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Analysis of Feto-Infant Mortality Using the BABIES Framework: Georgia 1981-83 through 2001-03

Abstract

Purpose: To measure changes in Georgia's feto-infant mortality rate (FIMR) from 1981-83 to 2001-03, whether excess feto-infant mortality persists and, if so, to identify interventions to reduce the excess FIMR.
Methods: Using vital records data from Georgia and the BABIES (birth weight and age-at-death boxes for intervention and evaluation system) approach, we calculated the total and excess birthweight proportionate FIMR for non-Hispanic blacks and whites for 1981-83 and 2001-03.
Results: From 1981-83 to 2001-03, the FIMR for non-Hispanic whites and blacks (combined) declined from 24.6 to 10.5 feto-infant deaths per 1,000. For 2001-03, the excess FIMR for blacks was 11.8 compared to 3.6 for whites, with the largest proportion of excess FIMR being attributable to poor women's health status for both groups (56% for blacks, 34% for whites).
Conclusions: Despite a large reduction in Georgia's FIMR from 1981-83 to 2001-03, substantial excess feto-infant mortality persists. The largest proportion of Georgia's excess FIMR was attributable to poor women's health, and was greater for blacks compared to whites. Interventions to improve the health of women prior to pregnancy hold the most promise for further reducing and closing racial gaps in Georgia's FIMR.

Keywords: Health status disparities, Perinatal mortality, Very low birth weight.

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Introduction

Since the 1960's, Georgia's infant mortality rate has placed it among the ten states with the highest rates in the U.S [1]. In an effort to reduce Georgia's high infant mortality, two activities were initiated: (1) In 1966, the State of Georgia initiated one of the first statewide regional maternal and perinatal healthcare delivery systems in the South in order to improve the content, quality, and access to appropriate health care for pregnant women and their infants at all levels of risk; (2) In 1981, the World Health Organization Collaborating Center in Reproductive Health (WHO/CC/RH) in Atlanta was created to investigate Georgia's poor reproductive outcomes and develop a more comprehensive surveillance system to assist in their improvement.

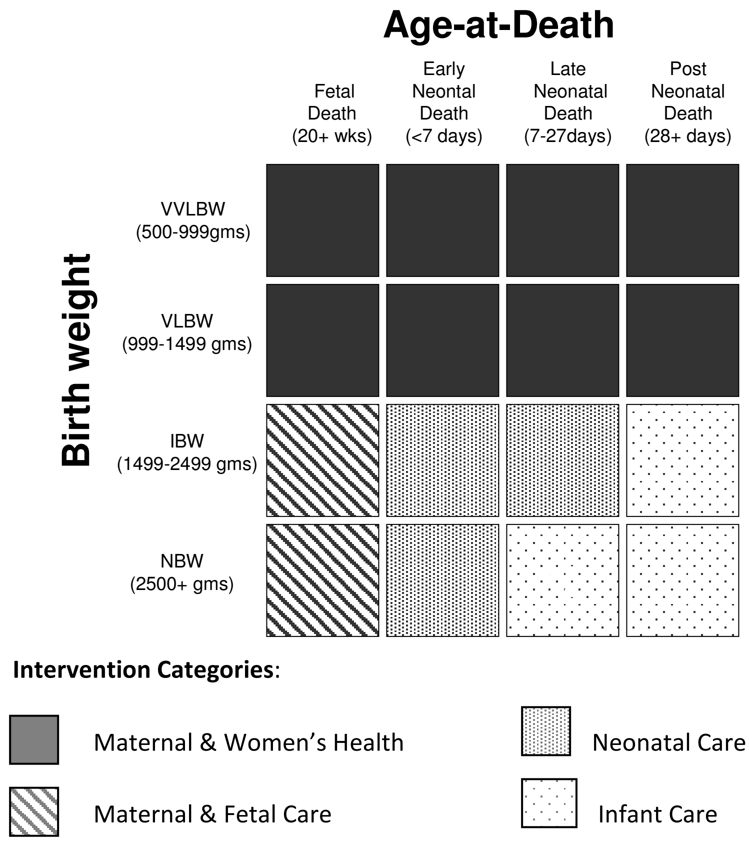
Prior to the 1980's, the State of Georgia monitored reproductive health and pregnancy outcomes using single dimension indicators such as the rates of infant mortality, low birth weight, and teen pregnancy. The WHO/CC/RH recognized that such single dimension indicators were not adequate to generate meaningful information regarding which factors most contribute to infant deaths in a given population [2-4]. In an effort to convert data into information upon which effective interventions could be based, the WHO/CC/RH developed a maternal and perinatal surveillance model – the birthweight and age-at-death boxes for intervention and evaluation system (BABIES) [5] – to accomplish the following: (1) capture the outcomes of all products of conception ≥ 20 weeks' gestation in order to measure feto-infant mortality and identify populations with excess feto-infant mortality; (2) identify intervention categories with the greatest potential for reducing feto-infant mortality for a given population; and (3) form the basis for a transparent program for continuous quality improvement of perinatal care.

The BABIES model maps feto-infant deaths two-dimensionally according to birth weight and age-at-death. Birth weight is critical in defining appropriate interventions for improving feto-infant survival, and age-at-death identifies the clinical period during which interventions should be focused [6]. To more accurately account for all products of conception and to avoid misclassification of deaths (as fetal vs. infant) arising from ill-defined judgment calls at parturition regarding the presence or absence of signs of life, feto-infant mortality rather than infant mortality is used as the mortality measure. The inclusion of fetal deaths addresses the concept of total cohort accountability for the outcomes of pregnancies. Specifically, the lower the recommended gestational age for fetal death registration the greater the overall infant mortality and the ratio of late fetal deaths to live births [7,8]. The World Health Organization recommends that infant mortality statistics include all fetuses and infants weighing at least 500 g.

The BABIES model evolved from methods used to examine for, and determine the causes of, underregistration of neonatal deaths in Georgia during 1974-76 [9] and risk assessment concepts developed at the Centers for Disease Control and Prevention and the Institute for the Care of Mother and Child in Prague [10]. The model is based upon earlier work conducted by the U.S. Department of Health, Education, and Welfare [11]; the National Center for Health Statistics [12]; the Institute of Medicine [13]; and the British Perinatal Mortality Survey [14]. A validation of the model was performed utilizing U.S. fetal death and linked birth and infant death files from 1995-97 to perform cluster analyses according to underlying cause of death and maternal risk factors. Cluster analyses revealed that the grouping of cells in the framework (**Figure 1**) is closely aligned with the grouping created when cells are clustered by cause of death and maternal risk factors and is in accord with the intervention categories that would address the infant deaths in each cell cluster [15].

The BABIES model has been used internationally to prioritize interventions to reduce feto-infant mortality [16] and to identify the underregistration of fetal deaths in the former Soviet Union [17]. Since 1999, the CityMatCH program has used a modified version of this model, the Perinatal Periods of Risk Approach

Figure 1: BABIES Model for Mapping Feto-infant Mortality



(PPOR), to study fetal and infant mortality in selected U.S. cities [18,19].

The objectives for this study were as follows: (1) to measure changes in Georgia's feto-infant mortality rate (FIMR) from 1981-83 to 2001-03; (2) to determine whether excess feto-infant mortality persists and; (3) to use the BABIES model to identify intervention strategies with the potential to result in the largest reduction in Georgia's excess FIMR.

Methods

We used vital records data from the Georgia Department of Human Resources, Division of Public Health to identify feto-infant deaths that occurred from 1981-83 and 2001-03 (inclusive). We included all pregnancy outcomes (fetal deaths and live births) with gestational age ≥ 20 weeks'. The inclusion of pregnancy outcomes ≥ 20 weeks' markedly enhances the accuracy of FIMR estimates of late fetal deaths [7,8]; Georgia is one of only eight states that legally requires a certificate to be recorded for all products of conception regardless of gestational age. Certificates for births in a given year were linked to the corresponding death certificate, even if death occurred in the subsequent year. For fetal deaths, the death certificate was based on the year of delivery.

We used the BABIES model to categorize feto-infant deaths ≥ 20 weeks' gestation according to four levels of birth weight (500-999 g, 1000-1499 g, 1500-2499 g, ≥ 2500 g) and age-at-death (fetal, early neonatal, late neonatal, post-neonatal) creating a 16-cell table (Figure 1). The 16 cells are grouped into four intervention categories known to reduce deaths at that particular birth weight and age-at-death (Figure 1, Table 1). According to the BABIES model, births of very-low-birth weight infants (500-1499 g), regardless of age-at-death, are most closely associated with women's and maternal health issues. Their deaths can best be reduced by increasing infant birth weight through addressing women's and maternal health in the preconception and interconception periods. Deaths to fetuses weighing 1500 g or more can best be reduced by improving access to and quality of maternal/fetal care during the prenatal and/or intrapartum periods. Neonatal deaths to infants weighing 1500 g or more can best be reduced by reducing the frequency of preterm births and improving access to and quality of maternal/fetal and newborn care, while postneonatal deaths can best be reduced by improving access to and quality of infant care.[5]

Table 1: Perinatal health care interventions for feto-infant mortality according to BABIES

Women's & Maternal Health: Family planning and child spacing Preconception & interconception care Early pregnancy identification Nutrition & supplementation Sexually transmitted infections Substance abuse Anticipatory guidance
Maternal & Fetal Care: Early pregnancy identification Prenatal surveillance and care Intrapartum monitoring Surgical services High-risk maternal follow-up "Assessment-Referral-Transfer" for complications
Neonatal Care: Clean delivery Resuscitation Thermal control Breast feeding Baby friendly concept "Assessment-Referral-Transfer" for at-risk infant Parenting skills education
Infant Care: Parenting skill education Child health supervision Community services

We distributed the numbers of feto-infant deaths during the two time periods into 4 x 4 tables defined by the birth weight and age-at-death categories. We regarded those cases in which both birth weight and age-at-death were unknown as 'missing', and these cases were excluded from the analysis. We used rules for imputation for cases in which either birth weight or age-at-death were unknown: fetal deaths of unknown gestational age-at-death and birth weight ≥ 1500 g were regarded as fetal deaths ≥ 20 weeks' gestation and were included in the analysis; fetal deaths ≥ 20 weeks' with unknown birth weight were regarded as fetal deaths 500-1499 grams and were included in the analysis [15].

We constructed separate 4 x 4 tables for non-Hispanic blacks and non-Hispanic whites. For both time periods, the reference standard population (*i.e*, that which achieved the lowest FIMR) was determined to be non-Hispanic white women ≥ 20 years of age with ≥ 13 years of education residing in the Atlanta perinatal region. We constructed a separate 4 x 4 table for this reference standard population to calculate the total reference standard FIMR (determined to be 4.3 per 1,000 total births for the 2001-03 population) and the reference standard FIMR for each intervention category (Table 2).

We calculated the proportionate mortality rate for each of the four intervention categories by dividing the total number of feto-infant deaths in that category by the total number of feto-infant deaths, then multiplying by 1000. To obtain the excess FIMR for each intervention category, we subtracted the proportionate mortality rate for the reference standard population from the proportionate mortality rate for the population of interest. The proportionate mortality rate describes the contribution of a given birth weight and age-at-death category to the total FIMR, and is utilized to estimate the relative contribution that interventions in the birth-related periods (i.e., prenatal, neonatal, postneonatal) could achieve in reducing the total FIMR.

To aid in the interpretation of data, we also calculated the following measures for 1981-83 and 2001-03: (1) the low birth weight (LBW) rate, by dividing the total number of infants with

Table 2: BABIES analysis of reto-infant deaths, Georgia, 1981-83 and 2001-03

Population	Intervention Categories				Total
	Women's & Maternal Health	**Maternal & Fetal Care**	**Neonatal Care**	**Infant Care**	
Reference standard population*					
Number of feto-infant deaths	16	31	60	70	**177**
Feto-infant mortality rate (per 1,000 total births)	2.0	0.4	0.9	1.0	**4.3**
1981-83					
Georgia, blacks & whites					
Number of feto-infant deaths	4,123	1,148	586	1,132	**6,989**
Feto-infant mortality rate (per 1,000 total births)	16.0	4.4	2.3	4.4	**27.0**
Excess feto-infant mortality rate**	14.0	4.0	1.4	3.4	**22.7**
Percent contribution of excess deaths***	61%	18%	6%	15%	
Georgia, blacks					
Number of feto-infant deaths	2,325	507	250	618	**3,700**
Feto-infant mortality rate (per 1,000 total births)	24.4	5.3	2.6	6.5	**38.9**
Excess feto-infant mortality rate**	22.4	4.9	1.7	5.5	**34.6**
Percent contribution of excess deaths***	65%	14%	5%	16%	
Georgia, whites					
Number of feto-infant deaths	1,798	641	336	514	**3,289**
Death rate per 1,000 total births	11.0	3.9	2.1	3.1	**20.1**
Excess feto-infant mortality rate**	9.0	3.5	1.2	2.1	**15.8**
Percent contribution of excess deaths***	57%	22%	8%	13%	
2001-03					
Georgia, blacks & whites					
Number of feto-infant deaths	1,847	685	464	933	**3,929**
Feto-infant mortality rate (per 1,000 total births)	5.0	1.8	1.3	2.5	**10.6**
Excess feto-infant mortality rate**	3.0	1.4	0.4	1.5	**6.3**
Percent contribution of excess deaths***	48%	22%	6%	24%	
Georgia, blacks					
Number of feto-infant deaths	1,067	341	180	407	**1,995**
Feto-infant mortality rate (per 1,000 total births)	8.6	2.8	1.5	3.3	**16.1**
Excess feto-infant mortality rate**	6.6	2.4	0.6	2.3	**11.8**
Percent contribution of excess deaths***	56%	20%	5%	19%	
Georgia, whites					
Number of feto-infant deaths	780	344	284	526	**1,934**
Feto-infant mortality rate (per 1,000 total births)	3.2	1.4	1.2	2.1	**7.8**
Excess feto-infant mortality rate**	1.2	1.0	0.3	1.1	**3.6**
Percent contribution of excess deaths***	34%	28%	8%	30%	

* Reference standard population consists of non-Hispanic white women in Atlanta perinatal region, ≥ 20 yrs of age, ≥ 13 yrs of education.
**Excess feto-infant mortality rate = feto-infant mortality rate for category minute feto-infant mortality rate for reference standard population.
*** Percent contribution of excess deaths = excess feto-infant mortality rate for category divided by total excess

birth weight 500-2499 grams by the total number of births (live births and stillbirths); (2) the very low birth weight (VLBW) rate, by dividing the total number of infants with birth weight 500-1499 grams by the total number of births (live births and stillbirths); (3) the birth weight-specific feto-infant mortality rate for VLBW infants, by dividing the total number of feto-infant deaths for infants with birth weight 500-1499 grams by the total number of births (livebirths and stillbirths) for infants with birth weight 500-1499 grams. The LBW rate, and especially the VLBW rate, primarily reflect the health and economic status of women and maternal or fetal biological factors [20]. Conversely, birthweight-specific mortality rates are associated with gestational age, race, sex, and intrapartum, neonatal, and postneonatal care, and can be used to indicate the quality of medical care received by the mother and infant during these periods [21].

Results

For 1981-83, there were 500 fetal deaths that occurred at an unknown birth weight and gestational age of the 258,464 total birth-fetal death events recorded (0.19% missing), which were excluded from analysis. Additionally, for 1981-83, there were a total of 906 (0.35%) feto-infant deaths in which either birth weight (n = 880) or age-at-death (n = 26) had to be imputed according to the rules described in the Methods section. For 2001-03, there were 452 fetal deaths that occurred at an unknown birth weight and gestational age of the 370,715 total birth-fetal deaths events recorded (0.12% missing), which were excluded from analysis. For 2001-03, there were a total of 282 (0.08%) feto-infant deaths in which either birth weight (n = 280) or age-at-death (n = 2) had to be imputed.

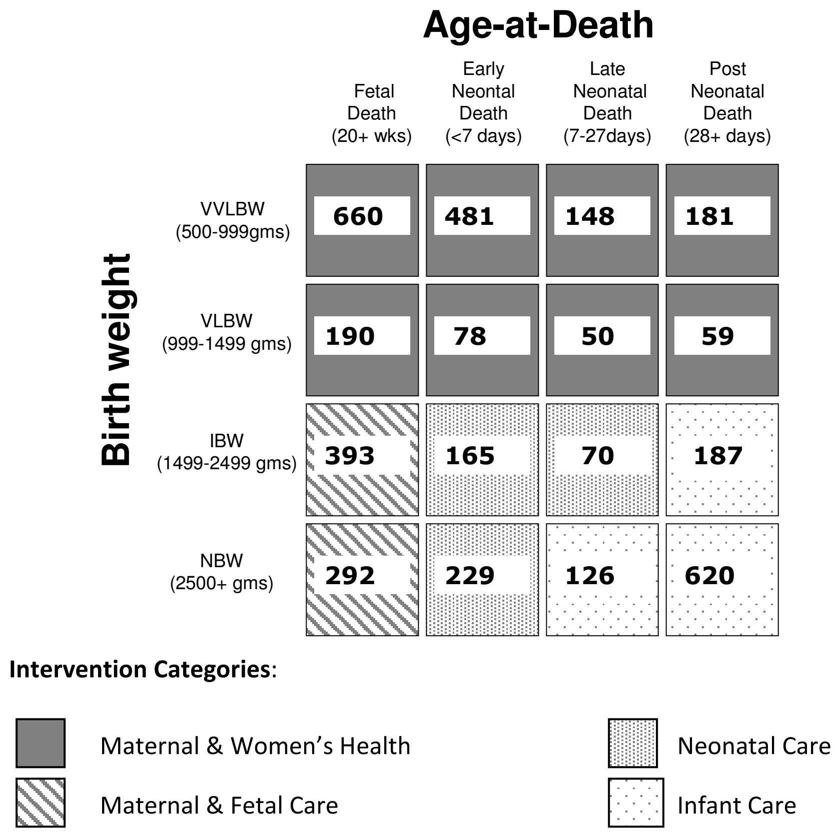
The total FIMR for non-Hispanic blacks and whites combined declined from 27.0 to 10.6 per 1,000 from 1981-83 to 2001-03 (-61%) (**Table 2**). The decline in proportionate feto-infant mortality from 1981-83 to 2001-03 according to the BABIES model was distributed as follows: -69% in Women's and Maternal Health (16.0 to 5.0), -59% in Maternal and Fetal Care (4.4 to 1.8), -44% in Neonatal Care (2.3 to 1.3), and -43% in Infant Care (4.4 to 2.5).

The excess FIMR for Georgia's non-Hispanic blacks and whites combined declined from 22.7 to 6.3 per 1,000 from 1981-83 to 2001-03 (-72%). Despite the greater overall drop in excess FIMR for blacks (34.6 to 11.8 = 22.8; -66%) compared to whites (15.8 to 3.6 = 12.2; -78%) from 1981-83 to 2001-03, the proportionate drop in excess FIMR was smaller for blacks compared to whites.

From 1981-83 to 2001-03, there was an increase in the total number of births and fetal deaths of ≥20 weeks' in Georgia from 257,751 to 322,596. From 1981-83 to 2001-03, there was no change in the overall rate of VLBW births (0.9% for both periods). However, there was a small but significant decline in LBW births (9.6% and 8.9%, $p < 0.0001$). From 1981-83 to 2001-03 the birth weight specific FIMR for infants with birth weight 500-999 grams declined from 860.7 to 474.3 per 1,000 total births (-45%), while the birth weight specific FIMR for infants with birth weight 1000-1499 grams declined from 225.2 to 115.5 per 1,000 total births (-49%).

For 2001-03, the excess FIMR for non-Hispanic whites and blacks combined was 6.3 feto-infant deaths per 1,000 births and was distributed as follows: 48% (3.0/6.3) in Women's and Maternal Health, 24% in the Infant Care category, 22% in the Maternal and Fetal Care category, and 6% in the Neonatal Care category. In stratifying by race, there was a substantial excess FIMR for blacks compared to whites (11.8 vs. 3.6 per 1,000, respectively). The largest proportion of excess FIMR for both groups was attributable to deaths in the Women's and Maternal Health category, with the proportion being substantially greater for blacks compared to whites (56% vs. 34%) (**Table 2**). The smallest proportion of excess FIMR for both groups was attributable to deaths in the Neonatal Care category (5% for blacks, 8% for whites). For blacks, a similar proportion of the excess FIMR was attributable to deaths in the Maternal and Fetal Care and the Infant Care categories (20% and 19%, respectively). Similarly, for whites, a similar proportion of the excess FIMR was attributable to deaths in the Maternal and Fetal Care and the

Figure 2: Number of feto-infant deaths for blacks and whites combined, Georgia 2001-03



Infant Care categories (28% and 30%, respectively).

For 2001-03, 47% (1,847/3,929) of all feto-infant deaths were among those with birth weight < 1500 g (Figure 2), yet these VLBW infants represented only 1.9% (6,084/322,596) of the total births (live births and stillbirths). While for 2001-03, 32.2% (1,267/3,929) of all feto-infant deaths were among those with birth weight ≥2500 g (Figure 2), who comprised 90.7% (292,448/322,596) of total births. Of the feto-infant deaths to those with birth weight ≥2500 g, 49% (620) occurred during the postneonatal period, 23% (292) occurred during the fetal period, 18% (229) occurred during the early neonatal period, and 9.9% (126) occurred during the late neonatal period.

Discussion

This study shows that from 1981-83 through 2001-03, Georgia experienced a substantial reduction in total FIMR. As there was no decline in the overall rate of VLBW births and only a small decline in the rate of LBW births across this period, much of the decline is a result of the significantly reduced mortality among LBW and VLBW infants [22].

These reductions in FIMR both in Georgia [22] and nationally [23] can be attributed to improvements in maternal-fetal and neonatal intensive care in concert with perinatal regionalization [24-27], or the "development within a geographic area of a coordinated, cooperative system of maternal and perinatal health care..." [28], that followed the Committee on Perinatal Health's proposed structure of regional perinatal care published in 1976 [29]. Georgia's statewide regional maternal and perinatal healthcare delivery system was initiated in 1966 with a federally-sponsored, specialized program of reproductive health care at Grady Memorial Hospital for high-risk women. By the early 1970's the system included three state-supported regional level III neonatal centers. By the 1980's, the level III neonatal centers were converted to perinatal centers that included level III maternal-fetal services. Two additional regional level III centers were added in the 1980's and another in the 1990's. Regionalization also involved establishing numerous level II and III perinatal units in private hospitals throughout the state. Prior to regionalization of care, Georgia's documented overall FIMR was 21.2 per 1,000 births with a marked racial disparity (17.0 per 1,000 for whites, and 29.8 per 1,000 for non-whites) [30].

In the U.S., variables related to social class, such as maternal age and educational status, are positively associated with infant survival [31]. From 1981-83 to 2001-03, there was a substantial shift in the demographic characteristics of women giving birth in Georgia that likely also contributed to the reduction in FIMR. For example, there was an approximately 50% increase in the number of births to non-Hispanic white and black women who were ≥ 20 years of age with ≥ 13 years of education and a 20% reduction in the number of births to non-Hispanic black teenagers during this time period [32].

Despite the measured reduction in Georgia's FIMR from 1981-83 to 2001-03, substantial excess feto-infant mortality persists. For blacks, who had a substantially higher excess FIMR compared to whites during 1981-83 (34.6 vs. 15.8 per 1,000) and 2001-03 (11.8 vs. 3.6 per 1,000), the proportionate reduction in FIMR was significantly less than it was for whites. This resulted in a widening of the racial disparity in Georgia's FIMR from 1981-83 through 2001-03 (from a gap of 2.2-fold to 3.3-fold). For both black and white women, the largest proportion of Georgia's excess FIMR for 2001-03 was attributable to feto-infant deaths in the Women's and Maternal Health Category. Furthermore, approximately 65% of the black-white disparity in FIMR was explained by feto-infant deaths in the Women's and Maternal Health category. These findings underscore the impact of the number of VLBW births on Georgia's excess FIMR and the need for the continued support of the regional perinatal centers until there has been a substantial reduction in the VLBW rate.

Furthermore, the excess feto-infant mortality in the Women's and Maternal Health Category underscores the need to improve women's underlying health status *prior* to pregnancy. Since approximately 98% of VLBW births are preterm, this suggests a need to identify strategies for reducing preterm births [33]. Preterm birth is associated with a number of modifiable risk factors including smoking, substance abuse, low rate of weight gain during pregnancy, anemia, urogenital infections, strenuous work, domestic violence, stress, and inadequate prenatal care [34-36]. In addition, preterm birth has been linked to socioeconomic factors, and is more frequent among the disadvantaged [34,37].

Because preterm birth prevention efforts for women at risk have been ineffective [38,39], a population health approach focusing on factors that enhance the well-being of women of reproductive age by addressing five categories of health determinants has been proposed [36]: (1) the social and economic environment; (2) the living and working environment; (3) personal health practices and the conditions that enable and support healthy choices; (4) individual capacity and coping skills; and (5) health services that maintain, promote, and restore health [40]. Specifically, a growing body of evidence links adverse outcomes of pregnancy to women's poor underlying health status prior to pregnancy, including poorly –controlled chronic diseases such as diabetes, hypertension, and thrombophilias [41-43]; short interpregnancy intervals [44]; reproductive tract infections [45-47]; periodontal disease [48]; nutritional deficiencies and disorders [49-51]; substance abuse [52]; and psychosocial conditions and stressors, including depression and domestic violence [53,54]. Empirical support for this approach comes from results of the Grady Interpregnancy Care Program, which found that primary health care and social support for lowincome, African-American women following a very low birth weight delivery may enhance achievement of a subsequent 18-month interpregnancy interval and reduce adverse pregnancy outcomes [55].

Finally, our analysis shows that feto-infant deaths to those with birth weights ≥ 2500 g accounted for one-third of the FIMR for 2001-03, and that nearly half (49%) of these deaths occurred during the postneonatal period. In the absence of a life threatening anomaly, the death of a ≥2500 g fetus or infant should be a rare event if access to standard maternal, neonatal and postneonatal health supervision and care is universally available. Thus, there should be a feto-infant mortality review process to determine a cause-specific diagnosis for deaths in this weight category to identify the most appropriate strategies to reduce these often preventable deaths.

In summary, the number of infants that are born VLBW is the key factor determining the gap between what is and what could be (*i.e.,* the excess FIMR) for Georgia overall and for the observed disparity in FIMR between blacks and whites. Specifically, VLBW births accounted for 47% of all feto-infant mortality yet only 1.9% of total births (live births and stillbirths) or on average only 2,028 total births per year. Thus, according to the BABIES model, public health strategies that improve the health of women *prior to pregnancy* hold the most promise for achieving further reductions in Georgia's overall FIMR and for closing racial gaps. As outlined in Table 1, such strategies might include promotion of family planning and optimal child spacing, preconception and interconception care, appropriate nutrition and supplementation, and screening and treatment for sexually transmitted infections and substance abuse. In addition, postneonatal deaths of infants weighing ≥2500 gm also contribute substantially to Georgia's excess FIMR. Thus, public health strategies, including assignment of a medical home for all infants at discharge, and the enhancement of parenting skills and child health supervision also hold promise for achieving substantial reductions in Georgia's excess FIMR.

Application of the BABIES method is limited by the percentage of missing data. When there are no more than 10% missing data for both birth weight and gestational age for feto-infant deaths or when greater than 10% of birth weight and/or gestational ages must be imputed, the technique is considered invalid [13]. The data used in this study was sufficiently complete (much less than 10% missing or imputed data) rendering the method valid. A final limitation relates to the fact that the conceptual framework employed is chiefly a framework for surveillance to help guide policy development and allocation of resources. Results should be followed up with in-depth analysis of the underlying causes for excess deaths in each category and an assessment of the prevalence of known risk factors and interventions by specific causes of death [10] to provide direction for program planning and policy making.

Conflict of Interest

No conflicts of interest are associated with this work.

Contribution of Authors

We declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. Drs Brian McCarthy and Alfred Brann conceived and designed the study. Dr Dunlop was principally responsible for carrying out the data analysis for this study, with the support of Mr Freymann, Mr Smith, and Dr Bugg. Dr Dunlop was principally responsible for authoring the manuscript with support from all co-authors.

References

1. Mathews TJ, Curtin SC, MacDorman MF. Infant mortality statistics from the 1998 period linked birth/infant death data set. National Vital Statistics Report 2000; 48(12):1-26.
2. Herrera LR, Kakehashi M. An international data analysis on the level of maternal and child health relation to socioeconomic factors. Hiroshima J Med Sci 2001; 50:9-16.

3. Richardus JH, Graafmans WC, Verloove-Vanhorick SP, Mackenback JP. The perinatal mortality rate as an indicator of quality of care in international comparisons. Med Care 1998; 36: 54-66.
4. Murray CJ. The infant mortality rate, life expectancy at birth, and a linear index of mortality as measures of general health status. Int J Epidemiol 1988; 17: 122-8.
5. Lawn J, McCarthy B, Ross SR. The Healthy Newborn: a reference manual for program managers. Atlanta, GA: CDC CARE Collaborative Health Initiative (CCHI), 2001. www.cdc.gov/nccdphp/drh.
6. Sappenfield W, Peck M. WHO Perinatal Periods of Risk Approach: The U.S. Urban Experience. Abstract (p.63) and presentation materials from the 1999 Maternal, Infant, and Child Health Epidemiology Workshop: Building Data Capacity in Maternal and Child Health, Dec. 8-9, 1999, Atlanta, GA. Atlanta: Centers for Disease Control and Prevention, 1999.
7. Evans, S. and Alberman, E.: International Collaborative Effort (ICE) on Birthweight; Plurality; and Perinatal and Infant Mortality: Comparisons Between Birthweight Distributions of Births in Member Countries from 1970 to 1984. Acta Obstet Gynecol Scand 1989;68:11-17,
8. Howell EM, Blondel B. International infant mortality rates: Bias from reporting differences. Am J Public Health 1994; 84(5): 850-2.
9. McCarthy BJ, Terry J, Rochat RW, Quave S, Tyler CW. The underregistration of neonatal deaths: Georgia 1974-77. Am J Public Health 1980; 70(9): 977-82.
10. World Health Organization. Risk approach for maternal and child health care. A managerial strategy to improve the coverage and quality of maternal and child health/family planning services based on the measurement of individual and community risk. Geneva, Switzerland, WHO, 1978, 42 p. (WHO Offset Publication No. 39).
11. Vital Statistics of the United States, 1960, Vol. 1, Natality, U.S. Department of Health, Education, and Welfare.
12. Department of Health, Education, and Welfare: a study of infant mortality from linked records. NCHS Report, Series 20, No. 12, May 1972.
13. Institute of Medicine, Panel on Health Services Research: Infant Death: An analysis of maternal risk and health care. Washington, DC, National Academy of Sciences, IOM, 1973.
14. Butler NR, Alberman ED. Perinatal Problems: The Second Report of the British Perinatal Mortality Survey. Williams & Wilkins, 1970.
15. Centers for Disease Control and Prevention. Perinatal Periods of Risk Analysis: using local, state, and national data. Centers for Disease Control and Prevention Maternal Child Health Epidemiology Webcast, November 14, 2003. Transcript available at: http://128.248.232.90/archives/cdc/mchepi/november2003/mchepinovember2003_transcript.pdf. Accessed November 11, 2007.
16. Kilonzo A, Kouletio M, Whitehead SJ, Curtis KM, McCarthy BJ. Improving surveillance for maternal and perinatal health in two districts of rural Tanzania. Am J Public Health 2001; 91(10): 1636-40.
17. Wuhib T, McCarthy BJ, Chorba T, Sinitsina TA, Ivasiv IV, McNabb SJ. Underestimation of infant mortality rates in one republic of the former Soviet Union. Pediatrics 2003; 111(5): e596-600.
18. Sappenfield W, Peck M. WHO Perinatal Periods of Risk Approach: The U.S. Urban Experience. Abstract (p.63) and presentation materials from the 1999 Maternal, Infant, and Child Health Epidemiology Workshop: Building Data Capacity in Maternal and Child Health, Dec. 8-9, 1999, Atlanta, GA. Atlanta: Centers for Disease Control and Prevention, 1999.
19. CityMatCH. Perinatal Periods of Risk Approach. Available from http://www.citymatch.org/ppor_index.php. Accessed November 7, 2007.
20. WHO Collaborating Center in Perinatal Care and Health Service Research in Maternal and Child Care. Unintended pregnancy and infant mortality/morbidity. In RW Amler, HB Dull (eds). Closing the gap: the burden of unnecessary illness. New York: Oxford University Press, 1987.
21. Lee K, Paneth N, Gartner LM, Pearlman MA, Gruss L. Neonatal mortality: an analysis of the recent improvements in the United States. Am J Public Health 1980; 70:15-21.
22. Georgia Perinatal Task Force. Georgia Perinatal Task Force Report on the regional perinatal health care delivery system – assessment and recommendations. World Health Organization Collaborating Center in Reproductive Health: Atlanta, Georgia, 1998.
23. Meadow W, Lee G, Lin K, Lantos J. Changes in mortality for extremely low birth weight infants in the 1990s: implications for treatment decisions and resource use. Pediatrics 2004; 113: 1223-9.
24. Guidelines for Perinatal Care. 34d ed. Elk Grove Village, IL, and Washington, DC: American Academy of Pediatrics and American College of Obstetricians and Gynecologists; 1993.
25. McCormick MC, Shapiro S, Starfield BH. The regionalization of perinatal services: summary of the evaluation of a national demonstration program. JAMA 1985; 253:799-804.
26. US Office of Technology Assessment. Neonatal Intensive Care for Low-Birthweight Infants: Costs and Effectiveness. Washington, DC: US Congress; 1987. Publication (OTA/HCS) 38.
27. Sinclair JC, Torance GW, Boyle MH, Horwood SP, Saigal S, Sackett DL. Evaluation of neonatal intensive care program. N Engl J Med 1981; 305:489-94.
28. Little GA, Merenstein GB. Toward improving the outcome of pregnancy, 1993: perinatal regionalization revisited. Pediatrics 1993; 92: 611-12.

29. Committee on Perinatal Health. Toward Improving the Outcome of Pregnancy: Recommendations for the regional development of maternal and perinatal health services. White Plains: NEW: The National Foundation of the March of Dimes; 1976.
30. Georgia Department of Human Resources, Division of Public Health. Summary report of Georgia vital and morbidity statistics. Georgia Department of Human Resources: Atlanta, Georgia, 1970, 1971, 1972.
31. Hogue CJR, Hargraves MA. Class, race, and infant mortality in the United States. Am J Public Health 1993; 83(1): 9-12.
32. Georgia Perinatal Healthcare Delivery System Report. World Health Organization Collaborating Center in Reproductive Health: Atlanta, Georgia, 2007.
33. U.S. Public Health Service, Healthy People 2010, Conference Edition. Chapter 16: Maternal, Infant, and Child Health. Washington, DC: U.S. Department of Health and Human Services, 1999.
34. Kramer M, Seguin L, Lydon J, Goulet L. Socioeconomic disparities in pregnancy outcome: Why do the poor fare so poorly? Paediatr Perinat Epidemiol 2000; 14: 194-210.
35. Berkowitz G, Papiernik E. Epidemiology of preterm birth. Epidemiol Rev 1993; 15: 414-43.
36. Heaman M, Sprague A, Stewart P. Reducing the preterm birth rate: a population health strategy. J Obstet Gynecol Neonat Nurs 2001; 30: 20-29.
37. Kogan M. Social causes of low birthweight. J Royal Society Med 1995; 88: 611-15.
38. Hueston W, Knox M, Eilers G, Pauwels J, Lonsdorf D. The effectiveness of preterm birth prevention educational programs for high-risk women: a meta-analysis. Obstet Gynecol 1995; 86: 705-12.
39. Moutquin J, Milot-Roy V, Irion O. Preterm birth prevention: effectiveness of current strategies. J Society Obstet Gynaecol Canada 1996; 18: 571-88.
40. Federal, Provincial and Territorial Advisory Committee on Population Health 1994. Strategies for population health: Investing in the health of Canadians. Ottawa: Health Canada.
41. Kovilam O, Khoury J, Miodovnik M, Chames M, Spinnota J, et al. Spontaneous preterm delivery in the type 1 diabetic pregnancy: the role of glycemic control. J Matern Fetal Neonatal Med 2002; 11: 245-48.
42. Sibai B, Caritis SN, Hauth JC, MacPherson C, VanDorsten JP, et al. Preterm delivery in women with pregestational diabetes mellitus or chronic hypertension relative to women with uncomplicated pregnancies. Am J Obstet Gynecol 2000; 183: 1520-4.
43. Lockwood CJ. Heritable coagulopathies in pregnancy. Obstet Gynecol Surv 1999; 54: 754-759.
44. Conde-Agudelo A, Rosas-Bermudez A, Kafury-Goeta A. Birth spacing and risk of adverse perinatal outcomes: a meta-analysis. JAMA 2006; 295: 1809-23.
45. Centers for Disease Control and Prevention. Sexually transmitted diseases treatment guidelines, 2006. MMWR Morb Mortal Wkly Rep 2006; 55(No. RR-11): 1-100.
46. Kurki T, Sivonen A, Renkonen OV, Savia E, Ylikorkala O. Bacterial vaginosis in early pregnancy and pregnancy outcome. Obstet Gynecol 1992; 80(2): 173-7.
47. Gravett MG, Nelson HP, DeRouen T, Critchlow C, Eschenbach DA, Holmes KK. Independent associations of bacterial vaginosis and Chlamydia trachomatis infection with adverse pregnancy outcome. JAMA 1986; 256(14):1899-1903.
48. Offenbacher, S.; Lieff, S.; Boggess, K. A.; Murtha, A. P.; Madianos, P. N. et al. Maternal periodontitis and prematurity. Part I: Obstetric outcome of prematurity and growth restriction. Ann Periodontol 2001; 6: 164-174.
49. Scholl, T. O.; Johnson, W. G. Folic acid: influence on the outcome of pregnancy. Am J Clin Nutr 2000;71: 1295-1303.
50. Xiong, X.; Buekens, P.; Alexander, S.; Demianczuk, N.; Wollast, E. Aneima during pregnancy and birth outcome: a meta-analysis. Am J Perinatol 2000; 17: 137-146.
51. Cnattingius, S.; Bergstrom, R.; Lipworth, L.; Kramer, M. S. Pre-pregnancy weight and the risk of adverse pregnancy outcomes. N Engl J Med 1998; 338: 147-152.
52. Kelly, R. H.; Russo, J.; Holt, V. L.; Danielsen, B. H.; Zatzick, D. F. et al. Psychiatric and substance use disorders as risk factors for low birth weight and preterm delivery. Obstet Gynecol 2002; 100: 297-304.
53. Centers for Disease Control and Prevention. Alcohol Consumption Among Women Who Are Pregnant or Who Might Become Pregnant --- United States, 2002. MMWR Morb Mortal Wkly Rep 2004; 53: 1178-1181.
54. Janssen PA, Holt VL, Sugg NK, Emanuel I, Critchlow CM, Henderson AD. Intimate partner violence and adverse pregnancy outcomes: A population-based study. Am J Obstet Gynecol 2003; 188: 1341-7.
55. Dunlop AL, Dubin C, Raynor B, Bugg G, Schmotzer B, Brann AW. Interpregnancy primary care and social support for African-American women at risk for recurrent very-low-birthweight delivery: a pilot evaluation. Matern Child Health J 2008; 12(4): 461-8.