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Developing a Maternally Linked Birth Dataset to Study the Generational Recurrence of Low Birthweight in Virginia

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Abstract This paper examined the generational recurrence of low birthweight (LBW) among first-born singletons using a statewide maternally-linked birth dataset. An intergenerational dataset was created by linking 2005–2009 to 1960–1997 Virginia resident live birth data. Maternal information from the recent birth cohort was linked to infant information in the historic birth file using various combinations of mother's name and birthdate. The linked dataset contained 170,624 records (87 % of all eligible records). The analysis dataset was limited to non-Hispanic black and non-Hispanic white first-born singleton infants linked to their mother's own birth record ($n = 69{,}702$). Maternal birthweight was a significant predictor of LBW for first-born singletons. The birthweight distribution for both non-Hispanic black and non-Hispanic white infants was shifted toward lower birthweights for infants whose mothers were born LBW. Even after adjusting for known maternal risk factors in the current pregnancy, non-Hispanic black (AOR = 1.6 [95 % CI 1.4, 1.8]) and non-Hispanic white (AOR = 2.0 [95 % CI 1.8, 2.3]) infants had increased odds of being born LBW if their mother was born LBW. A mother's early life experiences can impact the health of her children. These findings underscore the importance of applying a life course perspective to the prevention of LBW. Routine linkage of maternal and infant birth data is needed to strengthen the evidence base for policies and programs that address issues affecting maternal and child health throughout the life course.

Keywords Intergenerational factors · Low birthweight · Life course · Data linkage

Introduction

Low birthweight (LBW, <2,500 g) and its principal antecedent, preterm delivery (<37 completed weeks gestation), are the leading causes of infant mortality [1] and contribute substantially to the overall burden of childhood disability in developed countries [2]. The United States has experienced a substantial increase in preterm/LBW births over the past 30 years, with over 524,000 infants (or 12.3 % of all live births) born preterm in 2008 [3]. Some of this trend is attributed to a corresponding increase in the rate of multiple births, but the LBW rate has also been increasing among singleton births [4]. Historically, African-American women have experienced much higher rates of adverse birth outcomes compared to other racial/ethnic groups. For example, despite recent improvements, the proportion of infants born LBW in the US among non-Hispanic black women (11.4 %) was more than double that of non-Hispanic white women (5.2 %) in 2009 [5]. These differences have persisted even after controlling for sociodemographic and biomedical factors [6–9].

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A number of studies analyzing international population registers have documented a positive correlation between mother and infant birthweight [10–12]. More recently, the generational recurrence of LBW has been studied in the US using state Vital Records data. Emanuel et al. [13] linked a statewide database of vital records and hospital discharge data covering 1987–1995 births to the birth certificates of mothers born in the state of Washington ($n = 38{,}513$). Maternal LBW was associated with a 1.99 and 1.44 increased risk for infant LBW among white and black mothers, respectively.

The Illinois transgenerational birth file (ITBF) consists of births in Illinois from 1989 to 1991 linked to mothers and fathers born in Illinois between 1956 and 1976, resulting in an infant-mother match rate of 78 % ($n = 267{,}303$) [14]. Using a subset of the ITBF containing both fathers and mothers linked to infants ($n = 128{,}152$), Coutinho et al. [15] found that LBW rates for infants born to LBW mothers were 1.7 and 1.8 times that of infants born to normal birthweight mothers, among white and black women, respectively. Collins et al. [16] also utilized the ITBF to explore the relationship between maternal birthweight, prenatal care usage and infant birthweight. Maternal LBW was an independent risk factor for infant LBW, even after controlling for adequacy of prenatal care, maternal age, and maternal education. The authors reported that 4.1 % of LBW white and 10.9 % of LBW black infants' birthweight status was attributable to maternal LBW.

The Illinois and Washington intergenerational datasets have provided insight into the overall relationship between mother and infant birthweight in the US. However, the studies involve birth cohorts born 17–25 years ago and combined all births, regardless of parity. Due to the available years of vital records data, the ITBF was restricted to mothers 35 years of age and younger. The purpose of the current study is to investigate the association between maternal and infant birthweight among singleton first births using a larger, more recent population-based intergenerationally linked dataset that includes statewide data across the entire childbearing age range.

Methods

Creating the Virginia Intergenerational Linked Birth File

The Virginia Intergenerational Linked Birth File was created by linking maternal information from recent birth cohort (2005–2009 Virginia resident live birth certificate data) to infant information from Virginia resident live birth certificate data from 1960 to 1997. As an initial step, we had to standardize coding for variables that underwent changes in data collection across revisions of the birth certificate (e.g., birthweights recorded in pounds and ounces were converted to grams). Since this was a linkage involving only Virginia data dating back to 1960, the index cohort of 2005–2009 Virginia resident births was limited to records that indicated that the mother was born in Virginia between 1960 and 1997 ($n = 200{,}122$; 37.7 % of all 2005–2009 resident live births). Birth records were also removed from the index file if any key linking field (first name, middle initial, last name; month, day, and year birth) was missing ($n = 4{,}095$). Based on these criteria, 196,027 infants (36.9 % of the total 2005–2009 birth population) were eligible for linkage.

Data elements used for linkage were exported into Microsoft Access 2003 and linked using a customized application based on methodology described by Mason and Tu [17]. Infant and maternal birth records were linked using full or partial combinations of the mother's maiden name and exact or approximate date of birth. Once a record was linked, it was removed from subsequent iterations. The majority (76 %) of the 170,624 total matches were identified in the first iteration, an exact link on the mother's maiden name, first name, middle name, and date of birth. An additional 21 % were linked on mother's first and maiden name, middle initial, and date of birth. The remaining linkages, which were subjected to visual confirmation, were obtained through (1) partial maternal first name (first 4 letters), middle initial, and exact maiden name and birth date or (2) partial (first 4 letters) maternal first and maiden names, middle initial, and approximate (± 1 day) birth date (see Table 1).

The overall linkage rate across the six sets of linkage iterations was 87.0 % of eligible infants. The final Virginia Intergenerational Birth File contained 170,624 births to 136,021 mothers aged 11–48 years. Births not eligible for matching were primarily by foreign-born mothers and mothers born outside of Virginia (99 % of ineligible records). Linkage rates were comparable across maternal race/ethnicity (89.3, 82.1, and 76.4 % for non-Hispanic white, non-Hispanic black, and Hispanic mothers, respectively) and maternal birth years from 1965 to 1996 (ranging from 83.3 to 90.3 %). The average match rate among mothers born from 1960 to 1964 was lower (58.7 %) and ranged from 53.9 to 65.9 %.

Selected characteristics of all births, births eligible for linkage, linked mother-infant pairs, and non-linked pairs are presented in Table 2. The most striking difference was found for Hispanic ethnicity. Despite comprising 13.3 % of all 2005–2009 Virginia resident live births, <1 % of births eligible for linkage were to mothers reporting Hispanic ethnicity. This was due in large part to the fact that the Hispanic population Virginia has grown dramatically over

Table 1 Deterministic linkage criteria used to create the Virginia Intergenerational Birth File

Iteration	Infant birth record linkage field	Maternal birth record linkage field	Special requirement[a]	Number of matches (% of total matches)
1	Mom first	Child first		129,715 (76.0)
	Mom middle	Child middle		
	Mom maiden	Child last	If multiple surnames, cross link the first 2 surnames[b]	
	Mom DOB	Child DOB[c]		
2	Mom first	Child first		36,227 (21.2)
	Mom middle	Child middle	First letter	
	Mom maiden	Child last	If multiple surnames, cross link the first 2 surnames[b]	
	Mom DOB	Child DOB		
3	Mom first	Child first		1,096 (0.6)
	Mom maiden	Child last	If multiple surnames, cross link the first 2 surnames[b]	
	Mom DOB	Child DOB		
4	Mom first	Child first	First 4 letters	2,827 (1.7)
	Mom maiden	Child last		
	Mom DOB	Child DOB		
	Mom middle	Child middle	First letter	
5	Mom first	Child first		517 (0.3)
	Mom maiden	Child last	First 4 letters	
	Mom DOB	Child DOB		
	Mom middle	Child middle	First letter	
6	Mom first	Child first		242 (0.1)
	Mom Maiden	Child last		
	Mom DOB	Child DOB	±1 day	
	Mom middle	Child middle	First letter	

[a] Unless otherwise noted, matches required an exact match on the complete variable

[b] When multiple surnames were encountered, they were first linked using the entire name, then the first two surnames listed were saved in new fields use in separate linkage iterations

[c] Date of birth

the past two decades, including a large influx of Latino immigrants from Central and South America [18] who have not resided in the state for two generations and were not eligible for this linkage. When compared to all births, eligible births were more likely to be to mothers who were non-Hispanic, 25 years of age and older, and had 12 years of education or less. Among those who were eligible, linked births were more likely to be to mothers who were non-Hispanic white, 25–29 years old, and had >12 years of education. Consistent with these sociodemographic differences, LBW and preterm rates among linked births were slightly lower than the rates among unlinked births.

Analysis Dataset

Next we prepared an analysis dataset to investigate the generational recurrence of LBW. Because of our interest in studying intergenerational risks for LBW present at the time of a woman's first pregnancy, the analysis dataset was limited to first-born singleton events. Since only a small fraction of the Hispanic population in Virginia was eligible for linkage, they were not included in the current investigation.

Birthweight and gestational age fields were cleaned for both the infant and maternal generations. Birthweights <400 or >6,000 g were deemed invalid and flagged accordingly. Additionally, implausible birthweight-gestational age combinations were identified using the methods employed by Emanuel et al. [13]. The gestational age distribution of infants of the same race/ethnicity and sex were compared within 250-g birthweight intervals. Birth records with gestational ages more than 2.5 standard deviations away from the mean gestational age of infants within the same sex, race/ethnicity, and birthweight group were deemed implausible. In total, 2,211 record pairs (3.0 % of the intergenerational linked dataset) contained missing or invalid values for gestation or birthweight on the infant data, maternal data, or both. Since this was such a small fraction of the total dataset and birthweight was both the key predictor and outcome in this analysis, these 2,221 records were dropped.

Table 2 Selected characteristics of all births, births eligible for linkage, linked and unlinked births, and analysis sample

	All births $n = 530{,}936$ %	Eligible births[a] $n = 196{,}027$ %	Linked births[b] $n = 170{,}624$ %	Eligible, not linked $n = 25{,}403$ %	Linked versus unlinked comparison χ^2	Analysis sample $n = 69{,}702$ %
Race/ethnicity						
White, non-Hispanic	57.47	65.56	67.46	52.79	2,147.8[c]	70.05
Black, non-Hispanic	21.56	32.44	30.71	44.10		29.95
Hispanic, any race	13.23	1.07	0.96	1.81		–
Other, non-Hispanic	7.67	0.91	0.86	1.25		–
Missing/unknown	0.06	0.02	0.01	0.04		–
Maternal age						
<19 years	4.77	8.12	7.98	9.07	693.2[c]	15.59
19–24 years	27.10	36.45	35.62	42.01		43.83
25–34 years	51.71	45.39	46.40	38.61		35.45
35–44 years	16.14	9.98	9.96	10.09		5.11
45+ years	0.20	0.06	0.04	0.22		0.02
Missing/unknown	0.09	–	–	–		–
Maternal education						
<12 years	14.49	15.53	15.21	17.68	550.1[c]	14.67
12 years	30.30	40.47	39.79	45.04		39.99
>12 years	53.60	43.36	44.38	36.55		44.60
Missing/unknown	1.61	0.64	0.62	0.73		0.74
Method of payment						
Medicaid	25.56	36.82	35.81	43.61	698.3[c]	35.04
Private insurance	65.19	59.66	60.78	52.17		61.83
Self-pay	6.10	2.93	2.87	3.35		2.61
Missing/unknown	3.15	0.59	0.55	0.88		0.52
Tobacco use						
Yes	6.39	11.10	10.99	11.88	17.7[c]	8.87
No	93.61	88.90	89.01	88.12		91.13
Missing/unknown	0.01	–	–	–		–
Adequacy of prenatal care index						
Inadequate	10.32	9.45	9.19	11.23	143.9[c]	8.20
Intermediate	10.89	8.53	8.44	9.14		8.97
Adequate	47.84	48.14	48.46	45.94		51.06
Adequate plus	29.52	33.22	33.26	32.94		31.15
Missing/unknown	1.43	0.66	0.65	0.75		0.62
Birthweight						
<2,500 g	8.27	9.71	9.58	10.58	25.7[c]	8.77
2,500+ g	91.56	90.15	90.29	89.22		91.23
Missing/unknown	0.17	0.14	0.13	0.20		–
Gestational age						
<37 weeks	10.55	11.66	11.52	12.55	22.7[c]	8.88
37+ weeks	89.43	88.33	88.46	87.42		91.12
Missing/unknown	0.03	0.02	0.02	0.03		–

[a] Eligible births met the following criteria: mother born in Virginia between 1960 and 1997 and her complete maiden name and birth date was reported on the infant's certificate

[b] Linkage rate was computed as the number of linked infants divided by the number of infants eligible for linkage

[c] χ^2 test significant at the $p < 0.0001$ level

Table 3 Linkage success of infant and maternal birth records—Virginia, 2005–2009

	Number of records	% of previous line	% of all 2005–2009 live births
All Virginia resident live births 2005–2009	530,936	–	100.0
Intergenerational linked dataset			
Mothers born in Virginia	204,591	38.5	38.5
And mother born in 1960–1997	200,122	97.8	37.7
And complete maternal name and valid maternal birth date listed on infant birth certificate	196,027	98.0	36.9
And linked to 1960–1997 maternal birth certificate (complete Virginia Intergenerational Birth File)	170,624	87.0	32.1
Analysis dataset			
And first-born singleton born to non-Hispanic black or non-Hispanic white mother	71,913	40.9	13.1
And valid gestational age and birth weight for both maternal and infant (dataset used for analysis)	69,702	40.9	13.1

The final analysis dataset for the current study included the 69,702 linked mother-infant pairs where the infant was a first-born singleton birth between 2005 and 2009 to a mother aged 11–48 years who reported non-Hispanic black or non-Hispanic white race/ethnicity (see Table 3). Preliminary analyses indicated that race/ethnicity was an effect modifier of the association between maternal and infant LBW, therefore, all analyses were reported for non-Hispanic black and non-Hispanic white mothers separately.

To quantify the independent effect of maternal LBW on infant LBW we first examined mean birthweights and the birthweight distribution among black and white mothers stratified by their own LBW status. Second, we computed a series of multiple logistic regression models in SAS Version 9.2 to examine the crude and adjusted association between maternal LBW and infant LBW. Maternal factors known to be associated with LBW (maternal education, age at delivery, marital status, insurance status, adequacy of prenatal care index, and smoking during pregnancy) were treated as potential confounders and included in the final adjusted logistic regression model. To assess the public health relevance of maternal LBW on infant LBW, we computed the unadjusted population attributable risk (PAR) percentage.

Results

Table 4 presents data on the association between maternal LBW and infant birthweight. Compared to normal birthweight mothers, mean birthweights for infants born to LBW mothers were 174 g and 196 g lower among non-Hispanic black and non-Hispanic white mothers, respectively. Normal birthweight non-Hispanic black mothers had a mean infant birthweight 248 g lower than normal birthweight non-Hispanic white mothers. Similarly, the white-black difference among LBW mothers was 226 g.

Table 4 Infant birthweight among first-born singleton births by maternal race/ethnicity and maternal birthweight group

	N	Mean infant birthweight (g) (95 % CI)[c]	Infant LBW[d] %	Crude odds ratio (95 % CI)[c]	Adjusted odds ratio[e] (95 % CI)[c]
Non-Hispanic black mothers					
LBW[a]	2,481	2,892 (2,867, 2,917)	18.8	1.65 (1.47, 1.84)	1.60 (1.42, 1.79)
NBW[b]	18,397	3,066 (3,057, 3,075)	12.3	1.0	1.0
Non-Hispanic white mothers					
LBW[a]	2,645	3,118 (3,094, 3,143)	12.8	2.09 (1.85, 2.35)	2.03 (1.78, 2.30)
NBW[b]	46,179	3,314 (3,308, 3,319)	6.6	1.0	1.0

[a] Maternal low birthweight (<2,500 g)

[b] Maternal normal birthweight (2,500+ g)

[c] 95 % confidence interval

[d] Infant low birthweight (<2,500 g)

[e] Adjusted for the following maternal variables derived from the infant's birth certificate: education, age at delivery, marital status, insurance status, adequacy of prenatal care index, and smoking during pregnancy

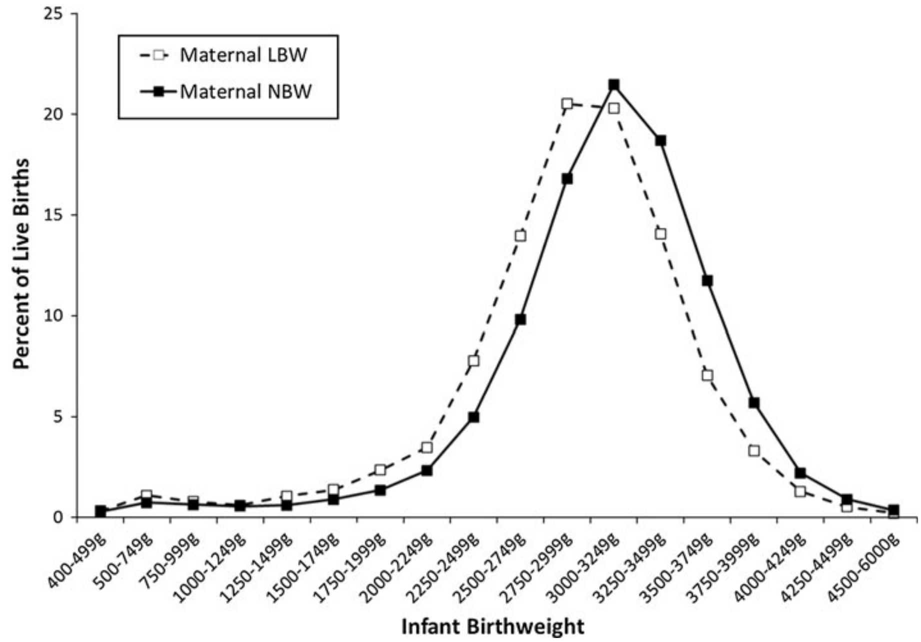

Fig. 1 Distribution of first-born singleton infant birthweight by maternal low birthweight status among infants born to black, non-Hispanic mothers

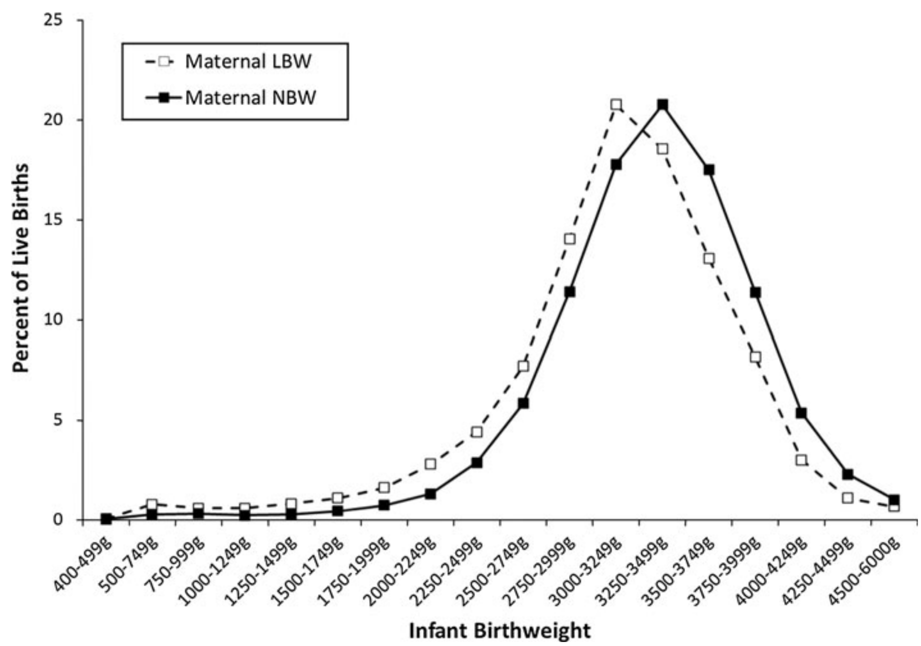

Fig. 2 Distribution of first-born singleton infant birthweight by maternal low birthweight status among infants born to white non-Hispanic mothers

The birthweight distribution in the infant generation (2005–2009 births) was shifted towards lower birthweights when mothers were born LBW for both races. Among non-Hispanic black mothers, the infant birthweight distribution was also shifted downward compared to non-Hispanic white women, even when mothers were normal birthweight (see Figs. 1, 2). The proportion of births that were LBW was higher among non-Hispanic black births compared to non-Hispanic white births in both the infant generation (13.1 vs. 6.9 %) and the maternal generation (11.9 vs. 5.4 %).

Crude analyses indicated increased odds of having a LBW infant when the mother was LBW for both racial/ethnic groups (see Table 4). This effect was larger for non-Hispanic white mothers and persisted after adjusting for a number of maternal variables derived from the infant birth certificate (education, age at delivery, marital status, insurance status, adequacy of prenatal care, and smoking during pregnancy). We found that 6.7 % of LBW among non-Hispanic black infants and 5.3 % of LBW among non-Hispanic white infants was attributable to maternal LBW.

Discussion

It is clear that by the time of a woman's first pregnancy, important risk factors for LBW have already been established, some of which may not be amenable to intervention in a single generation. We found that the entire birthweight distribution was shifted towards lower birthweights when the mothers themselves were born LBW. This trend was consistent among both non-Hispanic white and non-Hispanic black women. Mothers who were born LBW also had a greater chance of delivering LBW infants compared to women who were born normal birthweight. These differences in second generation LBW were found for both racial/ethnic groups studied, and persisted after adjusting for known maternal risk factors for LBW derived from the birth certificate.

The effect of maternal LBW on infant LBW was consistent with that reported in prior studies [13, 15, 16]. Also similar to previously reported studies [13, 16], we found that the relative odds of having a LBW infant among LBW mothers was higher among non-Hispanic white women compared to non-Hispanic black women. This likely reflects unmeasured risk associated with factors not available on the birth certificate that puts non-Hispanic black women at greater risk of delivering a LBW infant in general (e.g., stress, discrimination, height, weight, nutrition, and neighborhood factors). This is evident in the prevalence of LBW even among normal birthweight mothers: the LBW rate among non-Hispanic black second generation infants (12.3 %) was nearly double that of non-Hispanic white women (6.6 %). The difference in prevalence of LBW is also reflected in the PAR. Approximately 7 % of first-born singleton LBW births among non-Hispanic black women and 5 % among non-Hispanic white women, could be eliminated by removing the risk associated with maternal LBW.

A likely pathway through which maternal intergenerational factors impact physical growth and development is the quality of growth of the mother. Emanuel [19] proposed that it may be the degree to which a mother has achieved her own genetic growth potential. The causal mechanism underlying the intergenerational phenomenon is unknown, but different mechanisms have been proposed. In a recent review, Drake and Walker [20] provided evidence for seven different pathways through which the experiences of one generation may affect the offspring of subsequent generations: maternal growth, socio-economic factors, nutrition, glucocorticoids, blood pressure, sex-specific effects, and epigenetic mechanisms.

There has been vigorous debate in the literature concerning the nature of the mechanisms underlying the intergenerational effect, whether the effect is limited to in utero exposures only, and to what extent the effect is programmed/environmental versus genetic. Regardless of the specific causal mechanism, it is clear that improvement in a population's reproductive outcomes will not be fully addressed simply by the provision of health services and addressing risk factors in the current pregnancy [11]. Indeed, the life course approach which considers the impact of many factors, including broad social factors throughout the life span, [21] on reproductive and developmental outcomes has gained widespread acceptance in the field of maternal and child health as evidenced by the Maternal and Child Health Bureau's use of the life course perspective as the foundation of its current 5-year strategic plan [22].

Intergenerational effects such as those demonstrated in this paper underscore the importance of applying a life course perspective to the study of LBW. More research is needed to determine how key risk and protective factors such as socioeconomic status, race and racism, health care, disease status, stress, nutrition, weight status, and birth weight [21] accumulate or interact with each other over time to influence intrauterine growth. The creation of longitudinal datasets with multiple time points is necessary in order to elucidate whether these intergenerational effects exert influence primarily during critical/sensitive periods of development or are cumulative over time.

A life-course approach also has several implications for maternal and child health policy and practice. First, although there are long-standing public health efforts to prevent LBW, this issue cannot fully be addressed without consideration of key exposures occurring throughout the life span. Instead of solely focusing on risks occurring during the prenatal period, the life course perspective views pregnancy as part of an integrated continuum of health [23] that includes preconceptional, interconceptional, preventive, and primary care for women. Promotion of protective factors and mitigation of risk factors throughout the infant, child, adolescent, and child-bearing years may help reduce LBW. Second, intervention needs to occur at multiple time points and in multiple domains, taking into account health consequences of the social policies that provide the context in which families live [24, 25]. Mental (e.g., stress, depression), physical (e.g., safe housing, access to nutritious food), socioeconomic (e.g., job opportunities, access to health care, racism, poverty), and community factors are all potential targets for intervention that may play a role in shaping health across populations and communities [26]. Third, policy makers should evaluate the success of public health programs aimed at preventing poor birth outcomes using a generational yardstick [16]. Public health programs are often viewed in terms of the time frame of a grant funding period or political election cycle, but it is clear that it may take at least a generation to fully realize the benefits of life-course interventions.

The dataset used in the present study has some inherent limitations. First, by definition the linked data only contained intergenerational pairs that consisted of a Virginia resident infant born to a mother who was also born in Virginia. As might be expected, college-educated mothers were less likely to have remained in Virginia throughout their lives and are, therefore, less likely to be included in this dataset. As mentioned previously, only a small fraction of the Hispanic population in Virginia was eligible for linkage, which was expected given the large number of immigrants who have not resided in the state for two generations. Thus, our findings reflect only a subset of the entire Virginia birth population during the selected years. Second, as this was a maternally linked dataset, fathers were not included in the linkage. Although it is likely that paternal factors play a role, prior research suggests that paternal birthweight has a minimal effect on infant birthweight after controlling for maternal factors [15, 27–29].

Our linkage rate (87 % of eligible births) was higher than the Illinois study [15], which reported 79 %. The authors indicated that minor spelling errors in the names were usually the reason for a failed linkage. By using partial name matches and cross-linking parts of multiple surnames, we were able to link more records than would have been found with a simple exact matching process. In our dataset, failure to link records was most likely due to mothers using a different spelling or version of first name (e.g., Liz vs. Elizabeth) on their infant's birth certificate than was reported on their own birth certificate. Any record with an error in the mother's date of birth $>\pm 1$ day would also fail to link. These data discrepancies would be expected to be randomly distributed and thus have minimal influence on our analyses. It is also likely given the lower match rate among mothers born 1960–1964 (59 %) that data entry errors were more common in these years in the current study.

Despite these limitations the Virginia Intergenerational Birth File is a robust dataset that makes a number of important investigations possible, particularly in the area of life course research. The current investigation was limited to first births by design, but the entire maternal birth history is available for infants born to mothers aged 11–48 years, which is a much wider age range than found in the Illinois and Washington state datasets. This makes it possible to investigate research questions including those related to twins, siblings, birth order, and birth spacing. The role of neighborhood factors such as poverty and residential segregation on intergenerational risk can be investigated by geocoding the street address of the maternal residence. Birth data can also be readily linked to other administrative datasets with data on birth defects and other developmental disabilities. Once linked, one can study long term effects of the intergenerational factors like maternal LBW on children's growth and development [30–32].

In conclusion, the relative risks associated with maternal LBW for various suboptimal birth outcomes were 1.6–2.0, which is of the same order of magnitude as maternal smoking during pregnancy [33–35]. It is clear that public health program and policy must focus on factors throughout the life course in order to fully address inequities in birth outcomes. We have demonstrated the utility of creating a statewide intergenerationally linked database using existing administrative data. Other states are encouraged to build and maintain these types of surveillance data over time to facilitate the continued study of intergenerational effects.

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