1554. U.S. Government Printing Office, Washington, DC, 1978.

9. National Center for Health Statistics: Exercise and participation in sports among persons 20 years of age and over, United States. Advance Data No. 19. U.S. Government Printing Office, Washington, DC, 1978.
10. National Center for Health Statistics: Changes in cigarette smoking and current smoking practices among adults, United States, 1978. Advance Data No. 52. U.S. Government Printing Office, Washington, DC, Sept. 19, 1979.
11. Belloc, N. B., and Breslow, L.: Relationship of physical health status and health practices. Prev Med 1: 409–421 (1972).
12. Belloc, N. B.: Relationship of health practices and mortality. Prev Med 2: 67–81 (1973).
13. Breslow, L., and Enstrom, J. E.: Persistence of health habits and their relationship to mortality. Prev Med 9: 469–483 (1980).
14. Wiley, J., and Comacho, T.: Lifestyle and future health: evidence from the Alameda County study. Prev Med 9: 1–21 (1980).
15. Sudman, S.: New uses of telephone methods in survey research. J Marketing Res 3: 163–167 (1966).
16. Rogers, T.: Interviews by telephone and in person: quality of responses and field performance. Public Opinion Q 40: 51–65 (1976).
17. Waksburg, J.: Sampling methods for random digit dialing. J Am Statistical Assoc 73: 40–46 (1978).
18. Windsor, R., et al.: Perceptions of adults in rural Alabama toward skin cancer/melanoma: an educational diagnostic survey. UICC Technical Report Series 62:16–25, Geneva, 1981.
19. Monsees, M., and Massey, J.: Adapting procedures for collecting demographic data in a personal interview to a telephone interview. Proceedings of the American Statistical Association, Washington, DC, 1979, pp. 130–135.
20. Windsor, R., and Morris, J.: Consumer participation and payment for health promotion programs at an urban primary care center. Ala J Med Sci 21: 209–213, January 1984.

Racial Differences in the Relation of Birth Weight and Gestational Age to Neonatal Mortality

GREG R. ALEXANDER, MPH
MARK E. TOMPKINS, PhD
JOAN M. ALTEKRUSE, MD, DrPH
CARLTON A. HORNUNG, PhD, MPH

Mr. Alexander is an ScD candidate in the Department of Maternal and Child Health, School of Hygiene and Public Health, The Johns Hopkins University. The original version of this paper was prepared while he was a biostatistician with the Department of Preventive Medicine and Community Health, School of Medicine, University of South Carolina. Dr. Tompkins, Dr. Altekruse, and Dr. Hornung are with the USC Department of Preventive Medicine and Community Health, and Dr. Tompkins is also with the USC Department of Government and International Studies.

Requests for tearsheets should be addressed to Greg R. Alexander, Department of Preventive Medicine and Community Health, School of Medicine, University of South Carolina, Columbia, SC 29208. Detailed charts of birth-weight- and gestational-age-specific neonatal mortality rates for each racial group are available from the authors.

Synopsis

Utilizing South Carolina live birth-infant death cohort files for the period 1975–80, this study examines the bivariate distribution of birth weight-gestational age (BW-GA), intrauterine growth curves, and BW-GA specific neonatal mortality rates (NMRs) by race. Comparison of BW-GA distributions revealed an appreciable shift between racial subgroups. Nonwhites, on the average, were born 1 week earlier and 270 grams lighter in weight than whites. In addition to racial differences in rates of intrauterine growth, nonwhites experienced lower BW-GA NMRs than whites in BW-GA categories < 3,000 grams and < 38 weeks. However, the improved mortality experience of nonwhites at more immature BW-GA categories was not consistently present when different cause-specific NMRs were considered.

These persistent racial variations highlight continuing issues regarding both the use of a single norm for defining low birth weight or prematurity and the role of nonsocioeconomic factors related to racial BW-GA distribution and mortality disparities. As birth weight and gestational age represent empirical indicators of the maturity and survivability of an infant at birth, these data and previous supporting research raise further concerns regarding the ability of these indicators to accurately reflect equivalent fetal development and subsequent risk of mortality among racial groups.

IT HAS LONG BEEN RECOGNIZED that immaturity at birth is an important risk factor for neonatal mortality and that birth weight and gestational age serve as clinical indicators of a newborn infant's degree of fetal maturation. However, while birth weight and gestational age have traditionally performed well as measurable risk factors, there are systematic differences in birth weight and gestational age as indicators of the extent of fetal maturation for different population subgroups.

These differences have important implications for the assessment of neonatal medical needs and for the use of such assessments in formulating public policies that shape the delivery of services for specific groups. At issue is whether a given birth weight or gestational age reflects the same degree of fetal maturity for different groups of newborns. To examine this issue, we have analyzed birth weight and gestational age as noteworthy predictors of neonatal mortality in South Carolina, comparing the experience of whites and nonwhites from 1975 to 1980.

Immaturity at birth can be attributed to a variety of etiologies, including those producing preterm delivery and those associated with small-for-date infants. Preterm infants are born before completion of the normal term of pregnancy and often have a birth weight lower than that of a full-term infant. Small-for-date infants, on the other hand, exhibit birth weights that are relatively low for their gestational age.

The relation between gestational age and birth weight, because it indicates the underlying pattern of intrauterine growth and fetal development, has been employed to differentiate between etiologies producing preterm delivery and those implicated in small-for-date births. Moreover, mortality levels associated with gestational age and birth weight can be applied to predict the risk of problem pregnancies and can further be employed in determination of the level of specialized care required by a distressed newborn infant (*1*).

An analysis relating the distribution of births by weight and gestational age to specific neonatal mortality rates provides an indication of the origin of temporal changes in summary mortality rates. A decline in mortality rates within specific high-risk birth weight and gestational age categories over time may be the consequence of advances in medical care that improve the prospects for survival of high-risk infants. Changes in the distribution of infants at various levels of birth weight and gestational age may reflect improvements in use of prenatal care, in environmental conditions, and in nutrition or in the antenatal use of medical care technology or clinical procedures. Accordingly, both the proportion of births occurring within specific birth weight and gestational age categories and the mortality rates among these categories can be used to estimate the need for, and measure the impact of, services directed at various subgroups in the population.

Substantial research has been directed at describing fetal development by relating changes in birth weight to gestational age (*2–14*). Such intrauterine growth curve patterns are produced by calculating the distribution of birth weight by gestational age at birth for specific populations. Noteworthy variations in these fetal development or growth patterns have been observed between subpopulations, such as racial subgroups (*7,10–12*), and groups with specific disease etiologies—for example, trisomy 16–18 and osteogenesis imperfecta (*6*).

The assessment of birth-weight- and gestational-age-specific mortality has also drawn considerable research interest (*14–23*). Here as well, observable differences have been found between population subgroups. Most notable are the differences between whites and nonwhites.

In this study, we examine the relation of birth weight and gestational age to the risk of neonatal mortality within racial subgroups. Subgroup differences are related both to the risk of neonatal mortality attributable to the level of fetal development, given the duration of pregnancy, and to the risk attributable to premature birth. The importance of examining these differences between racial subgroups in perinatal experiences stems from the higher proportion of nonwhite infants born at low birth weights and their higher overall neonatal mortality rates (*24*). Of particular interest to this investigation is the observation that survival rates of nonwhites within low birth weight and early gestational age categories are higher than those of whites at the same birth weight and gestational age.

Methods

In this study, we used the 1975–80 South Carolina vital record live birth-infant death cohort data (*25*), employing single births to resident mothers in the analysis (290,184 cases). Cases with missing data, birth weights reported as less than 250 grams or more than 5,999 grams, and gestational ages calculated at less than 25 weeks or more than 50 weeks were excluded from the analysis. As a result, 282,366 births (169,549 whites and 112,817 nonwhites) were included. Racial subgroup was determined by race of the mother. For each of the years studied, blacks constituted approximately 98 percent of the nonwhite category.

Gestational age is calculated as the interval from the date of the last normal menses to the date of birth as reported on the birth certificate. Following recommended convention, gestational age is reported in completed weeks (*26*). For 8.2 percent of the study cases in which the specific day of the last normal menses was not reported, the 15th day of the indicated month was used in its place. For both whites and nonwhites, this imputed gestational age group demonstrated slightly lower than average birth weights and gestational ages; however, this and other studies using this methodological approach (*23*), as opposed to others that have been considered (*27*), did not show that inclusion of the imputed cases appreciably altered the basic mortality patterns under investigation.

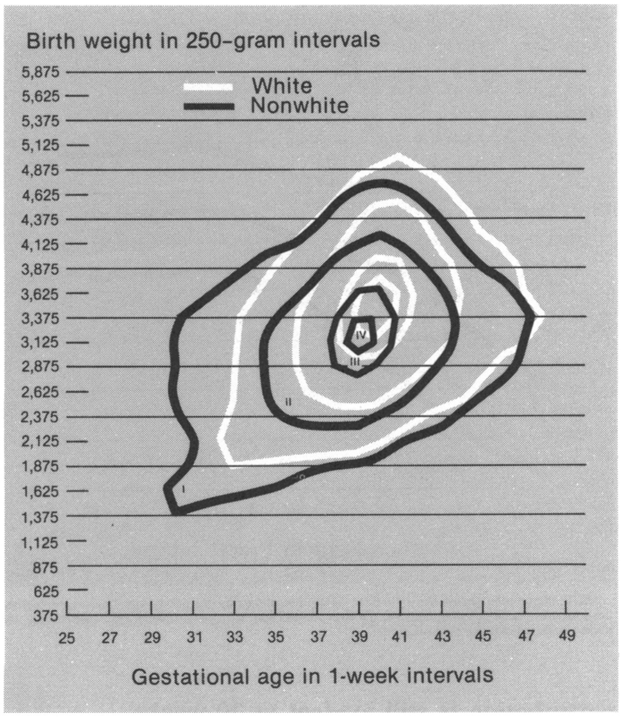
Results

A comparison of the bivariate distribution of birth weight and gestational age reveals an appreciable difference between the two racial subgroups. In figure 1, the contour diagram (equivalent to a geographer's use of contour maps to depict elevation patterns) provides an overhead view of the bivariate distribution of birth weight and gestational age for whites and nonwhites. The contour line values correspond to the percentage of total births within each birth weight and gestational age cell; the cells enclosed by a contour line have a percentage of total births equal to or higher than the line value. The contour patterns allow for comparisons of central location and shape between the respective racial distributions.

The contour pattern for nonwhites is shifted closer to the figure's origin (the intersection of the axes) than the pattern for whites, and slight differences in shape are apparent. The mean birth weight of the nonwhite subgroup is 270 grams less than that of the white subgroup, and the mean gestational age is roughly 1 week less for nonwhites than for whites. Similar findings of observable racial differences in birth weight and gestational age distributions have been reported previously (*12*).

In figure 2, birth weight percentiles are displayed by 1-week gestational age intervals. The lines in the figure suggest the pattern of intrauterine gains in birth weight with advancing gestational age; however, this pattern is based only on infants who were born at each gestational age. It is uncertain to what extent these infants' growth at delivery can be used to draw inferences about the weight of fetuses not yet born at a specific gestational age. The normal pattern of intrauterine growth for infants carried to term may differ from that of infants born prematurely, whose fetal growth patterns may result from known complications of pregnancy or other etiologic factors related to their early delivery.

Figure 1. Bivariate distribution contour pattern of birth weight and gestational age, 1975-80 South Carolina live birth-neonatal death cohort: percentage of single live births to resident mothers

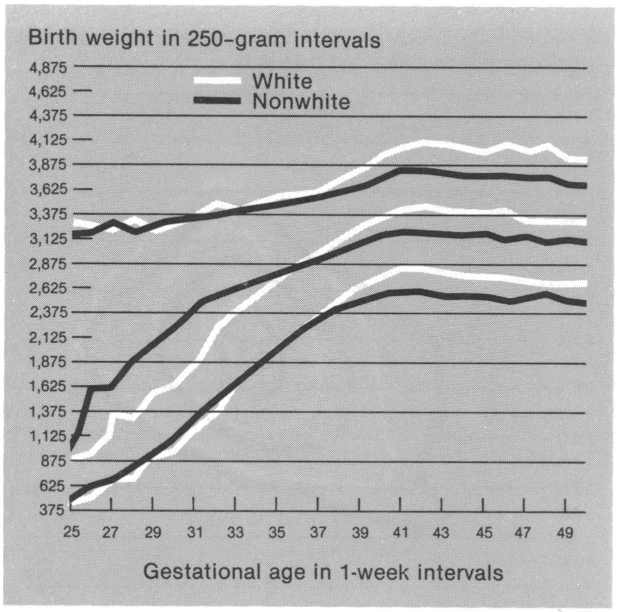


NOTE: In the contour pattern, percentage of live births is indicated as follows: I = 0.075; II = 0.500; III = 2.500; IV = 3.750.

Nevertheless, on the basis of these patterns, nonwhite fetuses appear to gain weight more quickly early in the gestational period. After the 35th week of pregnancy, the rate of fetal weight increase for nonwhites appears to slow in comparison with that for whites, and the median birth weight of white infants exceeds the median birth weight of nonwhites.

Other studies have shown that the distribution of birth weights is bimodal for early gestational ages (*3,14,28–30*), a finding confirmed in the South Carolina data. At 25 weeks' gestation, birth weights are distributed around a primary mode of approximately 1,000 grams and a secondary mode of approximately 3,000 grams. This phenomenon is more prominent within the nonwhite subgroup, and some indication of this can be observed in figure 1 in the outermost contour for nonwhites, where a bimodal

Figure 2. Intrauterine growth curves: birth weight percentiles by gestational age, 1975-80 South Carolina live birth-neonatal death cohort, single births to resident mothers



NOTE: Intrauterine growth shown in birth weight percentiles by gestational age. Lowest and highest lines for each racial subgroup indicate the 10th and the 90th birth weight percentiles, respectively; the middle lines indicate the 50th percentile.

perturbation is still evident at 30 weeks.

The bimodal distribution of birth weights at early gestational ages has noticeable impact on intrauterine growth curves. In figure 2, one can see that the 90th percentile lines are elevated at gestational ages less than 35 weeks, rather than closely paralleling the 50th percentile.

A number of explanations have been offered for this secondary mode in the distribution of birth weights at early gestational ages—for example:

- "The infants are truly too large and represent a form of pathophysiology characterized by an excessive growth rate" (*28*);
- Some mothers experience bleeding early in pregnancy and misinterpret this as their last normal menses, and this misinterpretation leads to inaccurate calculations of gestational age (*28–30*);
- Errors in recording or recalling data of last normal menses produce a unit shift (for example, 1 month) in the calculation of gestational age (*3*).

Although correctional techniques have been applied to recalculate gestational age in some studies (*14*), we have not attempted to do so in this study. Accordingly, some caution is required in interpreting the distribution and levels of mortality for infants with both an early gestational age (< 32 weeks) and a higher than expected birth weight (> 2,500 grams), since these births may, in fact, be normally distributed births that were miscoded or were the product of some intrauterine abnormality.

Birth-weight- and gestational-age-specific neonatal mortality rates are reported by racial subgroup in the table. For both whites and nonwhites, mortality rates decrease as birth weight and gestational age increase, until—at advanced gestational age and very high birth weights—rates begin to fluctuate and sometimes increase.

For births occurring before the 38th week, gestational-age-specific neonatal mortality rates are lower for nonwhites than for whites. In each gestational age category below the 38th week, births of nonwhites constitute the majority of births in South Carolina. Similarly, birth-weight-specific neonatal mortality rates are lower for nonwhites than for whites in weight categories below 3,000 grams, except for the very lowest category, where there are few cases. Births of nonwhites outnumber those of whites in each of these birth weight categories.

It has been recognized that, while nonwhites have lower neonatal mortality rates than whites at lower birth weights, whites have lower neonatal mortality rates than nonwhites at higher birth weights (*24*). Coupled with the shift between birth weight and gestational age distributions for the racial subgroups, better nonwhite mortality rates at low birth weights and early gestational ages and better white mortality rates at more typical birth weights and gestational ages create a "crossover" effect—at approximately 3,000 grams and 37 weeks—where the mortality experience of the two subgroups intersects and then diverges. This situation confounds the interpretation of birth-weight-standardized mortality rates if racial disparities are not taken into account (*24*), and it has been suggested that some standardized rates are biased as a result (*31*).

This crossover effect between racial subgroups was not consistently observed when different cause-specific neonatal mortality rates were compared over birth weight categories. When neonatal mortality from congenital anomalies and certain causes of perinatal mortality (International Classification of Diseases eighth and ninth revisions, codes 740–779: causes of death that we hypothesized to be related to fetal development and immaturity problems) were considered jointly, the crossover of birth-weight-specific neonatal mortality rates between racial subgroups was most prominent. These two neonatal mortality causal categories accounted for 72 percent of the total neonatal deaths of whites and 64 percent of those of nonwhites.

Birth-weight- and gestational-age-specific neonatal mortality by racial subgroup, 1975–80 South Carolina live birth–infant death cohort, single births to resident mothers

Gestational age (in weeks)	White: Number of births	White: NMR[1]	Nonwhite: Number of births	Nonwhite: NMR[1]
25	139	561.2	250	376.0
26	165	418.2	368	247.3
27	182	296.7	400	252.5
28	231	281.4	462	127.7
29	282	198.6	613	101.1
30	422	163.5	873	80.2
31	515	93.2	1,098	34.6
32	758	68.6	1,437	24.4
33	1,147	42.7	2,055	16.6
34	1,737	29.9	2,876	14.3
35	2,780	16.2	4,285	10.5
36	4,599	10.9	5,801	8.5
37	8,271	6.3	8,927	5.3
38	17,121	4.1	14,694	3.7
39	30,670	2.4	20,609	3.9
40	37,035	1.9	19,349	3.6
41	29,398	2.8	12,526	4.6
42	16,528	3.1	7,041	3.7
43	8,107	2.2	3,966	7.3
44	4,043	4.7	2,224	5.9
45	2,237	3.6	1,173	2.6
46	1,288	3.9	733	2.7
47	784	1.3	444	0.0
48	535	5.6	300	13.3
49	332	0.0	199	5.0
50	243	4.1	114	0.0

Birth weight (in grams)	White: Number of births	White: NMR[1]	Nonwhite: Number of births	Nonwhite: NMR[1]
250–499	20	850.0	23	956.5
500–749	101	901.0	168	827.4
750–999	227	674.0	365	553.4
1,000–1,249	331	359.5	480	258.3
1,250–1,499	376	207.5	541	112.8
1,500–1,749	594	136.4	929	79.7
1,750–1,999	1,034	62.9	1,418	38.8
2,000–2,249	1,880	31.4	2,537	20.5
2,250–2,499	4,073	14.7	5,825	8.9
2,500–2,749	8,883	8.8	11,267	5.9
2,750–2,999	16,065	4.5	17,588	3.1
3,000–3,249	27,831	2.7	23,280	3.0
3,250–3,499	34,478	1.8	21,068	2.7
3,500–3,749	31,596	1.8	14,448	2.8
3,750–3,999	21,817	1.6	7,435	2.8
4,000–4,249	10,990	1.4	3,124	2.9
4,250–4,449	5,794	1.9	1,429	2.8
4,500–4,749	2,299	1.7	580	3.5
4,750–4,999	789	5.1	202	9.9
5,000–5,249	241	0.0	61	16.4
5,250–5,449	92	32.6	27	0.0
5,500–5,749	29	0.0	15	133.3
5,750–5,999	9	0.0	7	0.0

[1] NMR = Neonatal mortality rate.

Assuming that socioeconomic conditions may play a larger role in neonatal mortality from all other causes, we then used only these "all other" neonatal deaths to calculate birth-weight-specific neonatal mortality rates by racial subgroup. In this calculation, nonwhites experienced higher mortality rates, essentially parallel to those of whites, across every birth weight category. Similar findings have also been reported elsewhere (*32*).

Birth-weight- and gestational-age-specific neonatal rates for whites and nonwhites are considered in combination in figure 3. The shaded background indicates those cells where the neonatal mortality rates for nonwhites are lower than those for whites.

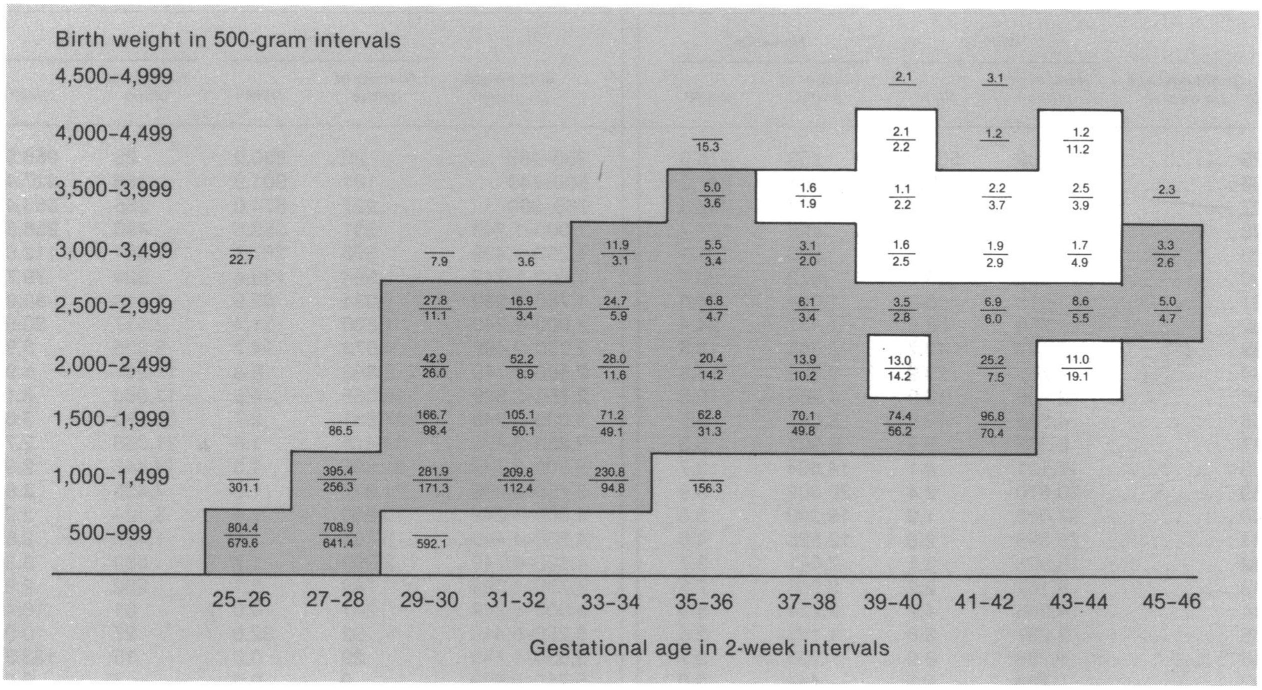
The relation of birth weight and gestational age to neonatal mortality is similar within the two racial subgroups. For any given gestational age, increases in birth weight are strongly associated with changes in mortality rates; however, within birth weight categories, gestational age variations have far less impact on mortality rates. These findings are generally consistent with those reported from California, where it was observed that, when birth weight was held constant, "mortality risk decreases with advancing gestational age, reaches a minimum, then again increases; that is, there is a U-shaped relationship" (*14*).

In most birth weight and gestational age categories in which birth weights are less than 3,000 grams, nonwhites show lower category-specific neonatal mortality rates than whites. The crossover effect, previously discussed for birth-weight- and gestational-age-specific neonatal mortality rates, is again apparent when birth weight and gestational age are considered simultaneously: whites have lower neonatal mortality rates than nonwhites at birth weights between 3,000 and 4,000 grams and gestational ages between 39 and 42 weeks. Forty-three percent of all live births included in this study occurred in this range.

Discussion

Many have observed that, on average, nonwhite infants are smaller at birth than white infants (*17,33–36*). Deficiencies in nutrition, prenatal care, and socioeconomic conditions are often suggested as explanations for what is perceived as a comparative deficit in nonwhite fetal development. While the overall disparity in socioeconomic status be-

Figure 3. Birth-weight-and gestational-age-specific neonatal mortality rates by race, 1975-80 South Carolina live birth-neonatal death cohort, single births to resident mothers



NOTE: All rates displayed are based on more than 60 births and at least 2 deaths. Within each cell, neonatal mortality rates for whites are shown above rates for nonwhites. Darker shaded area depicts cells where rates for whites are higher than rates for nonwhites.

tween the racial subgroups has been widely recognized, the higher survival rates of nonwhite infants at low birth weights and early gestational ages raise questions about whether the shift between white and nonwhite distributions can be explained by socioeconomic conditions considered in isolation. When data are controlled for those socioeconomic and demographic variables that are available, prominent racial differences remain (*37*).

Several investigators (*17,18,34,35*), faced with these findings, have noted the logical difficulties in suggesting that, on the one hand, nonwhites are born earlier and lighter because of socioeconomic deficiencies while, on the other hand, the same presumably compromised infants demonstrate higher survival rates. This apparent inconsistency has led to the conjecture that a biological mechanism works to mitigate the impact of unfavorable socioeconomic influences. It has also been suggested that genetic factors may be involved (*35*).

Before considering an explanation that posits genetic influences as an independent factor or as a modifier of adverse socioeconomic effects, we should reexamine the relation of fetal development to birth weight and gestational age. Birth weight and gestational age serve as empirical indicators of the physiological maturity of the infant. They may not, however, precisely reflect the extent of fetal development or maturation of a particular newborn infant. Shifts in the birth weight distribution, similar to those displayed between racial groups, have also been observed between newborn males and females. The relation between maturity and these indicators—birth weight and gestational age—and the degree to which this relationship varies among individuals or various groups in the population require further investigation. More may be learned about the underlying relationship by comparing racial subgroups on the incidence and severity of morbid conditions related to immaturity, such as retrolental fibroplasia and respiratory distress, while controlling for birth weight and other factors such as variations in prenatal and acute perinatal medical care.

Our initial investigation of birth-weight-specific neonatal mortality rates for two specific, although broadly grouped, cause-of-death categories suggests that etiologic factors related to racial differences in fetal development warrant further consideration if we are to understand better the underlying causes of racial variations in birth-weight- and gestational-age-specific mortality and, in particular, the racial crossover of patterns of neonatal mortality rates. Such questions are also pertinent to recent discussions of bias in standardized birth-weight-specific mortality rates (*31,38,39*). For causes of death, hypothesized as less likely to be directly related to immaturity at birth, the observation of higher neonatal mortality rates for nonwhites than for whites in every birth weight category is consistent with an assumption of the adverse socioeconomic effects of deprivation. In spite of the shift in the birth weight distribution between the racial subgroups, it would initially appear that little bias may occur from the use of standardization methods in this situation. But for causes of death that are more clearly a function of immaturity at birth, the distinct crossover pattern between the racial birth-weight-specific neonatal mortality rates and the shifted birthweight distributions indicates the influence of other factors that may well entail bias. This may not apply to standardization between populations that are predominantly homogeneous by race, but further research is needed in this area.

The consideration of the construct validity of treating birth weight and gestational age as equivalent indicators of fetal maturation between racial groups becomes crucial to the discussion of methodological issues involved in standardization techniques. To the extent that the same level of fetal development may be indicated by slightly different birth weight or gestational age values among racial groups, considerable caution should be used in applying standardization techniques to racially disparate populations until further insight is gained into potential racial variations in birth weight values as indicators of fetal maturation at birth. Such research may suggest the need to develop standardization measures of fetal development before valid comparisons between racial groups can be made.

While birth weight and gestational age cannot be viewed as error-free indicators of the maturity of infants at birth, conventional wisdom recognizes that an infant born too early or too small faces a substantial risk of mortality. This is an absolute risk of low birth weight and early gestation, in that a 27-week, 1,000-gram neonate runs a far greater risk of dying than a 39-week, 3,000-gram neonate, regardless of its racial group.

Apart from this absolute risk, birth weight and gestational age also serve in the estimation of risk for infants sharing similar attributes. That is, a specific infant's birth weight and gestational age can be compared with the overall distribution of infants from its distinctive group to arrive at an estimate of relative viability. As an example, consider an infant whose birth weight is very close to the subgroup's mean birth weight. This infant may be presumed to be at less risk than an infant whose birth weight is one or two standard deviations below the mean weight.

In a comparison of two subpopulations whose birth weight distributions are shifted relative to each other, any given birth weight value (say, 2,500 grams) represents different locations on the birth weight distributions for the two groups. In considering racial differences, this is important, because a nonwhite 2,500-gram neonate appears to be at less risk than a white infant of the same birth weight, since the former is much closer to the mean birth weight for its group than the latter. In effect, the risk associated with a given birth weight is related both to the absolute size of the infant and to its size compared with others in its distinctive reference group. The same concerns can be applied to gestational age (although the shift in distributions is somewhat less pronounced) and to birth weight and gestational age considered jointly.

The concepts of "relative" and absolute risk have implications for the genetic hypothesis evoked by previous studies of racial differences in neonatal mortality rates. They imply that variations in the biological patterns of reproduction may exist between subpopulations, yielding pervasive and consistent variations also in the length and extent of intrauterine development, as measured empirically by birth weight and gestational age. At the same time, intergroup variations found in birth weight and gestational age may be produced by socioeconomic conditions affecting, for example, maternal nutrition and physical condition. Whether an overall difference in birth weights or gestational ages, or both, is linked to a racial or ethnic trait is, at this point, still purely speculative. If differences in normal birth weight and typical gestational age are attributed to biological or genetic differences, it is still not certain that these differences indicate variations in fetal maturity and readiness for birth and that they influence the viability of a neonate.

Efforts to resolve these issues are further complicated when we recognize that racial differences in the indicators of maturity at birth extend beyond shifted distributions. Variations in the shape of the racial distributions are also apparent. For example, the birth weight distribution of nonwhites is more negatively skewed than that of whites, resulting in a further excess of low (< 2,500 grams) and very low (< 1,500 grams) birth weight newborns.

It has been suggested that the human birth weight distribution is composed of two distinct distributions: a normal, or Gaussian, distribution and a smaller and downward-shifted secondary distribution reflecting compromised infants (*40,41*). Although this is plausible, it is unclear whether differences in shape—for example, negative skewing—in a subpopulation's birth weight distribution indicate a greater influence of socioeconomic deprivations and suggest an area where the need for, and the effects of, intervention strategies can be observed.

It is apparent that optimal improvement in a birth weight distribution does not necessarily result in a shift in the entire distribution toward a heavier mean birth weight, an outcome that would result in a greater proportion of high birth weight infants. The measurement of improvement in birth weight, insofar as it is related to mortality risk, should focus on reductions in extreme birth weight values and a greater symmetric concentration of birth weights around a "normal" birth weight mean. Such measurement will require that research attention also be given to skewness and kurtosis of the birth weight distribution.

These additional points reemphasize that socioeconomic disparities persist among racial subgroups. The discussion of alternative, but not mutually exclusive, hypotheses for racial variations in pregnancy outcome measures is not intended to diminish the importance of alleviating these adverse socioeconomic differences and controlling their negative effects on the viability of infants.

These apparently theoretical issues have significant implications for clinical and public health practice. Substantial public health resources are being expended in programs such as WIC (Special Supplemental Food Program for Women, Infants, and Children) to alleviate deficiencies related to socioeconomic disadvantages. Change in the distribution of birth weight is one of several outcome measures considered in evaluating the effectiveness of these programs. Recent studies have shown little decrease in total nonwhite mortality attributable to improvements in the distribution of birth weights for nonwhites. In contrast, most of the decline in total nonwhite mortality has been related to the impact of improvements in birth-weight-specific mortality (*36,42–45*). Nonwhites in South Carolina experienced a decline in neonatal mortality from 1975–76 to 1979–80, with a reduction of 2.8 neonatal deaths per 1,000 live births. Less than 4 percent of the decline could be attributed to improvements in the birth weight distributions, which would result in fewer high-risk infants (*44*). The majority (71.4 percent for whites and 96.4 percent for nonwhites) of the State's decline in total neonatal mortality rates was related to increased survival within specific birth weight categories for both racial subgroups. If birth weight and gestational age are used to indicate risk (and therefore the need for and the effectiveness of services), a better understanding is needed of race-specific differences in these indicators of fetal maturity in racially disparate populations.

Similarly, if neonates are to be assigned to various treatment populations on the basis of their birth weight and gestational age, using some cutoff value (such as 2,500 grams for "low birth weight"), then population composition, accounting for these subgroup differences, should be considered in applying these criteria. A single, uniformly applied norm (say, for "low birth weight") will have different implications for infants drawn from different subgroups, where systematic differences in the distribution of gestational age and birth weight are known to occur. Infants at lower risk of mortality may be selected for treatment over heavier infants from another subgroup who on the average face higher risks.

Conclusion

Birth weight and gestational age are both used to estimate neonatal mortality risk; both are associated with changes in risk. These variables serve as indicators of fetal maturation, but as indicators they are imperfect. At low birth weights and early gestational ages, nonwhite infants in our South Carolina data set generally survived at higher rates than white infants in the same birth weight and gestational age category; however, at higher birth weights and later gestational ages, white infants had better survival rates. These findings parallel those of others using data sets from other populations. These differences have implications for the use of birth weight and gestational age as indicator variables, raising concerns of construct validity. Application of a single cutoff score, based on these indicators, will affect various subgroups differently. Involved are both fundamental questions regarding the etiology of immaturity and pragmatic concerns about inappropriate allocation of public health and clinical resources resulting from the use of undifferentiated indicators insensitive to differences in the groups to which they are applied.

References

1. Nelson, W. E.: Categorization by weight and gestational age of the infant at birth. J Pediatr 71: 309–310 (1967).
2. Lubchenco, L. O., Hansman, C., Dressler, M., and Boyd, E.: Intrauterine growth as estimated from liveborn birth-weight data at 24 to 42 weeks of gestation. Pediatrics 32: 793–800 (1963).
3. Gruenwald, P.: Growth of the human fetus. Am J Obstet Gynecol 94: 1112–1119 (1966).
4. Battaglia, F. C., and Lubchenco, L. O.: A practical

classification of newborn infants by weight and gestational age. J Pediatr 77: 159–163 (1967).
5. Yerushalmy, J.: The classification of newborn infants by birth weight and gestational age. J Pediatr 71: 164–172 (1967).
6. Lubchenco, L. O.: Assessment of gestational age and development at birth. Pediatr Clin North Am 17: 125–145 (1970).
7. Freeman, M. G., Graves, W. L., and Thompson, R. L.: Indigent Negro and caucasian birth weight-gestational age tables. Pediatrics 46: 9–15 (1970).
8. Tanner, J. M.: Commentary: Standards for birth weight or intra-uterine growth. Pediatrics 46: 1–6 (1970).
9. Lin, C., and Emanuel, I.: A comparison of American and Chinese intrauterine growth standards: are American babies really smaller? Am J Epidemiol 95: 418–430 (1972).
10. Williams, R. L.: Intrauterine growth curves: intra- and international comparisons with different ethnic groups in California. Prev Med 4: 163–172 (1975).
11. Brenner, W. E., Edelman, D. A., and Hendricks, C. H.: A standard of fetal growth for the USA. Am J Obstet Gynecol 126: 555–564 (1976).
12. Hoffman, H. J., et al.: Classification of births by weight and gestational age for future studies of prematurity. The epidemiology of prematurity. Urban & Schwarzenberg, Munich, 1977.
13. Wilcox, A. J.: Birth weight, gestation, and the fetal growth curve. Am J Obstet Gynecol 139: 863–867 (1981).
14. Williams, R. L., et al.: Fetal growth and perinatal viability in California. Obstet Gynecol 59: 624–632 (1982).
15. Karn, M. N., and Penrose, L. S.: Birth weight and gestational time in relation to maternal age, parity, and infant survival. Ann Eugenics 16: 147–163 (1951).
16. Anctil, A. O., et al.: Prematurity: a more precise approach to identification. Obstet Gynecol 24: 716–721 (1964).
17. Erhardt, C. L., et al.: Influence of weight and gestation on perinatal and neonatal mortality by ethnic group. Am J Public Health 54: 1841–1855 (1964).
18. Westphal, M. C., and Joshi, G. B.: The interrelationship of birth weight, length of gestation and neonatal mortality. Clin Obstet Gynecol 7: 670–686 (1964).
19. Lubchenco, L. O., Searls, D. T., and Brezie, J. V.: Neonatal mortality rate: relationship to birth weight and gestational age. Fetal Neonatal Med 81: 814–822 (1972).
20. Goldstein, H., and Peckham, C.: Birth-weight, gestation, neonatal mortality and child development. The biology of human fetal growth. Taylor & Francis, London, 1976.
21. Koops, B. L., Morgan, L. J., and Battaglia, F. C.: Neonatal mortality risk in relation to birth weight and gestational age. J Pediatr 101: 969–977 (1982).
22. Goldenberg, R. L., et al.: Survival of infants with low birth weight and early gestational age, 1979 to 1981. Am J Obstet Gynecol 149: 508–511 (1984).
23. Binkin, N. J., et al.: Reducing black neonatal mortality. JAMA 253: 372–375 (1985).
24. Alexander, G. R., and Altekruse, J. M.: Birth weight standardized neonatal mortality rates (correspondence). N Engl J Med 307: 1021–1022 (1982).
25. File documentation for South Carolina's public access vital event data files. Office of Vital Records and Public Health Statistics, South Carolina Department of Health and Environmental Control, Columbia, SC, May 1982.
26. Silverman, W. A., et al.: Nomenclature for duration of gestation, birth weight and intrauterine growth. Pediatrics 39: 935–939 (1967).
27. Taffel, S., Johnson, D., and Heuser, R.: A method of imputing length of gestation on birth certificates. Vital and Health Statistics, Series 2, No. 93. National Center for Health Statistics, Hyattsville, MD, 1982.
28. Battaglia, F. C., Frazier, T. M., and Hellegers, A. E.: Birth weight, gestational age, and pregnancy outcome, with special reference to high birth weight-low gestational age infants. Pediatrics 37: 417–422 (1966).
29. Milner, R. D. G., and Richards, B.: An analysis of birth weight by gestational age of infants born in England and Wales, 1967 to 1971. J Obstet Gynecol Br Commonwealth 81: 956–967 (1974).
30. David, R. J.: The quality and completeness of birthweight and gestational age data in computerized birth files. Am J Public Health 70: 964–973 (1980).
31. Wilcox, A. J., and Russell, I. T.: Perinatal mortality: standardizing for birthweight is biased. Am J Epidemiol 118: 857–864 (1983).
32. Eberstein, I. W., and Parker, J. R.: Racial differences in infant mortality by cause of death: the impact of birth weight and maternal age. Demography 21: 309–321 (1984).
33. Dodge, C. T. J.: Weight of colored infants. Am J Phys Anthropol 10: 337–345 (1927).
34. Anderson, N. A., Brown, E. W., and Lyon, R. A.: Causes of prematurity: III. Influence of race and sex on deviation of gestation and weight at birth. Am J Dis Child 65: 523–534 (1943).
35. North, A. F., and MacDonald, H. M.: Why are neonatal mortality rates lower in small black infants than in white infants in similar birth weight? J Pediatr 90: 809–810 (1977).
36. Williams, R. L., and Chen, P. M.: Identifying the sources of the recent decline in perinatal mortality rates in California. N Engl J Med 306: 207–214 (1982).
37. Carlson, E. D.: Social determinants of low birth weight in a high risk population. Demography 21: 207–215 (1984).
38. Kleinman, J. C.: Re: perinatal mortality: standardizing for birthweight is biased [Letter to the Editor]. Am J Epidemiol 120: 798–801 (1984).
39. Wilcox, A. J., and Russell, I. T.: Birthweight and perinatal mortality, I and II. Int J Epidemiol 12: 314–325 (1983).
40. Adams, M. S., MacLean, C. J., and Niswander, J. D.: Discrimination between deviant and ordinary low birth weight: American Indian infants. Growth 32: 153–159 (1968).
41. Pethybridge, R. J., Ashford, J. R., and Fryer, J. G.: Some features of the distribution of birthweights of human infants. Br J Prev Soc Med 28: 10–18 (1974).
42. Goldenberg, R. L., et al.: Neonatal deaths in Alabama, 1970–1980: An analysis of birth weight and race specific neonatal mortality rates. Am J Obstet Gynecol 145: 545–552 (1983).
43. David, R. J., and Siegel, E.: Decline in neonatal mortality, 1968 to 1977: better babies or better care? Pediatrics 71: 531–540 (1983).
44. Alexander, G. R., and Altekruse, J. M.: Infant and neonatal mortality in South Carolina: the parallax and paradox of where we stand. Prev Med Q 7: 1–5 (1983).
45. Buescher, P. A., Nugent, R. R., and Levine, R. H.: The impact of low birth weight on North Carolina neonatal mortality, 1976–1982. NC Med J 45: 437–441 (1984).