency in public health administration	Medical care
1903	Congress adopts a resolution on the importance of a complete and uniform system of registration throughout the country and requests State authorities to cooperate with the Census Bureau in securing a uniform system of birth and death registration	Civil and vital registration
1904	59 cities have mandatory TB notification	Governance and new institutions

1905	Census Bureau, American Medical Association, American Public Health Association and other organizations develop a Model Law for states to adopt	Civil and vital registration
1905	Pennsylvania passes a law based on the Model Law which leads to a striking improvement in birth and death registration, and several other states to adopt similar Acts, or to amend existing laws to conform to it.	Civil and vital registration
1906	Pure Food and Drug Act	Breast feeding and milk purification
1907	American Public Health Association establishes a Vital Statistics Section	Civil and vital registration
1908	Pasteurization compulsory in Chicago	Breast feeding and milk purification
1908	84 cities have mandatory TB notification	Governance and new institutions
1908	Chlorine's use for disinfection demonstrated and most cities disinfect water within the next decade	Sanitation
1909	White House Conference on Infant Mortality	Governance and new institutions
1909	American Association for Study and Prevention of Infant Mortality created after a meeting of the nation's most prominent physicians, nurses, social workers, and reformers, and designed to improve methods of baby-saving, help local associations, and bring the IMR to national attention	Governance and new institutions
1910	10.8 million had filtered water	Sanitation
1910	US Census	Civil and vital registration
1910	297 milk stations in 38 cities	Breast feeding and milk purification
1912	Mandatory pasteurization of all milk coming into New York city	Breast feeding and milk purification
1912	Children's Bureau formed	Governance and new institutions
1912	Congress passed a measure which expanded the functions of the Marine Hospital Service, changing its name to the United States Public Health Service	Governance and new institutions
1912	National Organization for Public Health Nursing founded	Governance and new institutions
1913	The Census Bureau begins appointing agents in State health agencies and authorizing them to use the mailing privileges of Federal offices, to promote registration, and correct certificates of birth and death	Civil and vital registration
1913	Children's Bureau issues first report entitled *"Work of the First Year: Infant Mortality Investigation"*	Governance and new institutions
1914	Pamphlet on infant care created by Children's Bureau	Health education for mothers
1915	National birth-registration era was formed and consisted of 10 States and the District of Columbia	Civil and vital registration
1915	The first report on birth statistics for the year 1915 is issued and includes data from an area including approximately only 31 per cent of the population of the country	Civil and vital registration
1916	First federal child labour law passed	Governance and new institutions
1916	Rockefeller Foundation funded the School of Hygiene and Public Health at Johns Hopkins	Governance and new institutions
1918	The 1918 birth statistics report gives data from an area including 53 per cent, of the population	Civil and vital registration
1918	Children's Bureau declares 1918 Children's Year	Governance and new institutions
1919	Draft developed of "Minimum Standards of Child Welfare"	Governance and new institutions
1920	Over 20 million (about 37% of the whole urban population) have filtered water	Sanitation
1920	Coverage of the death registration area increased to 34 states and the District of Columbia (81% of the population)	Civil and vital registration
1920	pasteurization of the milk supply is common and widely accessible (??)	Sanitation
1921	Sheppard-Towner Act becomes law	Governance and new institutions
1921	90% of cities over 100,000 have pasteurization	Breast feeding and milk purification
1922	Child hygiene divisions established in 44 states	Sanitation
1923	Diphtheria vaccine	Medical care
1924	Census Bureau establishes a committee to bring all States into the registration areas by 1930	Civil and vital registration
1925	Woodbury conducts an eight city study of infant mortality for the Children's Bureau	Governance and new institutions
1926	Pertussis vaccine	Medical care
1927	TB vaccine	Medical care
1930	US Census	Civil and vital registration
1930	American Academy of Pediatrics founded	Medical care
1933	Birth registration area covers the entire country except Alaska	Civil and vital registration
1933	Death registration area covers the country	Civil and vital registration
1935	Social Security Act	Governance and new institutions
1946	Responsibility for collecting and publishing vital statistics at the federal level transferred to the US Public Health Service's National Office of Vital Statistics	Civil and vital registration
1960	National Office of Vital Statistics was merged with the National Health Survey to establish the National Center for Health Statistics	Civil and vital registration

1969	Children's Bureau eliminated	Governance and new institutions
1987	The National Center for Health Statistics became part of the Centers for Disease Control and Prevention, US Department of Health and Human Services.	Civil and vital registration
1990	1.86 million people had filtered water	Sanitation

Sources: [26,27,63,65,66,71,72,77,136,36,39,40,55,57,60–62]