BIRTH WEIGHT, FETAL AGE AND PERINATAL MORTALITY

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Susser, M., F. A. Marolla, and J. Fleiss (Columbia Univ. School of Public Health New York, N.Y. 10032). Birth weight, fetal age and perinatal mortality. Am J Epidemiol 96: 197–204, 1972.—Four sets of data that give perinatal mortality rates by birth weight and duration of pregnancy have been studied to discover the relative contributions of birth weight and fetal age to perinatal mortality. Two approaches are used: graphic representation, and the Mantel-Stark method of indirect standardization. Consistently in all sets of data, birth weight makes the predominant contribution to perinatal mortality. The contribution of fetal age seems to be notable only in the period around 37 to 42 weeks of gestation. The implications of these findings for prediction and prevention of pregnancy outcomes, and for characterizing syndromes of fetal growth and maturity, are noted.

birth weight; fetal death; gestational age; growth; infant mortality; statistics

This paper deals with the contributions of birth weight and of fetal age to perinatal mortality. Knowledge of their relative contributions to outcomes of pregnancy, and of their interactions, has several applications. First, such knowledge aids in the prediction of the reproductive efficiency of groups, and leads to the selection of appropriate targets for prevention of reproductive loss. Should attention be directed more to the criterion of birth weight, more to fetal age, or equally to both?

Second, the study of these relationships is necessary to cogent analysis of syndromes related to fetal maturity and rates of growth. Direct and reliable measures of physiological maturity are not available. A number of workers have approached the analysis of fetal growth problems by the device of combining the indices of birth weight and fetal age to produce developmental “types” distinguished by different rates of intrauterine growth (1–4). To establish the contribution of rate of growth as a variable in its own right, however, requires measures of the separate and relative contributions of birth weight and fetal age to various outcomes.

Knowledge of the relationships of birth weight and fetal age also provides a pragmatic test of the best combination of the two variables into a single index. The combined indices have been derived in two ways. Some authors have distributed infants by birthweight at defined intervals of fetal age; for instance, in rank order, to obtain percentile fetal growth charts (1). Others have distributed infants by fetal age at defined levels of birth weight for similar

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purposes (3). Should birth weight and fetal age not vary equally one with the other, however, the types created by each method would not be congruent with each other: an infant might fall into the majority class on one classification of types, and into a deviant class on the other.

We have indicated briefly in a previous paper that birth weight has a much stronger association with perinatal mortality than fetal age (5). Here that introductory observation is extended by means of a method recently invented (6).

METHOD

In the analysis reported here, four sets of published data were used. Each set gives information on perinatal mortality by birth weight, and by fetal age as measured by duration of pregnancy. These sources are the following:

1) Fetal and early neonatal deaths (from 20 weeks gestation through the first seven days of life) among births to white mothers in New York City, 1958–1961 (7).

2) Fetal and early neonatal deaths among births to nonwhite mothers in New York City, 1958–1961 (7).

3) Stillbirths and neonatal deaths from 28 weeks gestation up to 28 days of life in the United Kingdom, among a cohort born during the week of March 3–9, 1958 (8).

4) Fetal and early neonatal deaths (during first seven days after delivery) in 10 university teaching hospitals in Canada (9).

The intervals we have used for birth weight and duration of pregnancy were imposed by the published data. This constraint creates some unavoidable distortions. For instance, in the New York City data, all durations of pregnancy 40 weeks and over are grouped together to produce a truncated curve, and the grouping of intervals under 40 weeks is such that some 40 per cent of all births cluster in the single interval 37 to 39 weeks. In the British data, all weights above 4,000 gm are grouped to produce a similarly truncated curve.

The only available index of fetal age for these studies is duration of pregnancy. This measure could be unreliable both because the last menstrual period is imprecisely recalled and reported, and because menstrual cycles are so variable. With the large numbers involved, however, these errors can be treated as random. There is no reason to suspect systematic bias. In each set of data, duration of pregnancy was calculated from the record of last menstrual period made before delivery of the child, and this method stands up under validity tests against other criteria (10).

The data have been considered in two ways. The first approach is graphic. Groups are specified by one variable and to that degree held constant; the mortality contour of each group is then examined in relation to the available intervals for the other variable set out along the abscissa. In this paper, only one set of data is set out in this manner for illustration.

The second approach summarizes the somewhat complex graphic representation. It relies on an iterative standardizing procedure devised by Mantel and Stark (6) to remove confounding between two independent variables that vary systematically with each other. The key feature of the method is the indirect adjustment of each of two independent variables, in a two-way table of rates, by the other variable. By this procedure, a set of adjusted marginal rates is produced, for each of the two variables in turn, that is unconfounded by the effect of the other variable.

The calculations required are quite extensive and were carried out by a special program written for the IBM 360/91 computer of Columbia University. The alternative method of adjustment, straightforward direct standardization, was deemed inappropriate here because many specific rates, required in direct adjustment, were based on small numbers of births and were thus unreliable. In our data, these occurred particularly where a low value on one independ-
ent variable was combined with a high value on the other. In some of these extreme cells, moreover, recording and coding errors seem likely to be important; a normal birth weight in an infant of low fetal age is an improbable event.

**Fetal age**

Figure 1 shows by graphic representation that among whites in New York City perinatal mortality has a curvilinear relationship with duration of pregnancy. The data on nonwhites, and the Ontario and British data are essentially similar to figure 1. (The additional graphs and tables are available on request from the authors.) Perinatal mortality varies little with duration of pregnancy up to the 1001–1500 gm birthweight group. For most birthweight groups above 1500 gm, the successive curves of mortality decline to a minimum around 38–40 weeks and then rise.

Because of the relatively small numbers of births for the shorter durations of preg-

![Figure 1](image_url)

**Figure 1.** Crude perinatal mortality rates by duration of pregnancy within birth weight categories, New York City whites, 1958–1961.
nancy, the apparent gradients in perinatal mortality from 22 to 26 weeks of gestation (noticeable at birth weights between 1500 and 3500 gm but based on sample sizes less than 200 births) are not statistically reliable and might therefore be the result of sampling variation. For the longer durations of pregnancy, on the other hand, the numbers of births are relatively high. The decline in perinatal mortality from approximately 38 weeks of gestation, and the subsequent increase at 40 or more weeks (noticeable at birth weights above 2000 gm and based on sample sizes in the thousands) seems to be real and not a result of imprecise estimation.

Figure 2 shows the crude rates of perinatal mortality by duration of pregnancy, and the rates standardized for birth weight by the Mantel and Stark procedure. The steep gradient of mortality by duration of pregnancy found in the crude rates becomes, when fetal age is unconfounded by birth weight, almost a flat, nonpredictive curve, with the exception of a U-shaped coda around the norm for a full term pregnancy.

![Graph showing perinatal mortality rates by birth weight and duration of pregnancy.](image)

**Figure 3.** Crude perinatal mortality rates by birth weight within duration of pregnancy categories, New York City whites 1958–1961.
In the Ontario and British data, where intervals were given beyond 40 weeks, the curvilinearity of the relationship in the region of 37 to 42 weeks is given clearer expression. These standardized curves suggest that duration of pregnancy makes some independent contribution to the variance in perinatal mortality only in late pregnancy.

**Birth weight**

Figure 3 shows by graphic representation that perinatal mortality among New York City whites also has a curvilinear relationship with birth weight. Here, too, the remaining three sets of data are essentially similar. (The additional graphs and tables are available on request from the authors.)

For the duration of pregnancy categories that include the heavier birth weights (i.e., for the longer durations), the mortality rates decline to a minimum in the range between 3000 and 4000 gm approximately, and then rise again. The curves for each specific duration of pregnancy demonstrate marked variation in mortality by birth weight. The crowding of the curves reflects the relative lack of variation between the categories of duration of pregnancy.

Figure 4 shows the crude rates of perinatal mortality by birth weight, and the rates standardized for duration of pregnancy by the Mantel-Stark procedure. The standardization does little to alter the relation between perinatal mortality and birth weight, viz., a sharp declining gradient in perinatal mortality as birth weight increases to 3500 gm or 4000 gm, and an equally sharp increasing gradient thereafter. Only in the data for the British Perinatal Survey (figure 4, extreme right), in which the birth weight distribution is truncated at 4000 gm, does the increasing gradient fail to emerge.

For each pair of curves in figure 4, a difference is apparent between the crude and adjusted rates for the lower birth weights. These differences are artifacts of indirect adjustment, and are not a result of any independent contribution of length of gestation to perinatal mortality at the lowest birth weights. On the contrary, figure 1 shows that for New York City whites there is no effect of length of gestation for either of the two lowest birthweight intervals: ≤ 1000 gm, and 1001–1500 gm.

**Discussion**

This analysis tests the utility of the Mantel-Stark method. In addition to the artifacts that we have observed indirect adjustment can create, another limitation of the method is worth noting. It does not permit comparisons across groups, because the procedure of indirect standardization sets different standard values, derived internally from the population under study. Thus a direct comparison of standardized rates between our four sets of data cannot be made with this method.

Faced with these limitations, some might ask whether the method does not obscure more than it clarifies, especially where large numbers are available. In our view, the technique has proved useful in clarifying these data. Figure 1 and figure 3 are typical of all the figures constructed from our four sets of data. The general relationships between gestation, birth weight and perinatal mortality reported here are present in all the figures and tables, but are by no means self-evident. These relationships would doubtless have been commented on sooner, we venture to think, had the data been easier to read.

Birth weight has served as the main operational index of maturity for the past half-century. The validity of most known correlates with 'prematurity', especially mortality and neurological impairments, rests on their relation with birth weight. Our analysis shows that birth weight is indeed a good predictor of perinatal mortality. It also demonstrates unequivocally the predominance of the contribution of birth weight over that of duration of pregnancy to perinatal mortality. In this regard, differences in duration of pregnancy observed between whites and nonwhites have been taken to indicate an innate difference between races.
in the reproductive process that relates to outcomes of pregnancy (11). The analysis presented here, however, gives fresh force to the observation that in New York City virtually the entire excess of the perinatal death rate of nonwhites over that of whites (an excess of about 70 per cent) could be accounted for by the difference in birth weight between the two groups (5).

The analysis also suggests that types or syndromes constructed from the distribution of birth weights at intervals defined by fetal age will prove more discriminating prognostic indicators than will types constructed from the distribution of fetal age at intervals defined by birth weight. Insofar as the purpose of defining a syndrome is to make a prognosis and to indicate the most likely therapeutic intervention that will be effective, these data suggest that the prognosis for perinatal death can be made almost as well from birth weight alone as it can from a combined index of birth weight and fetal age. Only in the few weeks around term does fetal age appear to contribute much to the variance in mortality. A preliminary multiple regression analysis, with transformations for curtulinearity, showed that birth weight contributes 90 per cent or more to the variance in perinatal mortality. Fetal age contributes no more than 5 per cent, and interaction only 2–3 per cent.

Finally, the result strengthens the hypothesis that birth weight may be a crucial intervening variable between the circumstances of pregnancy and mortality. If so, to raise birth weight could be a preventive measure. An appropriate first step is to try and do so, and to evaluate the effect of doing so.

References