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Fetal health stagnation: Have health conditions in *utero* improved in the United States and Western and Northern Europe over the past 150 years?

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ABSTRACT

Many empirical studies have shown that health conditions *in utero* can have long lasting consequences for health across the life course. However, despite this evidence, there is no clear consensus about how fetal health has changed in the very long run. This paper analyses historical birth weights and perinatal mortality rates to construct a coherent picture of how health conditions *in utero* have changed over the past 150 years. In short, the evidence suggests that fetal health has been relatively stagnant. Limited evidence on birth weights shows that they had already reached their current levels in North America and Northern and Western Europe by the late nineteenth century, and they have changed very little in between. Perinatal mortality rates have fallen dramatically since the late 1930s, but this decline was mainly caused by improvements in intrapartum treatments after the introduction of Sulfa drugs and antibiotics. Thus, the health benefits associated with the perinatal mortality decline were concentrated among those at risk and did not influence the population at large. Finding stagnant fetal health during a period when many other indicators of health improved dramatically is provocative and suggests two conclusions: either fetal health did not improve or the indicators used to measure fetal health, indicators still widely used today, may not accurately capture all aspects of health *in utero*. If fetal health has been stagnant, then better conditions *in utero* cannot explain cohort improvements in life expectancy over the twentieth century. If the indicators of fetal health are problematic, then researchers must move beyond birth weight and perinatal mortality to understand how developmental plasticity based on the prenatal environment influences later life health.

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1. Introduction

Many empirical studies have shown that health conditions experienced by foetuses *in utero* have significant long-lasting health consequences. Babies exposed to poor conditions are at higher risk for heart disease, stroke and diabetes in later life and have lower lifetime earnings and educational attainment and greater disability than healthier cohorts (Almond and Currie, 2011; Barker, 1997; Conley et al., 2003; Figlio et al., 2014; Godfrey et al., 2007). Studies to date have established a causal link between fetal health and later life health, but they have often relied on exogenous shocks to cleanly identify causal links. Thus, there have been relatively few studies that attempt to explain how fetal health has changed over time.

The period between 1860 and the present has been a period of epidemiological transition where many standard indicators of human health have improved dramatically around the world. Crude death rates, child mortality, infant mortality and stillbirth rates have fallen. Life expectancy and average adult height have increased. Western Europe and North America led these trends with the rest of the world following suit in the second half of the twentieth century. The earliest aspects of the mortality decline occurred apart from modern medical science before the germ theory of disease or antibiotics, highlighting the importance of improvements in sanitation and to a lesser extent nutrition in reducing mortality in the nineteenth century (Floud et al., 2011).

Despite these general improvements in health, there is as of yet no consensus on the trajectory of fetal health, or health conditions *in utero*, over the same time period. Woods (2009) and his co-authors (2006) have reconstructed perinatal mortality rates for a number of countries in Western Europe and North America,

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showing that these rates have declined in the past 150 years. Likewise, several studies have shown that mean birth weights of infants born in hospitals in the nineteenth century were very close to their modern levels (Costa, 1998, 2013; Floud et al., 2011; Ward, 1993). This paper attempts to collate all of this evidence into a coherent story about how fetal health has changed over time.

The paper first defines and discusses the complications in measuring fetal health. It then presents the historical birth weight evidence primarily focussing on the United States with other countries provided as a reference and estimates the influence of changes in environmental and demographic factors on birth weight. It closes with a detailed analysis of trends in perinatal mortality and a discussion of the consequences of the results.

2. Measuring fetal health

Before presenting changes in fetal health in the very long run, it is necessary to discuss what fetal health means and some of the challenges and problems with measuring fetal health in general. Plasticity is very strong in the embryonic and fetal period making the developing child extremely sensitive to changes in conditions *in utero*. Poor conditions such as a nutritional shortage, a lack of key micronutrients, the infection of the placenta or a viral infection can stunt prenatal development harming organ functioning and fetal growth among other negative consequences. Recent research suggests that these conditions and the physiological responses of the fetus to the environment *in utero* may have consequences for the health of an individual across their life course including higher risk of chronic diseases in old age (Godfrey et al., 2007). Thus, the purpose in attempting to measure fetal health over the past 150 years is to understand how the prevalence of unhealthy conditions and unhealthy physiological responses has changed over time and influenced cohort health. This purpose shifts the focus of analysis toward understanding the average health and distribution of health outcomes of the population rather than identifying a subset of individuals that might be at risk. It also leads to an emphasis on conditions that would significantly alter fetal development and the health of surviving infants since these will influence trends in cohort morbidity and mortality.

Given the complexity of prenatal development and the requirements of measuring fetal health, it is very unlikely that any one indicator would be able to perfectly capture fetal health. Thus, we are left with imperfect options from which to choose, especially when pushing measurement into history. Birth weight and length reflect the outcome of fetal growth at one point in time, but they cannot reveal the trajectory of fetal growth before birth. Fetal growth itself is determined by some combination of genetic and epigenetic inheritance as well as dynamic responses to conditions in the womb. Thus, using birth anthropometry, it is impossible to distinguish between an individual born with high inherited growth potential who experiences intrauterine growth restriction and is born at a normal birth weight close to the population mean and an individual of average inherited growth potential who does not experience poor conditions and is born at the same birth weight. Measuring fetal growth directly using ultrasound technology may help ameliorate this problem, but these measurements are not available historically. In addition, fetal growth (and especially weight gain) occurs mostly in the third trimester, so birth weight may not fully capture fetal health in the first and second trimester (Hanson et al., 2015; Roseboom et al., 2011; Wilcox, 2001).

Another potential proxy for fetal health is perinatal mortality since poor conditions *in utero* can lead to stillbirths or early neonatal deaths. Perinatal mortality is especially attractive as a historical proxy since perinatal deaths were systematically registered in a number of countries beginning in the nineteenth century (Woods, 2009). However, perinatal deaths were a relatively rare occurrence even in the nineteenth century when 3–6% of total births ended in a stillbirth or neonatal death. Thus, using perinatal mortality as an indicator of population fetal health could be problematic if the factors that led to these extreme outcomes did not reflect the general, population experience of children during the prenatal period (Wilcox, 2001).

A final indicator of fetal health could be the rate of spontaneous abortions occurring in the population. However, spontaneous abortions are notoriously difficult to measure, and the method employed in the literature of looking at the secondary sex ratio as a proxy for male frailty does not inform about the overall rates of fetal wastage in a population in a way that could be systematically incorporated into the analysis below (Catalano et al., 2008). Thus, this article will focus on birth weights and perinatal mortality.

3. Birth weights, 1840 to the present

Rosenberg (1988), Goldin and Margo (1989) and Ward (1993) pioneered the study of historical maternity records containing birth weight that have survived for a number of European and North American maternity hospitals. These hospitals all served slightly different, though mostly working-class populations, in their hinterlands, and they used various selection criteria to admit patients. Supplementary appendix B discusses the inclusion and exclusion criteria for the historical hospitals included in the analysis and discusses selection further. While any given hospital may suffer specific defects, taken together the hospitals can provide a tentative indication of general birth weight levels. As Table 1 shows these authors found that birth weight levels in the nineteenth century had already reached modern levels.

Indeed if we compare these with the recent INTERGROWTH-21st standards, nearly all of these populations had birth weights at or above the median birth weight (3320 g) for full-term babies (Villar et al., 2014). As Steckel (1998) and Ward (2016) have pointed out, there have been some increases and decreases in birth weights over time. However, these differences are small if the change in birth weight is expressed relative to its standard deviation. Taking the 1985 US population birth weight distribution as a reference (standard deviation of 602 g), these increases or decreases averaged to 0.18 standard deviations and are all less than 0.45 standard deviations. For reference, to shift the average birth weight in Pakistan in the 1980s (2770 g) to the median INTERGROWTH-21st level would require a 0.91 standard deviation increase in birth weight. In addition, the changes in birth weight pale in comparison to the changes in final adult male stature in North America and Europe, which have increased by between 1.4 and 2.3 standard deviations (Hatton and Bray, 2010).

There is not space in this paper to discuss all of the historical maternity hospitals in detail, but a closer study of the maternity hospitals in Boston, MA may assuage doubts that the high birth weights were driven by the selection of women into each hospital. Ward (1993) collected samples of maternity patient records from three nineteenth-century hospitals in Boston: the New England Hospital for Women and Children (NEH) (1872–1900), the Boston Lying-in Hospital inpatient ward (1886–1900) and the Boston Lying-in Hospital outpatient ward (1884–1900). The NEH and Lying-in inpatient ward provided women a place to give birth and recover afterwards, often for three to four weeks. These hospitals served mainly married and respectable single women. Both required a fee to be paid by the women. The NEH charged $10 per week, which probably excluded some poorer patients from giving birth there. The occupations of women patients in the NEH suggest that most women were from the upper working class or lower middle class. The Lying-in inpatient ward also charged a $20 fee for

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