Descriptive analysis of fetal mortality in the United States:
a historical, racial and geographical perspective

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1. Introduction

Stillbirth is one of pregnancy's most common adverse outcomes (American College of Obstetricians and Gynecologists and the Society for Maternal-Fetal Medicine, 2020). Fetal mortality is an important reproductive health indicator and a major, but often overlooked, public health problem. Stillbirth has received little attention from historical demographers who, when analyzing reproductive mortality, have traditionally relied on infant mortality as a more orthodox indicator for changes in human survival (Schofield, Reher, Bideau 1991). One reason for this lack of attention lies in the difficulty of correctly identifying stillbirths in demographic sources, at least in the historical ones. This complex issue has recently been the subject of deep analyses focused on the criteria of classification adopted, and their consequences on the measures of stillbirth and infant mortality (Mooney 1994; Woods 2005; 2009; Davies 2009; Gourdon, Rollet 2009; Breschi *et al.* 2012).

The infant mortality rate (IMR) has traditionally been the main indicator for measuring a population's health status. Its use is based on the belief that it is highly accurate in reflecting the social, economic and medical circumstances of childbearing and, therefore, the quality of life in a society (González, Gilleskie 2017).

A stillbirth is a delivery after 20 completed weeks of gestation of a fetus showing no signs of life. The United States (US) National Center for Health Statistics (NCHS 2023) recommends that all fetal deaths at 20 weeks of gestation or more (20+) or over 350 grams (if the gestational age is not known) should be reported through the National Vital Statistics System. Most US states report fetal death data but with substantial differences in terms of quality and completeness.

According to the National Center for Health Statistics (2023), fetal death refers to the spontaneous intrauterine death of a fetus at any time during pregnancy. Fetal deaths later in pregnancy (at 20 weeks of gestation or more, or 28 weeks or more, for example) are also sometimes referred to as stillbirths. Since this study is only about fetal deaths that occur from 20 weeks gestation onwards, the terms "fetal deaths" and "stillbirth" are here regarded as synonyms and used interchangeably.

According to our database that is described below, stillbirths account for an increasing percentage of fetal-infant mortality in the US Between 1922 and 1924, they represented 32% of all fetal-infant deaths. Between 1950-1952 it was 40%, and for 2016-2018 it was 51%. In 2019, there were more deaths of fetuses 20+

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weeks of gestational age (21,501) than children who died within their first year of age (20,927). We therefore consider that the study of mortality during the fetal period is of great socio-demographic importance, owing to its historical significance in terms of absolute numbers, its large relative weight in perinatal deaths over recent decades and its sociological and healthcare implications.

Even though longer term studies are crucial for secular trend analyses, there are no publications compiling historical trends for different aspects of fetal deaths in the US Woods (2009: 76) and Schneider (2017) compile information for the 20th century but do not provide in-depth analysis of variables such as race and geography.

The majority of existing studies on fetal deaths in the US lack a historical perspective. For example, Greulich (1931) and Ciocco (1938) analyzed the sex ratio of stillbirths in the US over a short period (1925-1934). One of the most important corollaries to be drawn from Ciocco's observations is that apparently there is no evidence to justify the current assumption that males under all conditions are more liable to stillbirth. Teitze (1948) also focused on the sex ratio of abortions based on 5,667 fetuses from the Carnegie Collection. McMillen (1979) studied the differential mortality by sex in fetal and neonatal deaths in the United States from 1922 to 1936 and from 1950 to 1972. This analysis corroborated the previously established pattern of the sex ratio of fetal deaths (highest from months 3 to 5, lower from months 6 to 7 or 8, and increasing at term).

Hsieh *et al.* (1997), using data for the period 1979-1990, found that disparity in the fetal death rates for Blacks and Whites is explained almost entirely by differences in birth weight distribution. Ananth *et al.* (2005) conducted a cohort study of Black and White women who delivered a singleton live-born or stillborn infant from 1981 through 2000. They found that strong effects of age and period were observed in stillbirth trends, but these factors fail to explain the persistent disparity between groups in stillbirths. Reddy *et al.* (2006) examined the relationship of maternal age with stillbirth risk throughout gestation for just two years (2001-2002), and found that women who are of advanced maternal age are at higher risk of stillbirth throughout gestation.

Davis *et al.* (2007) described trends in fetal deaths by race in the United States from 1970 to 2002, and found that the male proportion of fetal deaths had increased. Willinger *et al.* (2009) analyzed the factors associated with racial disparities in stillbirth risk, finding that Black women have a 2.2 times the risk of stillbirth compared with White women. Rowland Hogue and Silver (2011) reviewed the available data regarding risk factors for stillbirth in the US with a focus on those that are more prevalent and have a more profound effect on certain racial/ethnic groups. Although they provide data on fetal mortality rates by sex with a historical perspective (1942-2005), they emphasize their analysis on the year 2005. Although many factors contribute to racial disparity in stillbirth, they highlight that the reasons for this disparity remain unclear. MacDorman *et al.* (2015a and 2015b), Gregory *et al.* (2021) and Henry *et al.* (2021) evaluate stillbirth trends by race for very short recent periods. MacDorman (2015a and 2015b) found that fetal mortality rates were highest for teenagers, women aged 35 and over, unmarried women, and women with multiple pregnancies. Gregory *et al.* (2021) found that mortality rates were highest for women aged 40 and over, for women who smoked during pregnancy, and for women with multiple gestation pregnancies. Five selected causes accounted for 89.9% of fetal deaths in the 42-state and District of Columbia reporting area. Henry *et al.* (2021) used a multivariate analysis accounting for correlations among variables. They showed a group of risk factors that differed between Black women and White women: age < 20, lower education, pre-pregnancy obesity, hypertension (chronic and pregnancy-associated), nulliparity before stillbirth, and earlier gestation.

Fetal mortality and infant mortality rates vary by race in the US over the twentieth century (Hsieh *et al.* 1997; MacDorman 2011; Rowland Hogue, Silver 2011; Willinger *et al.* 2009). However, Rowland Hogue and Silver (2011, 224) consider that even at the beginning of the 21st century, we know very little about the racial differences in fetal mortality. Sánchez-Barricarte (2022) conducted a previous historical study of fetal mortality in the US, focusing on the analysis of sex differences in the fetuses.

To address this knowledge gap, this study compiles information for the different variables analyzed for two racial groups: Whites and Blacks. For the periods where we have no existing information for the Black population, we have used non-White groups as a proxy variable[1].

It is important for readers to understand that the differences in the fetal mortality rates when these are classified taking into account specific sociodemographic variables should be regarded as mere correlations. The analyses presented in this study should not be used to infer relations of causality. The attribution of causality would need a more ambitious analysis taking account of additional potential influences (and likely using a more sophisticated empirical model).

One of the main aims of this study is to provide a historical understanding of fetal mortality in the US by analyzing it from different perspectives: state of residence, civil status and mother's age, gestation duration, weight, race, etc. This historical perspective can help us to identify the socioeconomic variables that may affect fetal mortality levels and the notable racial and geographical differences that characterize it. This information might help us to devise policies that help to reduce fetal death rates.

This article will cover the following sections: in the second section, we describe our sources and the problems associated with their use. We then focus our attention on the historical evolution of fetal death ratios, with particular attention to racial differences (white and black populations). In the fourth section, we analyze the differences in fetal mortality according to the i) mother's age and race; ii) solar radiation and fetal mortality; iii) gestational age using a different denominator (the so-called prospective fetal mortality rate); iv) fetus's gestational age and the mother's age; v) the fetus's weight and the mother's marital status.

2. Source

At the beginning of statistical records of fetal deaths, the registers varied greatly from one state to another. When the first attempts were made to collect data in

1922, each state established its own rules about which fetal deaths should be registered. Some states take 23 weeks gestation as the cut-off point, some take 20 weeks, and some use fetal weight. In 1933, the 48 states of the Continental US became part of the National Vital Statistical System. In 1942, records on fetal deaths were standardized, but the regulatory variation between different states still generates doubts about the quality and consistency of the data (Woods 2009, 75).

During the first half of the 20th century, there was significant under-reporting of stillbirths, particularly those occurring outside hospitals. Levels of under-reporting varied between states as each state had different requirements for recording the data. As late as the early 1950s it was estimated that 10% of fetal deaths at 28+ weeks were not registered (Chase 1967, 14-17). Also, an unknown number of early neonatal deaths were incorrectly registered as stillbirths. In addition, many reporting areas did not distinguish fetuses by gestational age, leading to an inflation of the stillbirth ratio (Rowland Hogue, Silver 2011, 222). The latest report from the Division of Vital Statistics still warned in 2019 of the variations between states in terms of how exhaustive fetal death records are, which can affect the correct interpretation of the data (Gregory *et al.* 2021, 2).

The indicators of fetal mortality intensity are clearly affected by under-reporting and, therefore, we must warn the reader that the Figures and Tables in this paper that represent the historical evolution of this phenomenon should be interpreted with caution. Yuan *et al*. (2005) suggest that the fetal death rates reported nationally should have decreased further over time than they have, were it not for increased reporting of fetal deaths at early gestational age in recent years. In any case, these indicators of fetal mortality intensity can help guide us - in an approximate way – in terms of understanding variations over time, and can allow us to detect points in time where its decline was more pronounced. Despite the limitations in the sources, we believe it is worth the effort to compile the historical information published on fetal mortality, taking precautions where necessary, because this might help us understand how this phenomenon has evolved over time.

The data used in this research comes from the following sources:

– Period 1920-1967: fetal deaths and live births come from the annual reports of the Vital Statistics of the United States. These reports are available to download at the National Center for Health Statistics Webpage: www.cdc.gov/nchs/products/vsus.htm.
– Period 1968-1981: fetal deaths come from the annual reports of the Vital Statistics of the United States available to download at the National Center for Health Statistics Webpage: www.cdc.gov/nchs/products/vsus.htm; live births come from Birth Data Files available at the Vital Statistics Online Data Portal: www.cdc.gov/nchs/data_access/vitalstatsonline.htm.
– Period 1982 onwards: fetal deaths and live births come from Birth and Fetal Death Data Files available at the Vital Statistics Online Data Portal: www.cdc.gov/nchs/data_access/vitalstatsonline.htm.

We compiled almost 199 million birth records between 1968-2019 and over 2.2 million fetal death records for the 1982-2019 period.

3. Historical evolution of fetal death ratio and fetal death rate in the US

The fetal death ratio (FDR) is calculated as:

$$\frac{\text{(Stillbirths (20 + weeks of gestation))}}{\text{(Live births)}} \text{ x 1,000}$$

The fetal death rate is calculated as:

$$\frac{\text{(Stillbirths (20 + weeks of gestation))}}{\text{(Live births + Stillbirths (20+ weeks of gestation))}} \text{ x1,000}$$

Both the fetal death ratio (FDR) and the fetal death rate are indicators of fetal death intensity. Before 1942, US stillbirth statistics were reported as ratios. From 1991 onwards, stillbirth statistics have been reported only as rates. Between 1942 and 1990, both rates and ratios were reported.

Figure 1 shows the historical evolution of the US fetal death ratio (FDR). The data before 1945 was calculated using all registered stillbirths, without taking into account gestational age. From 1945 onwards, only deaths at 20+ weeks of gestation were considered. However, deaths registered at under 20 weeks before 1945 represented a small percentage of the total (e.g. between 1922 and 1936, only 1.9% of registered stillbirths were under 20 weeks old).

As early as the 1920s, the FDR declined. Figure 1 distinguishes three periods. The first period ended in 1955 and was characterized by a large drop for both White and Black populations. Between 1955 and 1965 there is a plateau in the data, and from 1965 onwards, we can see a slow decrease which continues to this day. Woods (2009: 82) compiled information on fetal mortality in several Western countries and concluded that, regardless of the criteria used to register these events, there has been a major overall decline since the 1930s. Therefore, the accelerated drop in the FDR, which we observe in the US from the 1920s onwards is common to a number of Western countries.

One of the traditional debates on the modern mortality transition in the Western world was between those who believed that the historical decrease in mortality (non-fetal) was due to medical improvements and those who considered that it was due to economic advances, an increase in productivity and improved access to food (Schofield, Reher, Bideau 1991). Before the 20th century, medicine had only a minimal impact on improvements in health. According to Wootton (2006, 26), “before 1865 all medicine was bad medicine; that is to say, it did far more harm than good”.

On fetal mortality, Woods (2009, 236) argues that the first advances in maternal and childcare during pregnancy and birth took place in Scandinavia, whereas in the United Kingdom and US, even in the 1920s and 1930s, the low quality of obstetric care was acknowledged.

Maternal infections likely passed on to the fetus in utero were significant causes of death before the availability of effective antibiotics. Løkke (2012) presents abundant evidence that links the drop in perinatal mortality in Denmark to the introduction of antibiotics. Penicillin was initially used on soldiers during the Second World War to treat infections from battle-field wounds and pneumonia. By 1944, enough penicillin was being made for civilians to finally access it in the US (Lax 2015).

Likely that decreases in fetal mortality levels before the generalized use of penicillin in the US could be linked to improved health and nutritional conditions for women. The nutritional status of women before and during pregnancy is known to affect fetal-growth patterns and fetal death. Exactly how these mechanisms work is not fully understood (Woods 2009, 235). More research is needed to analyze in detail the possible reasons for the historical decline in fetal mortality in the different states of the US.

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3.1. Racial differences. Figure 1 shows that, in parallel to the historical decrease in fetal mortality, there was a convergence process in the values of both population groups analyzed. However, although absolute differences between the FDR in Whites and Blacks decreased over time, the relative differences have remained practically the same over the last 100 years. To measure the relative differences in the FDR by race, we calculated the following ratio:

$$= \frac{\text{(Black' Fetal Death Ratio)}}{\text{(White' Fetal Death Ratio)}}$$

A value of 1 means that the FDR is equal in both populational groups. A value over 1 means that it is higher amongst the Black population. And a value under 1 means that mortality is higher amongst Whites. At the start of the 1930s, the Black FDR was double that of the White population. This difference slowly decreased until the first half of the 1980s, but then experienced a renewed growth. During the first two decades of the 21st Century, FDR for blacks was double that of the White population.

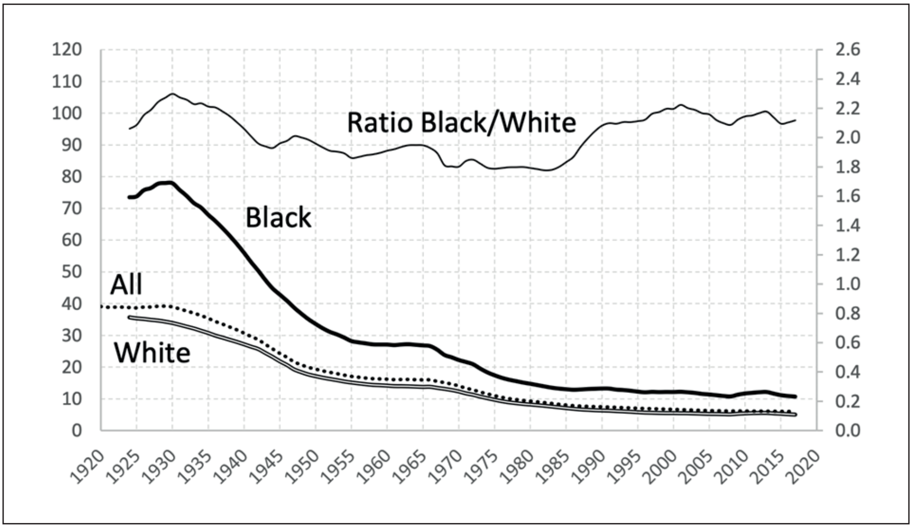
4. Fetal mortality

4.1. Maternal age. Fetal mortality varies considerably according to maternal age. We have calculated the mother's age-specific fetal death rates as follows:

$$= \frac{\text{(Stillbirths (20+ weeks of gestation) at maternal age x)}}{\text{(Live births at maternal age x + Stillbirths (20+ weeks of gestation) at maternal age x)}} \times 1{,}000$$

The historical data we compiled shows that, from 1942 onwards, there was a notable decrease in the specific fetal mortality rates for all maternal age groups, and, from 1982 onwards in particular, amongst mothers 30+ (fig. 2), reaffirming previous findings (Fretts *et al.* 1995). In both racial groups, we find a strong influence of maternal age on stillbirth trends. Stillbirth rates are much higher at the extremes of maternal age (Ananth *et al.* 2005; Rowland Hogue and Silver 2011). The rates of stillbirths for women over 39 double those of women between 20-24.

Fig. 1. *Fetal death ratio by race in the US (left axis) (5-years-moving-average) and ratio Black/White (right axis)*



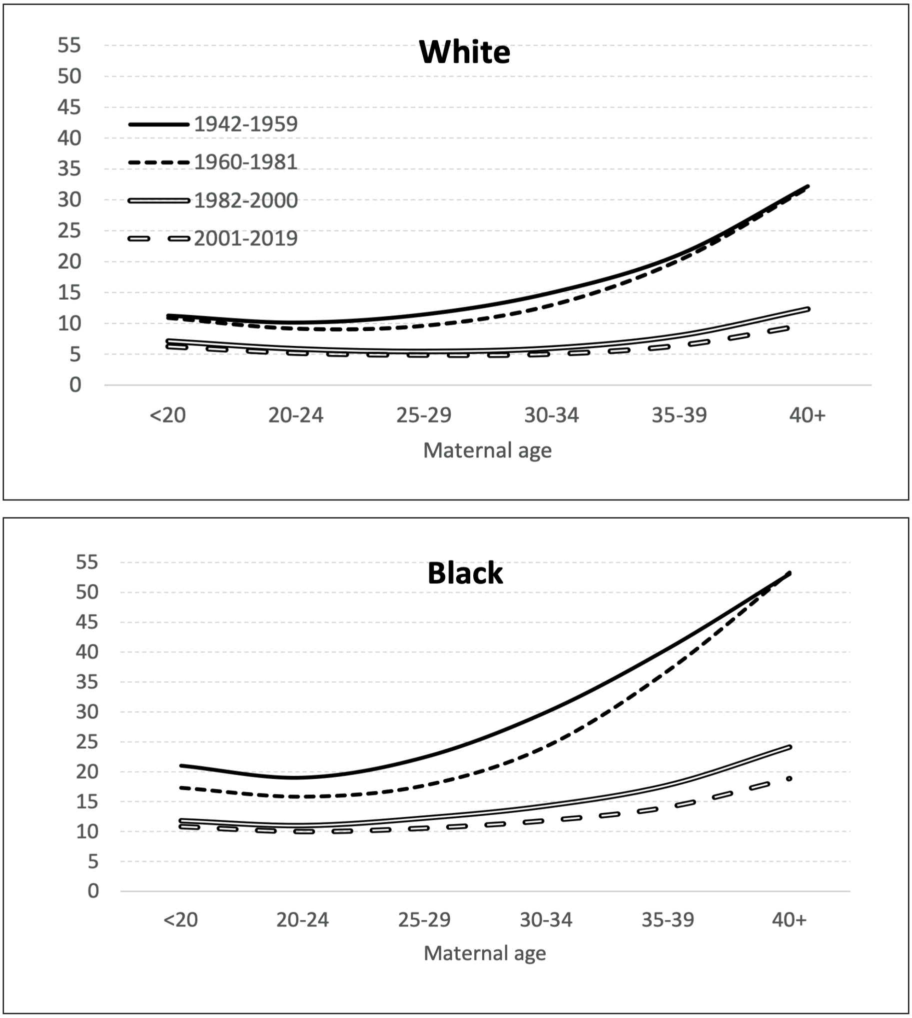
Note: data before 1945 takes into account all registered stillbirths, without taking account of gestational age. From 1945 onwards, only stillbirths over 19 weeks are included. Source: Carter et al. 2006: 1-458 and 1-459, Table Ab912-927). Between 1950 and 1967, data represents non-Whites instead of Blacks.

Fetal mortality may be slightly higher amongst teenagers due to socioeconomic and behavioral conditions, although biological immaturity may also play a role. Women 35+ have a greatly increased risk of fetal mortality. Different studies (Raymond *et al.* 1994; Miller 2005, Reddy *et al.* 2006; Rowland Hogue, Silver 2011; MacDorman 2011) have confirmed that stillbirth risk in older women persists even after adjusting for medical conditions (hypertension, placental problems, diabetes, and multiple gestation).

Like many other Western countries, the United States has experienced an acute process of maternal aging in the last few decades. The mean age of motherhood went from 25.1 for the White population and 23.6 for the Black population in 1968 to corresponding values of 29.2 and 28 in 2019[2]. Because the risk of fetal mortality varies significantly in relation to the mother's age, it is clear that the change in the demographic structure towards older childbearing can explain the halt in decline in indicators such as the fetal death rate or the fetal death ratio which we observe at the start of the 21st century. As with other demographic indicators, such as the gross birth rate or the gross death rate, the previously mentioned summary indicators of fetal mortality are impacted by the percentage distribution of stillbirths according to maternal age.

4.2. States with lowest / highest solar radiation and differences in mother's age-specific fetal death ratese. Purdue-Smithe *et al.* (2019a, 2019b and 2021) suggest that

Fig. 2. *Mother's age-specific fetal death rates by race, US 1942-2019*

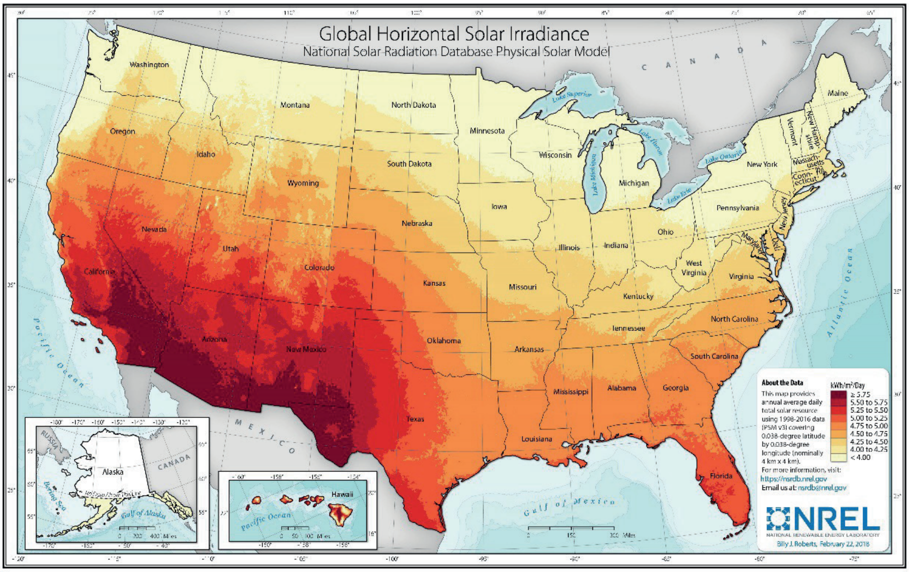


Note: stillbirths with no known gestational age have been proportionally distributed across different maternal age groups. Before 1982 data is for non-Whites instead of Blacks.

vitamin D may mitigate maternal inflammation that would otherwise be detrimental to the implantation or survival of conceptuses in utero. Vitamin D is synthesized in the skin from cholesterol thanks to a chemical reaction naturally activated by type B ultraviolet light (UVB) from sunlight. According to the United States National Solar Radiation Data Base, the South West and South states receive the most Global Horizontal Irradiance (Senguptaa *et al.* 2018) (see fig. 3).

To test whether solar radiation (and therefore vitamin D levels) could be influ-

Fig. 3. *Global Horizontal Solar Irradiance in the United States*



Source: National Solar Radiation Database (https://nsrdb.nrel.gov/).

encing the mother's age-specific fetal death rates values, we contrasted the figures for two groups of states:

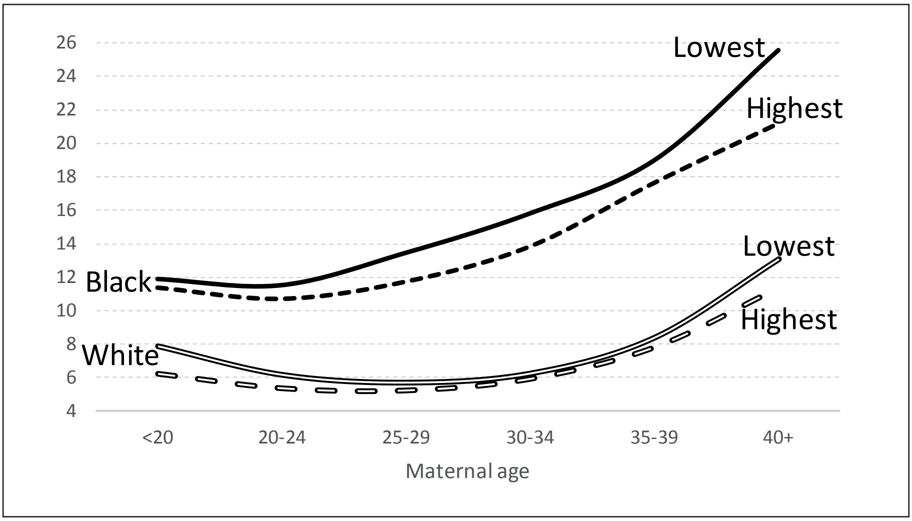
1. States with the lowest level of solar radiation (Northern states): Wisconsin, Washington, Vermont, Pennsylvania, North Dakota, New York, New Hampshire, Montana, Minnesota, Michigan, Maine and Alaska.
2. States with the highest level of solar radiation (Southern states): Utah, New Mexico, Nevada, Florida, California, Arizona.

These two groups of states have been formed based on the intensity of solar radiation shown in Map 1. We have excluded Texas from the group with the highest levels of solar radiation because most of the population of this state is concentrated in its eastern part (Houston, Dallas, San Antonio, Austin...), which is precisely the area that receives the least solar radiation. We use this geographical division further to contrast values for other indicators.

In figure 4 we can see that the states with higher levels of solar radiation have lower levels of fetal mortality. Americans living north of 37° latitude are at greater risk of vitamin D deficiency because of low UVB sunlight from late October to late April (Wickham 2012; Ghareghani *et al.* 2018). Although we do not have the blood vitamin D levels for each state classified by sex and race, we can say that the higher solar radiation from which women in the Southern States of the US benefit appears to have a potential protective effect for fetuses in all maternal age groups.

People with dark skin need six times more exposure to solar radiation than those of fair skin to produce the same amount of vitamin D, which explains why

Fig. 4. *Mother's age-specific fetal death rates according to maternal race and place of residence (states with lowest / highest solar radiation), US 1982-2019*



Note: stillbirths with no gestational age have been proportionally distributed across all maternal ages.

the percentage of people with low levels of this vitamin is much higher among the Black population than the White population residing in the US (Tangpricha *et al.* 2020). In the future it would be helpful to conduct more detailed research about whether it is possible to conclude that this biological difference between races that affects vitamin D production also accounts for the different fetal mortality rates found between Blacks and Whites.

It is, therefore, likely that this biological difference in vitamin D production between races contributes to the different fetal mortality rates found between Blacks and Whites.

4.3. Prospective fetal mortality rate. Fetal death rates by gestational age can be computed using a different denominator, representing the population at risk of the event, that is, all of the women still pregnant at a given gestational age (Yudkin *et al.* 1987; MacDorman 2015b). Using a denominator of women who are still pregnant at a given gestational age allows for the calculation of a prospective fetal mortality rate (PFMR). This rate is calculated as follows:

$$= \frac{\text{(Stillbirths (20+ weeks of gestation) at gestational age x (in single weeks))}}{\text{(Live births at gestational age x or greater + Stillbirths (20+ weeks of gestation) at gestational age x or greater))}} \text{ x } 1{,}000$$

The PFMR is preferred when measuring stillbirth risk because traditional stillbirth rates tend to show considerable volatility. This rate appears to be a more reliable indicator of stillbirth trends during periods when the distribution of live births by gestational age is changing.

Figure 5 shows that, though there are differences in levels, the overall trend in PFMR by gestational age is similar for both racial groups. In general, rates were high at the earliest and latest gestational ages. Over time, values of the PFMR have increased in weeks 20 to 23 of gestation for both population groups. Changes from week 39 onwards have, however, been different for both groups.

The prospective risk of stillbirth can be clinically valuable to make predictions for individual pregnancies and to help doctors balance the risks of expectant management with those of intervention (American College of Obstetricians and Gynecologists and the Society for Maternal-Fetal Medicine 2020). It is also useful to identify two distinct peaks in fetal mortality risk. As MacDorman and Gregory (2015, 9) point out, these two peaks could result from etiological factors. A large proportion of early fetal mortality is related to congenital abnormalities, infections, and intrauterine growth restriction. Fetal mortality at 40 weeks or more can be related to problems that occur around the time of birth (placental abruption, prolapse, etc.).

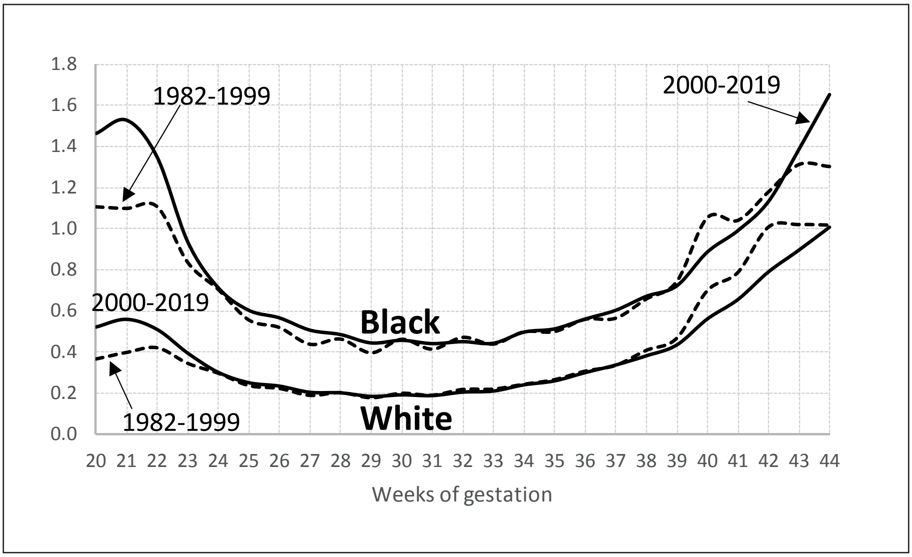
The cumulative risk of fetal death at a given gestation interval estimates the probability of having a stillbirth while in that interval of pregnancy. The cumulative risk for stillbirth/1,000 pregnancies from week 20-44 of gestation was 10.27 (period 1982-1999) and 10.03 (period 2000-2019) for the White population and 18.40 (period 1982-1999) and 19.97 (period 2000-2019) for the Black population. That is, in the last 40 years, the cumulative risk of stillbirth has decreased amongst the White population but has increased amongst the Black population.

Willinger, Ko and Reddy (2009) found that, in general, a higher educational level was associated with a substantial reduction in stillbirth risk. They also found that underlying medical risk and advanced maternal age contribute to the increased risk of stillbirth at term. Another study on racial disparities in stillbirth risk factors in the US found that less formal education, age < 20, obesity, nulliparity, chronic and pregnancy-associated hypertension, and earlier gestation are very important factors to consider in stillbirth prevention interventions to decrease racial disparity (Henry *et al.* 2021).

4.3.1 Gestational age. Figure 6 shows that the average gestational age for stillbirths in the US in the year 1950 was very similar across racial groups. Since then, it has decreased considerably, particularly amongst the Black population, first slowly and, from 1975 onwards, much faster. In the last few years, however, there has been a slight upward trend for both population groups.

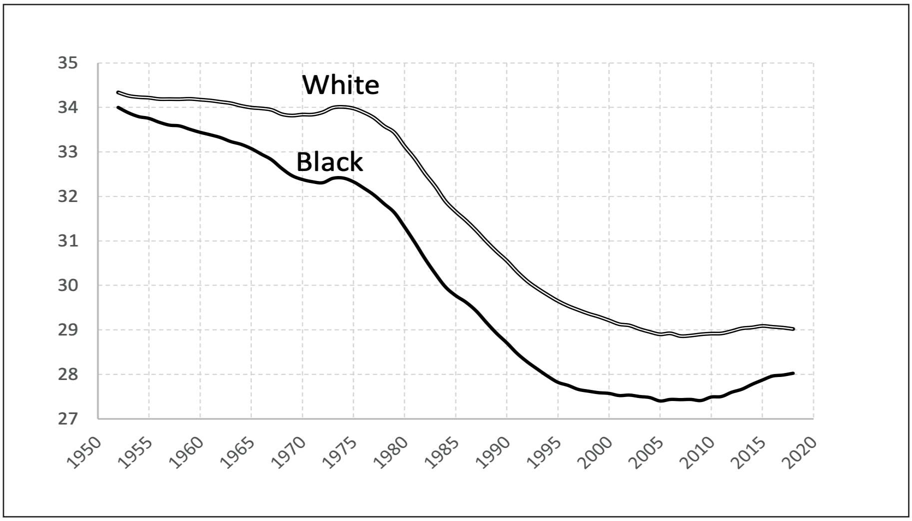
This drop in the average gestational age is probably explained, at least in part, by the fact that mortality dropped at a higher rate in late gestational periods compared to earlier ones, as we will see further in table 1. Due to the fact that underreporting is more common in the early stages of pregnancy, improvements in the accuracy of the recording of stillbirths with lower gestational ages over time could have influenced the drop in average gestational age.

Fig. 5. *Prospective fetal mortality rate by single weeks of gestation, US*



Note: for the PFMR calculation, stillbirths and live births whose gestational age was not recorded have been distributed proportionally.

Fig. 6. *Prospective fetal mortality rate by single weeks of gestation, US*



Note: for the 1950-1981 period, we present data for non-Whites instead of Blacks. We have had to estimate the average gestational age for the 1950-1981 period as available data is grouped by different age ranges. These are the average ages that have been taken into account for each gestational age: 20-27 weeks (23.8), 28-31 (29.9), 32-35 (32.9), 36 (36.5), 37-39 (38.5), 40 (40.5) and 41+ (41.9).

Tab. 1. *Gestational age-specific mortality rates, US*

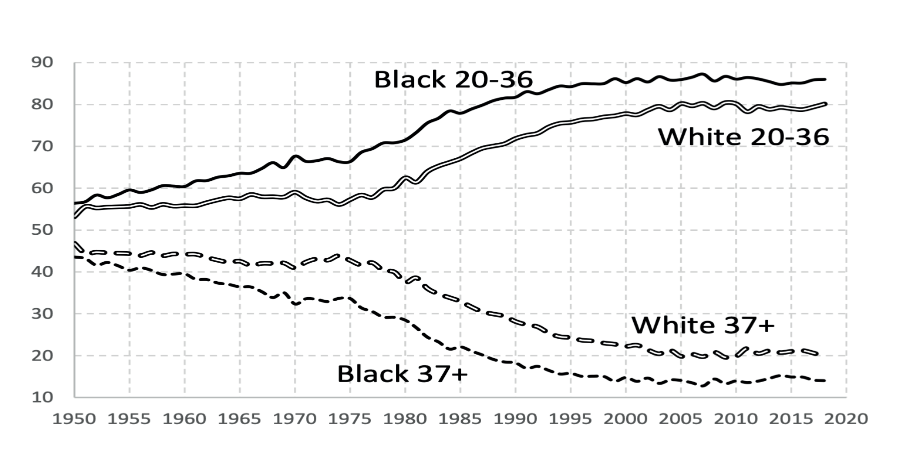
	White			Black		
Age in weeks	1982-1999	2000-2019	Percentage change	1982-1999	2000-2019	Percentage change
20	645.4	706.4	9.5	552.5	647.5	17.2
21	568.1	651.6	14.7	469.0	597.7	27.4
22	506.4	564.8	11.5	407.3	506.0	24.2
23	400.1	427.8	6.9	301.6	350.8	16.3
24	313.4	291.9	-6.9	229.7	239.1	4.1
25	231.5	224.6	-3.0	167.4	190.4	13.7
26	185.8	185.3	-0.3	135.4	163.1	20.5
27	145.0	144.8	-0.1	111.6	139.2	24.8
28	122.2	106.4	-12.9	95.2	112.5	18.2
29	89.3	81.2	-9.0	69.9	90.3	29.3
30	72.5	61.9	-14.6	59.5	72.7	22.4
31	53.8	46.5	-13.4	44.9	57.0	27.0
32	44.7	35.4	-20.8	39.4	43.6	10.6
33	30.7	24.4	-20.4	26.4	30.5	15.3
34	19.9	15.9	-19.9	18.9	20.7	9.6
35	12.9	10.6	-17.9	12.7	14.2	11.4
36	8.6	6.6	-22.9	9.5	9.1	-4.5
37	4.8	3.4	-28.5	5.5	4.8	-12.8
38	2.6	1.8	-31.3	3.4	2.8	-17.3
39	1.5	1.0	-34.9	2.2	1.6	-27.4
40	1.5	1.0	-34.0	2.2	1.5	-30.3
41+	1.7	1.4	-20.0	2.4	2.2	-8.1

Note: stillbirths and live births whose gestational age is not detailed in the records have been distributed proportionally.

One of the main discoveries of the so-called Euro-Peristat Project, which took data from 29 European countries and regions, was that on average, low fetal mortality countries had higher percentages of their fetal deaths at earlier gestational ages, while high fetal mortality countries had higher percentages at and near term (Mohangoo *et al.* 2011, 4). If we individually analyze each racial group, we can also see that in the US we also find this same pattern, because, as the fetal mortality intensity has fallen, stillbirths over 36 weeks old (at term) have become a lower proportional percentage of the total (fig. 6).

Because fetal death ratios for the Black population have always been higher than for Whites (see figg. 1, 3, 4, 5), according to the discoveries made by the Euro-

Fig. 7. *Percentage distribution of fetal deaths (20+ weeks of gestational age) according to race and two gestational groups (20-36 weeks and 37+ weeks), US*



Note: the 1950-1981 period presents data for non-Whites instead of Blacks.

Peristat Project, the percentage of death fetuses at 37+ weeks of gestation in the White population should be lower than for Blacks, but this has not been the case since at least 1950 (fig. 7).

4.3.2. Gestational age-specific mortality rates. We calculated gestational age-specific mortality rates as follows:

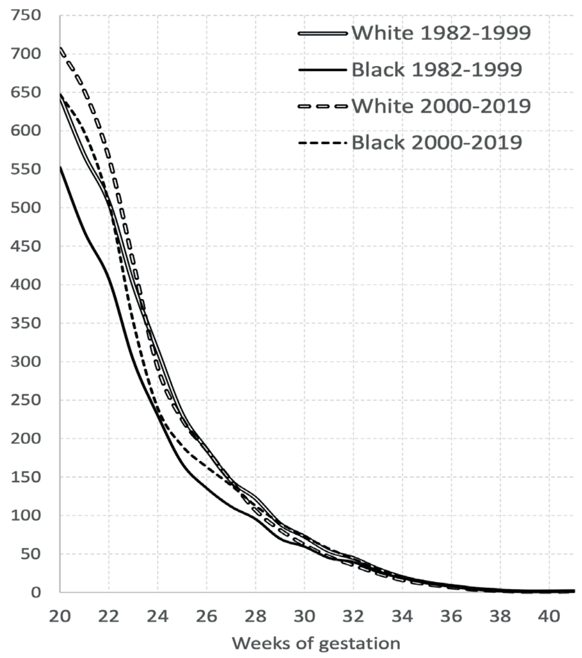
$$= \frac{\text{(Stillbirths at gestational age x (in single weeks))}}{\text{(Live births at gestational age x + Stillbirths at gestational age x)}} \text{ x 1,000}$$

Normally, fetal deaths at a lower gestational age are less likely to be registered. It is therefore very likely that fetal mortality rates at earlier gestational ages are also underestimated.

In table 1 and figure 8 we can see the values for each of these rates for the two different time periods. There are a number of aspects to highlight:

a. Gestational age-specific death rates decrease markedly as gestational age increases.
b. Among the White population, gestational age-specific death rates between 20 and 34 weeks in the 1982-1999 period and between 20 and 27 weeks for the 2000-2019 period are higher than for the Black population.
c. While in the White population gestational age-specific death rates for 24+ weeks of gestation have markedly decreased, amongst the Black population this decrease has only taken place amongst fetuses under 36 weeks of age.

Fig. 8. *Gestational age-specific mortality rates, US*



d. Declines in gestational age-specific death rates have been higher as gestational age increases. At younger gestational ages, mortality rates have increased. The fetuses in advanced gestational phases have benefited most from improved obstetric care in the last few decades, by contrast to those in initial fetal phases.

As gestational age-specific mortality rates change markedly as gestational age increases, and the proportional distribution of those born (both dead and alive) according to gestational age is different depending on race (see tab. 2), it is relevant to compute standardized fetal death rates[3].

What we can see in figure 9 is that, once values for fetal death rates are standardized, racial differences practically disappear. From this, we can deduce that, most likely, the historical racial differences in fetal death rates for the US which we can see in figure 1 would greatly decline if we could calculate standardized data.

So the differences we observe in fetal death rates for White and Black populations can be almost entirely explained by the different proportional distribution of births (dead and alive) according to gestational age. Births (both dead and alive) for the Black population happen at earlier gestational ages than for Whites, and this impacts fetal death ratios and non-standardized fetal death rates. It would be very interesting to carry out research that would provide a detailed analysis of what causes these earlier births.

Tab. 2. *Proportional distribution of births (dead and alive) according to gestational age, US 1982-2019*

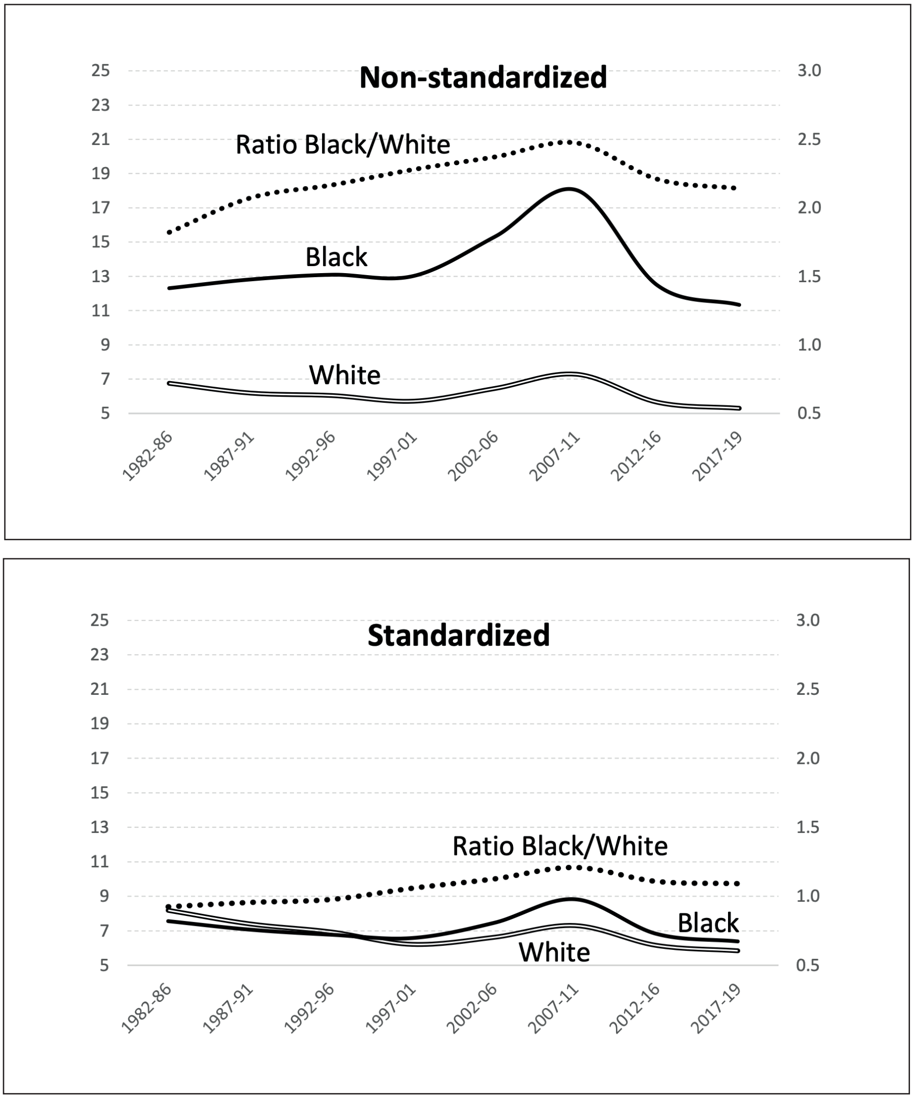
Gestational age	All races	White	Black	Differences Black - White (in %)
20-22	0.003	0.002	0.007	68.4
23-25	0.004	0.003	0.009	66.9
26-28	0.005	0.004	0.012	63.1
29-31	0.010	0.009	0.020	56.4
32-33	0.015	0.013	0.025	48.7
34-35	0.037	0.035	0.057	39.3
36-37	0.113	0.113	0.145	22.1
38	0.147	0.151	0.158	4.7
39	0.239	0.250	0.227	-10.5
40	0.213	0.215	0.176	-22.5
41+	0.215	0.205	0.165	-24.5
Total	1	1	1	

4.4. States with lowest / highest solar radiation and differences in gestational age. Solar radiation intensity (and, supposedly, vitamin D levels in blood for pregnant women) appears to have an influence on the average gestational age of stillbirths. Fetuses of mothers in the states with highest solar radiation live, on average, a week longer than in the states with lowest solar radiation. In particular, younger fetuses (20-28 weeks) benefit most from mothers having higher solar exposure (tab. 3). In figure 10 we can see that fetuses between 20 and 24 weeks of gestational age whose mothers live in the states with highest solar radiation represent a lower percentage of all stillbirths compared to the states with lowest solar radiation, independently of race.

4.5. Birth weight. The historical evolution of average birth weight for stillbirths that we can observe in figure 11 is very similar to the evolution we observed in figure 5 in the average gestational age, because there is a direct link between the two variables (the higher the gestational age of the fetus the higher its weight)[4]. Average weights for stillbirths for both races were the same in 1950, but, since then, they have begun to fall, particularly amongst the Black population. This decrease in average weight occurred at the same time as the decrease in gestational age. If the average weight for stillbirths amongst the Black population decreased more than for Whites, it was precisely because the average gestational age did so too.

Hsieh *et al.* (1997, 33) state that the disparity in the crude fetal death rates for

Fig. 9. Non-standardized and standardized fetal death rates (left axis) and Black/White ratio (right axis), US



Blacks and Whites is explained almost entirely by differences in birth weight distribution[5]. Because the terms "birth weight" and "gestational age" are practically interchangeable due to the high correlation between them, the conclusions these authors reached are the same ones we have reached by analyzing gestational age.

Thanks to the information provided in figure 12, we can verify that the decrease in the mean weight of stillbirths among both races observed in figure 11 was indeed

Tab. 3. Average gestational age for stillbirths according to location of the mother's state of residence, US (1982-2019)

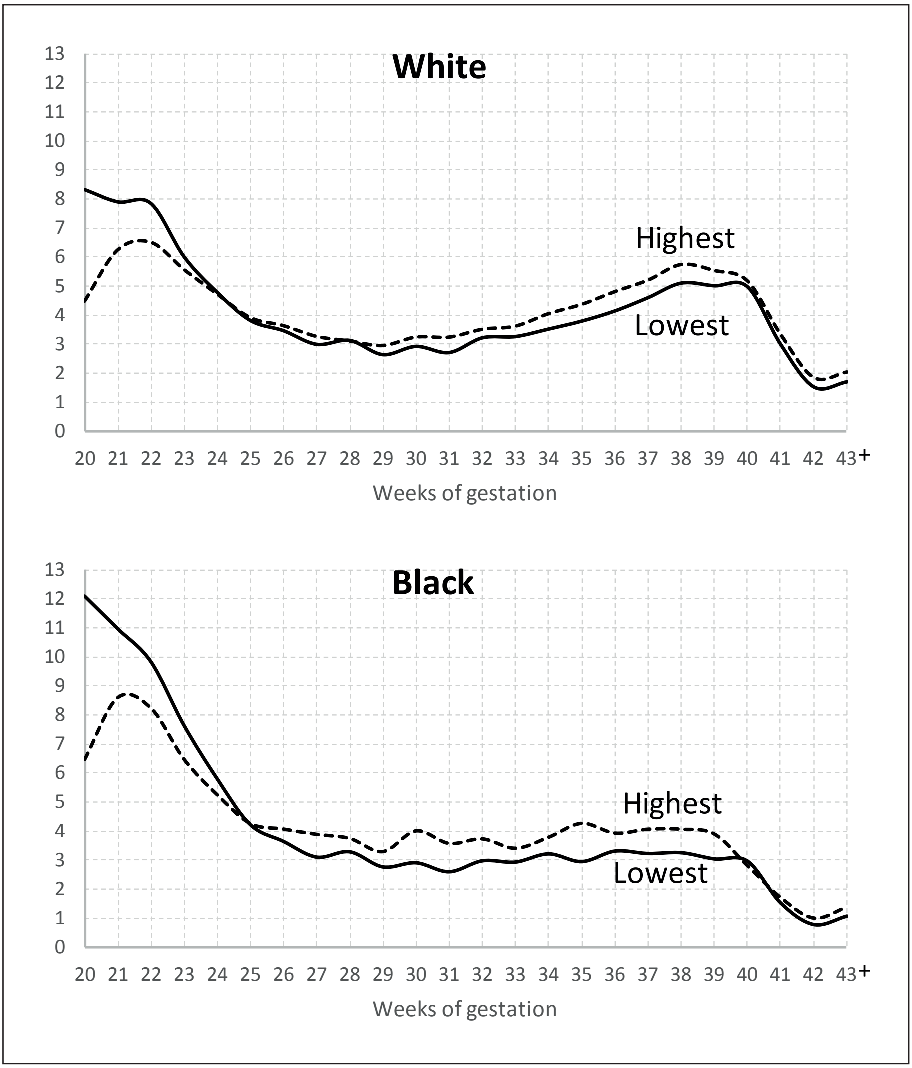
		Period of gestation in weeks			
		20+	20-28	29-36	37+
White	Highest solar radiation states	30.74	23.45	32.84	39.41
	Lowest solar radiation states	29.74	23.02	32.83	39.40
	Difference highest - lowest	**1.00**	**0.43**	**0.01**	**0.01**

		Period of gestation in weeks			
		20+	20-28	29-36	37+
Black	Highest solar radiation states	29.02	23.26	32.62	39.21
	Lowest solar radiation states	27.65	22.75	32.61	39.26
	Difference highest - lowest	**1.37**	**0.51**	**0.01**	**-0.05**

due to a change in the gestational age structure. Improvements in obstetrics have particularly benefited fetuses at more advanced stages of gestation. For this reason, among stillbirths as a whole, those with fewer weeks of gestation represent an increasing percentage, while those with more weeks account for a smaller proportion. Figure 12 shows us that when we control for the gestational age, the mean weight varies very little (it increases slightly in stillbirths at 32-39 weeks of gestation and declines somewhat in the others). Before 36 weeks of gestation, there are no racial differences in the weight of stillbirths. The largest differences are found in stillbirths at 36+ weeks (greater weight in the White population).

In short, there is scarcely any change in the weight of stillbirths according to

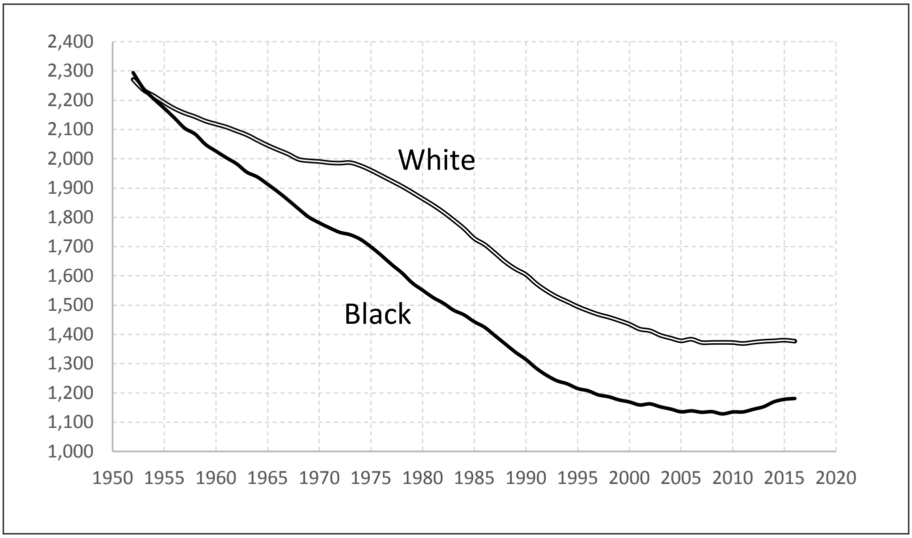
Fig. 10. *Percent distribution of stillbirths by gestational age and according to mother's state of residence (states with highest and lowest solar radiation), US 1982-2004*



gestational age. The declines in the mean weight of stillbirths and the racial differences are due exclusively to variations in the percentage distribution according to gestational age of stillbirths. We can therefore confirm again the conclusions drawn by Hsieh *et al.* (1997).

4.5.1. States with lowest / highest solar radiation and differences in birth weight. Once again, we can observe that the area where the mother lives appears to have a

Fig. 11. *Average stillbirth weight at birth in grams (20+ weeks of gestation), US (5-year-moving-average)*



Note: For the 1950-1981 period we present data for non-Whites instead of for Blacks. We had to estimate average gestational weight for the 1950-1981 period as the available data is grouped in different ranges. These are the average weights which we have taken into account for each of the groups: under 350 g. (275), 350-499 g. (375), 500-999 g. (750), 1,000-1,499 g. (1,250), 1,500-1,999 g. (1,750), 2,000-2,499 g. (2,250), 2,500-2,999 g. (2,750), 3,000-3,499 g. (3,250), 3,500-3,999 g. (3,750), 4,000-4,999 g. (4,250), 4,500-4,999 g. (4,750) and 5,000 g. or more (5,500).

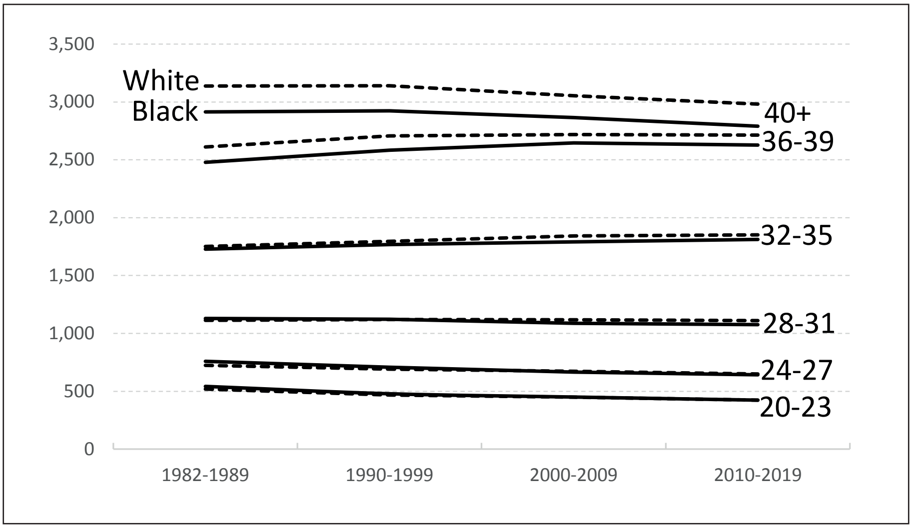
significant influence on stillbirth weight. Preterm stillbirths (under 37 weeks old) of mothers who live in the states with the highest solar radiation are heavier than those living in the states with the lowest solar radiation. This geographical disparity is even more marked amongst the Black population (see tab. 4).

The correlation found in table 4 should not necessarily be interpreted as a sign of causality. More research is needed to establish whether solar radiation is a factor that conditions fetal weight.

4.6. Marital status. For several decades, experts in obstetric care have warned that stress levels in pregnant women can affect the risk of death of children in gestation. A number of authors have detected an increase in fetal deaths when women experience particular events that increase their stress levels (wars, economic crises, massive layoffs, earthquakes, epidemics, famines, Ramadan fasting) (Ruckstuhl *et al.* 2010; Catalano *et al.* 2012; Catalano *et al.* 2013; Grech 2018; Catalano 2021).

We can assume that pregnant women who have the support of a stable partner experience lower stress levels than those facing pregnancy alone. The help a partner can provide to a pregnant woman goes further than any economic support. The

Fig. 12. *Average stillbirth weight at birth in grams (20+ weeks of gestation), US (5-year-moving-average)*



partner can also be of great help in a number of areas (household tasks, shopping and chores) and can provide great psychological support. The sense of security in married pregnant women increases, greatly reducing their uncertainty about how to manage the care and upbringing of the child in the future.

In figure 13, we can see distinct racial differences in the percentage of births that occur outside of marriage. Historically, the percentage amongst the Black population has been 7 to 11 times higher than for the White population. Though this relationship has greatly declined in recent decades, it is still currently more than double.

Luo *et al.* (2004) found that pregnancy outcomes are worse among Canadian mothers in common-law unions versus traditional marriage relationships but better than among mothers living alone. Raatikainen *et al.* (2005) concluded that even in the 1990s, when cohabitation was already common in Finland, pregnancy outside marriage was associated with an overall 20% increase in adverse outcomes, and free maternity care did not eliminate this difference. Balayla *et al.* (2011) found that non-marital childbearing in the United States in the period 1995-2004 seems to be associated with an increased risk of fetal and infant death.

Figure 14 shows the evolution of the FDR in the US by race and mother's marital status. Historically, married women have experienced lower fetal mortality rates when compared to unmarried women, though these differences have greatly declined over time for both racial groups (fig. 15). It is possible that the homogenization of FDR for married and unmarried women is due to the fact that in recent decades, the number of unmarried couples who cohabitate and have children has increased. Women who, without being married, can rely on the support of a stable partner will likely have similar stress levels to married women. If for unmarried

Tab. 4. *Average weight at birth for stillbirths (in grams) according to location of the mother's state of residence, US (1982-2019)*

		Period of gestation in weeks			
		20+	**20-28**	**29-36**	**37+**
White	Highest solar radiation states	1,598.34	611.50	1,706.40	2,921.33
	Lowest solar radiation states	1,520.63	561.29	1,677.22	2,946.57
	Difference highest - lowest	**77.71**	**50.21**	**29.18**	**-25.24**

		Period of gestation in weeks			
		20+	**20-28**	**29-36**	**37+**
Black	Highest solar radiation states	1,317.91	610.99	1,635.53	2,717.27
	Lowest solar radiation states	1,192.42	558.65	1,610.00	2,772.04
	Difference highest - lowest	**125.49**	**52.34**	**25.53**	**-54.77**

women we only took into account those who do not have the support of a partner, likely, the FDR values would not have dropped as much in recent decades.

5. Conclusions

Stillbirths are one of the most common adverse outcomes of pregnancy but also one of the least studied. Despite limitations in official statistics, the compilation of historical data on fetal mortality in the US has been of great utility to achieve an improved perspective on this phenomenon, which has so many consequences for the demographic, health and social environment.

Even if we apply all due precaution when interpreting data from the first half of

Fig. 13. *Percentage of children born outside marriage by race in the US (left axis) and Black/White ratio (right axis)*

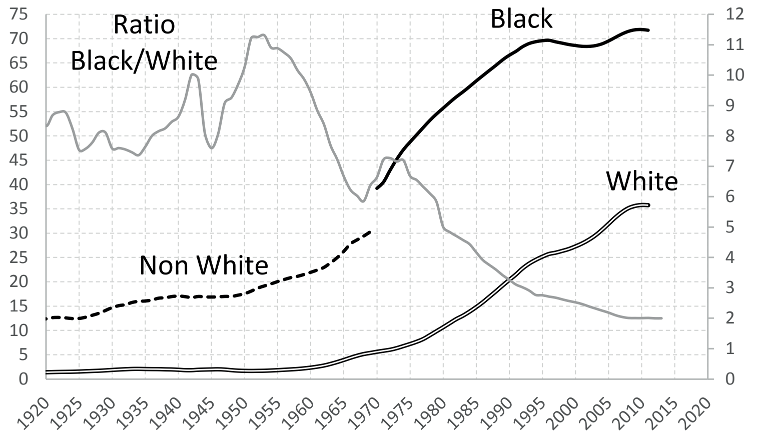
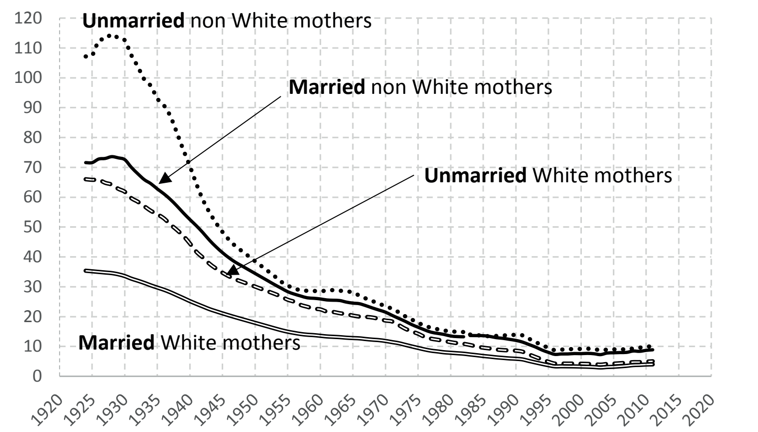


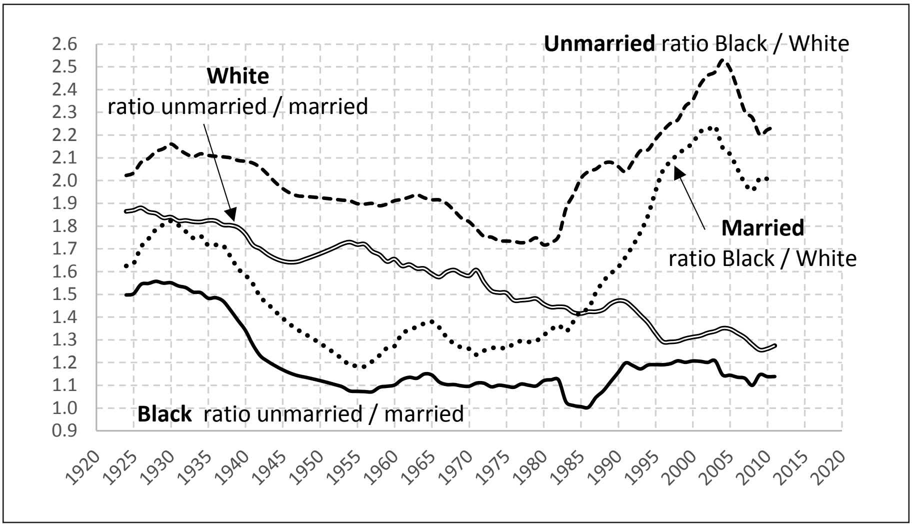
Fig. 14. *Fetal death ratio by race and marital status in the US (5-years-moving-average*



Note: from 1982 onwards data for non-Whites refers to the Black population.

the twentieth century, the historical data points to major differences in fetal mortality found in the US according to the mother's place of residence and marital status. The intensity of solar radiation (and probably its impact on vitamin D levels among pregnant women) seems to be a not inconsiderable factor which might help us to understand the differences between states with lowest and highest solar radiation

Fig. 15. *Ratios of fetal death ratio by race and marital status in the US (5-years-moving-average)*



and between races (given that the Black population requires much more exposure to solar radiation than their White counterparts to produce the same levels of vitamin D).

One major contribution of this paper is that it provides evidence that racial differences in fetal death rates could be explained by the different proportional distribution of births (both dead and alive) according to gestational age or weight at birth.

A further insight afforded by the historical data that is worth mentioning concerns the influence of the mother's marital status on the fetal mortality rate. For both the White and the Black population, the fetal mortality rates are notably higher among unmarried mothers. This confirms the results of other studies carried out in the US and elsewhere.

The purpose of the present study was only to gather historical information about fetal mortality in the US that can help us gain a better understanding of the nature of this important demographic phenomenon and guide us towards new possible lines of research that might allow us to confirm or refute some of the possible hypotheses concerning the reasons for changes in fetal mortality rates raised in this paper. This may, in turn, help us develop public policies intended to reduce both the rates themselves and the differences between races.

The descriptive historical analysis in this paper may serve to guide future researchers concerning the potential research questions that they should try to address in order to confirm or reject possible relations of causality linking specific sociodemographic variables to fetal mortality.

We were not able to analyze other high-risk factors for stillbirths, as we did not have data available on aspects with longer term perspectives required for our analysis, such as behavioral and pre-pregnancy health factors (obesity, smoking), maternal medical disorders (chronic hypertension, pre-gestational diabetes) or pregnancy-linked factors (birth defects, placental abruption, pre-eclampsia).

[1] Historically, the differences between the values for the Black population in relation to the non-White population are small, due to the fact that the former represented a very high proportion of the latter.
[2] Birth and Fetal Death Data Files available at the Vital Statistics Online Data Portal: www.cdc.gov/nchs/data_access/vitalstatsonline.htm.
[3] Demographers and other social scientists have traditionally used the technique of direct standardization to eliminate the compositional effects (of age and sex, for example) from the overall rates (say, crude death rates) in two or more populations (Das Gupta 1993).
The direct standardization that we performed is a procedure that consists of applying the same distribution of births (dead and alive) to both races and observing what their overall fetal death rates would be.
In direct standardization, the distribution of a given population as the "standard population" is used. To do this calculation, we used the standard proportional distribution of births (dead and alive) of all races observed in the US for the 1982-2019 period (see second column in Tab. 2).
Direct standardization serves to answer the following question: what would the overall fetal death rates of the two populations be, if both had the same distribution of births (dead and alive) but maintained their own gestational age-specific mortality rates?
[4] Fetal growth restriction (small-for-gestational age) is also an important risk factor for stillbirth. It may occur as a result of infections, chromosome disorders or structural factors. However, when the gestational age of stillborn children is correlated with their weight, a strong positive relationship is found (0.80, R2 = 0.64, period: 1982-2019).
[5] Hsieh *et al.* (1997) use crude fetal death rate to describe what we call fetal death rate.

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Summary

Descriptive analysis of fetal mortality in the United States: a historical, racial and geographical perspective

Despite being one of pregnancy's most common adverse outcomes, in the United States stillbirths are barely studied, probably due to limitations with sources of reliable information on this demographic phenomenon. The aims of this study are: To compile information on different aspects of fetal mortality in the United States to achieve the long historical perspective that is crucial for secular trend analyses and to examine the biggest differences by race and latitude. We obtained information from 1922 onwards from the annual Vital Statistics reports. We calculated that the disparity in distribution of births (dead and alive) by gestational age almost entirely explains fetal death ratio differences between Black and White populations. Some variables (marital status, age of motherhood, gestational age and stillbirth weight, solar radiation) may explain racial and geographical differences.

Riassunto

Analisi descrittiva della mortalità fetale negli Stati Uniti: una prospettiva storica, di popolazione e geografica

Nonostante rientri tra gli esiti avversi più comuni della gravidanza, la natimortalitá negli Stati Uniti è poco studiata, anche a causa delle limitazioni delle fonti su questo fenomeno demografico. Gli obiettivi di questo studio sono: raccogliere informazioni sui diversi aspetti della mortalità fetale negli Stati Uniti e ottenere una prospettiva storica di lungo periodo indispensabile per le analisi delle tendenze secolari e per meglio comprendere le maggiori differenze per latitudine e popolazione (bianca e nera). Dai rapporti annuali delle statistiche demografiche, abbiamo ottenuto informazioni dall'anno 1922 in avanti. Dai dati in nostro possesso, si evince che la disparità nella distribuzione delle nascite (nati vivi e morti) per età gestazionale spiega, quasi interamente, le differenze nel rapporto di mortalità fetale tra la popolazione bianca e nera. Inoltre variabili come stato civile, età della maternità, età gestazionale e peso dei nati morti e radiazione solare possono spiegare le differenze geografiche così come quelle tra la popolazione bianca e quella nera.

Keywords

Stillbirth; Fetal death ratio; United States; Solar radiation; Racial inequalities; Maternal age; Gestational age; Stillbirth weight.

Parole chiave

Natimortalità; Rapporto di mortalità fetale; Stati Uniti, Radiazione solare; Diseguaglianze; Età della madre; Età gestazionale; Peso dei natimorti.