FOUR FACTORS INFLUENCING BIRTH WEIGHT

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The birth weight of newborn infants is usually studied as a concomitant variable to prematurity or infant mortality and less frequently as the variable of primary interest. This investigation concentrates on the relationship of infant birth weight to four other variables. The combined effect of birth order and mother's age on birth weight is analysed in a large sample of births. The influence of maternal age on the birth weight is investigated for each birth order group and, conversely, the influence of birth order is studied at different maternal ages. Both secular and seasonal trends in mean birth weight, which in general are neglected in the literature, are included here.

MATERIALS AND METHODS

The source of the data used for this investigation was birth certificates of infants born in New York State exclusive of New York City. The studied population consisted of all white single births recorded during the years 1959 through 1967 (a total of 1,524,229 births). The variables employed in this paper were defined as follows:

Live birth: defined by New York State Public Health Law, although in this case interest was restricted to infants of 28 or more weeks' gestation

Fetal death: a birth of 28 or more weeks' gestation that was not classified as a live birth

Birth weight: the original measurement of birth weight in pounds and ounces was converted into grammes and the infants were classified into birth weight intervals for the convenience of coding

Birth order: the mother's number of pregnancies including stillbirths

Age of mother: the mother's age at last birthday

Month, year: the month and year of the infant's birth.

All mean birth weights were estimated from the grouped data by using the centre of the class intervals or the end points of 1,000 grammes and 4,500 grammes. This type of calculation of a mean from grouped observations includes a certain amount of error due to the assumption that the frequencies are concentrated at a single point for each interval. For the means estimated here, this type of inaccuracy is minimized by the use of rather small intervals which

include large numbers of observations.

The length of gestation on the New York State birth certificates for the years 1959-67 was not considered to be accurate enough for analysis and, clearly, birth weight is associated with length of gestation. Therefore separation of these two variables was not possible. In the discussion that follows, one should keep in mind that the association between birth weight and the other variables investigated may be in whole or in part a reflection of a relationship with length of gestation rather than due to factors related only to birth weight itself.

BIRTH ORDER AND MOTHER'S AGE

The mean birth weight rises sharply as maternal age increases to 30 and then increases at a much slower rate for infants born to mothers over 30 (Fig. 1). A similar pattern is observed when birth weight is plotted against birth order. This similarity is certainly expected since maternal age and the birth order of an infant are highly correlated. A more complete picture emerges when the birth weight of the infant is classified into a two-way table so that the joint effects of mother's age and birth order can be separated (Table I and Fig. 2).

Within each birth order there are large differences in the mean birth weight for different ages of the mother. Also for each maternal age group there are considerable differences in the mean weight for each

FIG. 1.—Mean birth weight (grammes) by maternal age.

birth order. These data indicate that the influences of birth order and maternal age associated with these differences are not independent. In young mothers (less than 20 years old), the effect of increased values of birth order is accompanied by decreases in the mean birth weight. The opposite effect is observed in the birth weight of infants born to older mothers. For these mothers the mean birth weight increases with increasing values of birth order. In the light of this interaction, no general inference can be made about the direction of the influence of birth order on birth weight without reference to particular age categories.

FIG. 2.—Mean birth weight at each maternal age for the six birth orders. *Maximum birth weight within a birth order group.

As maternal age increases from age 20–24, the influence of birth order is progressively stronger and is associated with increased birth weight of the infant (Fig. 2). The influence of increased birth order for mothers less than 20 years of age is also strong but, as mentioned before, it is associated with a decrease in birth weight.

The influence of maternal age on birth weight shows a fairly consistent effect of about the same magnitude for each individual birth order. Within the birth orders 1 through 5, the mean birth weight increases to a maximum and then decreases with increasing maternal age (Fig. 2). Birth weight increases consistently with increased maternal age for the infants of birth order 6 and over. In the first five birth orders the younger and older mothers have, on the average, the lightest infants within each birth order group. These two groups of women differ from the remaining women of the same birth order group by the average interval between their pregnancies. In any specific birth order, young mothers have shorter mean intervals between pregnancies than other women, and older mothers have on the average longer intervals between pregnancies. From this point of view, a lower average birth weight is associated with maternal groups experiencing both long and short intervals between pregnancies. A similar association was noted by Yerushalmy (1945) between the survival of the infant and the interval between successive pregnancies.

The maximum mean birth weight for each birth order occurs at increasing maternal age levels for each successive birth order. The age groups that have the largest or next to largest number of mothers for a given birth order group show the highest birth weights for birth orders 1 to 4. The mean birth weight for birth orders 5 and 6 and over do not show

TABLE I

ESTIMATED MEAN BIRTH WEIGHT (g) OF LIVE BIRTHS AND NUMBER OF OBSERVATIONS FOR EACH BIRTH ORDER AND MATERNAL AGE CATEGORY FROM NYS BIRTH CERTIFICATES 1959–67

Birth Order	Maternal Age (yr)						Mean
	< 20	20–24	25–29	30–34	35–39	> 40	
1	3,281 (103,841)	3,305 (202,977)	3,291 (61,839)	3,258 (19,131)	3,225 (7,481)	3,202 (1,874)	3,293 (397,143)
2	3,278 (25,842)	3,354 (171,531)	3,371 (114,558)	3,356 (41,650)	3,322 (15,448)	3,303 (3,419)	3,352 (372,448)
3	3,280 (4,200)	3,360 (78,886)	3,397 (116,647)	3,390 (68,390)	3,374 (27,948)	3,335 (6,184)	3,381 (302,255)
4	3,220 (512)	3,345 (26,952)	3,405 (70,718)	3,422 (61,263)	3,412 (30,295)	3,392 (7,386)	3,402 (197,126)
5	3,202 (52)	3,332 (7,726)	3,399 (33,719)	3,434 (39,486)	3,435 (23,867)	3,417 (6,610)	3,417 (111,460)
6+	•	3,315 (2,555)	3,398 (23,395)	3,443 (46,034)	3,467 (41,240)	3,482 (15,141)	3,444 (128,365)
Mean	3,280 (134,447)	3,334 (490,627)	3,376 (420,876)	3,398 (275,954)	3,405 (146,279)	3,405 (40,614)	3,361 (1,508,797)

*Only four observations

FIG. 3.—Seasonal trend of mean birth weight of live births.

this association between the maximum birth weight and the modal maternal age group as clearly, but this is probably a result of the way the data are grouped. This type of association between a characteristic like birth weight and the most normal value is probably a consequence of natural selection, as pointed out by Karn and Penrose (1951–52) in their study of the relationship between infant mortality and birth weight.

SECULAR AND SEASONAL TRENDS

The seasonal trend of the mean birth weight for live births is given in Table II and Fig. 3. Infants born in the summer months (June, July, and August) have significantly lower than average birth weights. The infants with the highest mean birth weight are born in the months of March, April and May. The standard error of the mean for each month is approximately 1.6 g. This seasonal pattern remains constant when the infants are separated by birth order (Fig. 4) with the exception of February. The difference between the mean for the month of February and the overall mean for each birth order generally

FIG. 4.—Seasonal trend of mean birth weight for live births for the six birth orders.

increases with each successive birth order. For example, among February births this difference is zero for birth order 1, whereas in birth order 5 the

TABLE II
SEASONAL TREND OF MEAN BIRTH WEIGHT (g) OF LIVE BIRTHS FOR BIRTH ORDERS 1 TO 6+ AND FETAL DEATHS

	Month of Birth											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Birth order 1	3,286	3,293	3,295	3,304	3,301	3,292	3,286	3,285	3,297	3,301	3,294	3,277
2	3,347	3,357	3,357	3,367	3,358	3,351	3,343	3,339	3,352	3,355	3,361	3,341
3	3,383	3,386	3,388	3,404	3,390	3,372	3,373	3,369	3,373	3,372	3,388	3,374
4	3,400	3,413	3,415	3,418	3,415	3,388	3,384	3,396	3,400	3,406	3,404	3,387
5	3,408	3,451	3,419	3,423	3,426	3,413	3,406	3,405	3,413	3,417	3,420	3,407
6+	3,443	3,468	3,456	3,454	3,453	3,443	3,426	3,430	3,443	3,441	3,448	3,431
All live births	3,359	3,371	3,368	3,375	3,369	3,356	3,350	3,350	3,360	3,363	3,367	3,350
Fetal deaths	2,443	2,465	2,488	2,457	2,397	2,430	2,448	2,402	2,525	2,468	2,481	2,447
Total no.	122,178	116,221	129,982	125,711	129,905	126,158	133,093	133,832	132,482	129,750	121,154	123,763

FIG. 5.—Seasonal trend of mean birth weight of fetal deaths.

difference has increased to 34 g. The birth weight of fetal deaths is expectedly much lower and more variable but seems to follow a pattern similar to that of the live births (Fig. 5).

The secular trend in live birth weights for the period 1959–67 is given in Table III. An average downward trend is shown in Fig. 6 for all live born infants. The effect of possible changing family patterns (e.g., less children born of high birth order) during the period 1959–67 was eliminated as a source of variation in mean birth weight by the separation of the data into individual birth orders. The same secular trend was detected for all birth orders (Table III), as is seen in Fig. 6. In fact the rate of decrease seems to be slightly faster in the higher birth orders. The secular trend in the birth weight of fetal deaths shows an even more conspicuous downward trend.

DISCUSSION

The observation that increased birth order is associated with increased birth weight has been made by a number of authors using data from diverse populations (e.g., Karn and Penrose, 1951–52; Salber and

FIG. 6.—Secular trend in mean birth weight for live births.

Bradshaw, 1953; Fraccaro, 1956; Roberts and Tanner, 1963). Few studies have had available sufficient data to investigate the separate influences of birth order and maternal age. Karn and Penrose (1951–52) employed a sample of 13,730 births to examine the effects of these two variables. They found that birth order and maternal age had independent effects on birth weight, with birth order having a positive and strong influence and maternal age having a weaker and negative influence. The inconsistencies between this set of data and the present one are probably due to our use of a much larger number of observations, especially for young mothers of high birth orders. Fraccaro (1956) also discussed the joint effects of birth order and maternal age. He was able to make only a few cautious inferences because of the small numbers of observations in the extreme categories. Loeb (1965) employed over 800,000 births obtained from the entire United States (exclusive of Massachusetts) from 1 January 1950, through 31 March 1950, to study the relationship of weight at birth and survival of the newborn. There seem to be no evident major inconsistencies between the data

TABLE III
SECULAR TREND OF MEAN BIRTH WEIGHT (g) OF LIVE BIRTHS FOR BIRTH ORDERS 1 TO 6+ AND FETAL DEATHS 1959–67

	Year of Birth								
	1959	1960	1961	1962	1963	1964	1965	1966	1967
Birth order 1	3,296	3,302	3,295	3,288	3,291	3,293	3,289	3,290	3,291
2	3,361	3,368	3,357	3,350	3,345	3,355	3,349	3,340	3,341
3	3,391	3,398	3,390	3,381	3,373	3,378	3,374	3,368	3,364
4	3,425	3,420	3,407	3,400	3,398	3,398	3,388	3,383	3,386
5	3,425	3,436	3,426	3,411	3,415	3,418	3,410	3,400	3,401
6+	3,462	3,463	3,452	3,443	3,433	3,448	3,444	3,424	3,427
All live births	3,372	3,379	3,370	3,361	3,358	3,363	3,355	3,346	3,344
Fetal deaths	2,509	2,499	2,466	2,509	2,454	2,451	2,402	2,375	2,381
Total no.	180,005	180,362	180,687	175,164	173,313	170,789	162,186	153,170	148,553

for the United States as a whole and the data employed here. However, it is difficult to make a precise comparison since Loeb's main objective was to investigate survival. Her data differ from the New York State data in two important respects. First, if the seasonal trend observed here applies to the population studied by Loeb, her data have a seasonal bias, especially because it is deficient of births in the summer months when infants have a lower mean weight. Secondly, the single, white population of upstate New York, although not homogeneous, probably represents a more uniform population from a socio-economic point of view.

Roberts and Tanner (1963), in a sample of African infants, noted that males born in May to September were slightly heavier than those born in the remainder of the year but overall they saw no significant variations in birth weight either within months or between months. There are few other published data to compare with the observed seasonal pattern in New York State. Seasonal trends in birth data associated with various health-related variables, such as birth weight, generally are ascribed to environmental factors operating during gestation. In this respect, the low mean weight seen in June, July, and August might be a reflection of factors operating during the early stages of gestation in the fall and early winter months.

Ashford, Fryer, and Brimblecombe (1969) noted a secular trend in birth weight in data covering a 10-year period in England and Wales. In the years 1956 through 1965 the percent of birth weights less than 2,501 g decreased from 7.83 to 7.17. Similar to seasonal trend in birth weight, there are few published data on secular trend.

SUMMARY

Mean birth weight was found generally to increase with increases in both maternal age and birth order. When the joint influences of these variables

on birth weight were separated a more complicated picture emerged. Increasing birth order was shown to be associated with increased birth weight for mothers older than 20–24 years. But for mothers less than 20 years of age increasing birth order was associated with a decrease in birth weight. The influence of maternal age within birth orders 1 to 6 was associated with an increased birth weight up to maximum and then a decrease. For infants of birth order 6 and over, increased maternal age was related only to increased birth weight. The seasonal trend in birth weight was characterized by high-weight infants born in the months of March, April, and May and significantly low-weight infants born in June, July, and August. This seasonal pattern was consistent for all birth orders with the exception of February. The secular trend in birth weight was downward and this pattern was also consistent for all birth orders.

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