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Changing sex ratio in the United States, 1969–1995

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Objective: To determine if the sex ratio of live births in the United States has changed during the 27 years from 1969 through 1995.

Design: Regression analysis of secular trends in sex ratios.

Setting: Population-based data.

Patient(s): Liveborn infants in the United States 1969–1995.

Main Outcome Measure(s): Sex of liveborn infant.

Result(s): The sex ratio (number of male births divided by number of female births) declined significantly among whites during the 27 years under study. Among black newborns, the sex ratio significantly *increased* during the same time period.

Conclusion(s): These secular trends could not be explained by changing maternal or paternal age, or by changing proportions of specific birth orders. Possible explanations for the observed changes in sex ratio include random fluctuations in sex ratio over time, changes in demographic characteristics of the population (other than the characteristics controlled for in this analysis), and changes in frequency or timing of intercourse. Environmental exposures are unlikely to account for the observed trends. (Fertil Steril® 1998;70:270–3. ©1998 by American Society for Reproductive Medicine.)

Key Words: Sex ratio, vital statistics, time trends

Little is known about the factors that affect the sex ratio of humans (1). There is some evidence that the timing of intercourse relative to ovulation (2) and coital frequency (3) affect the probability of delivering an infant of a particular sex. Recently, Weinberg and colleagues (4) presented data and argued that follicular phase length actually explains differences in sex ratio attributed to these two factors. Demographic factors, such as birth order and race also are associated with the sex ratio in populations (5).

A number of environmental or occupational exposures of men have been examined in relation to the sex ratio of their offspring. Exposure to the nematocide dibromochloropropane among male factory workers (6) and exposure to a mixture of pesticides among male fruit growers (7) has been associated with a deficit in male offspring. Most recently, residents of Seveso, Italy, living in the area most heavily contaminated with dioxin from an industrial accident, had more female births than male (a reversal of the usual sex ratio) during the 7 years after the accident (8).

Investigators in Denmark (9) and Canada (10) have reported a decline in the sex ratio in their respective countries since the 1960s. To determine if the sex ratio has changed in the United States, we examined live births from 1969 through 1995.

MATERIALS AND METHODS

Data from birth certificates of liveborn infants are routinely compiled by the United States National Center for Health Statistics (NCHS), of the Centers for Disease Control and Prevention (CDC). Data on sex, live birth order of the infant, race, age, and geographic region of residence of the mother, and age of the father were obtained for the years 1969–1995. From 1969 to 1971 these data are based on a 50% random sample of live births obtained from each of the 50 states of the United States; from 1972 to 1984 the data are based on

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100% of live births from some states and a 50% sample of live births from other states; and from 1985 to 1995 the data consist of 100% of live births from each of the 50 states. Wherever a 50% sample was obtained by NCHS, the data files were adjusted to reflect the sampling.

Based on the literature on sex ratio the following variables were examined for an association with sex ratio: maternal age, paternal age, birth order, and race. Mother's age was categorized as <18 years, 18–19 years, 20–24 years, 25–29 years, 30–39 years, or ≥40 years; the father's age was categorized as <40 years, 40–49 years, ≥50 years, or unknown; birth order was categorized as first birth, second, third, fourth and higher, or unknown. Race of the mother was categorized as white, black, or other race. We also examined trends in the sex ratio within nine different geographic regions of the United States: New England, Middle Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, or Pacific.

The association between year of birth and the sex ratio was modeled with the use of logistic regression with race, birth order, maternal age, and paternal age considered as potentially confounding or effect-modifying variables. Because a significant interaction between race and year of birth was found, models were estimated separately for women of black race, white race, and other race. The odds ratios (ORs) for year were obtained by taking the antilog of the parameter estimate for year (11). Therefore, the OR for year represents the estimated change in the sex ratio (the odds of being male) for each calendar year from 1969 to 1995.

To summarize the change in the sex ratio over the 27-year period, adjusted for covariates, we multiplied the year coefficient by 27 before taking the antilog (11). An OR >1.0 indicates an increase in the sex ratio and an OR <1.0 indicates a decrease in the sex ratio over the period studied. We then estimated region-specific changes in the sex ratio, adjusting for covariates by including in each race-specific logistic model a variable for each region (using the largest region as the reference group) and an interaction term for each region with year. We did not estimate region-specific changes over time for live births to women of other races because of small numbers. This study was exempt from review by the institutional review board because it involved analyses of aggregate data only; no individuals were identifiable.

RESULTS

The sex ratio for all live births in the United States in 1969 was 105.3 males born for each 100 females born and declined to 104.9 males for each 100 females in 1995. Each year's data represent 3–4 million births. If the sex ratio in 1995 had been the same as the sex ratio in 1969, approximately 3,771 female infants would have been male infants.

When analyzed separately by race, however, the decline in sex ratio was found only among births to white mothers (Fig. 1). Controlling for maternal age, paternal age, and birth order, the sex ratio significantly declined among live births to white mothers but significantly increased among live births to black mothers and mothers of other races (Table 1). The adjusted change in the sex ratio over the 27-year period was small but was consistent among the nine geographic regions of the United States (Table 2). Within each of the nine regions, the sex ratio declined among live births to white women and increased among live births to black women. The only exception to these trends was that the sex ratio declined among black women in the Pacific region.

DISCUSSION

From 1969 through 1995 we found a significant decline in the sex ratio among live births to white mothers. During the same period the sex ratio among live births to black mothers increased. These trends persisted after adjustment for changes in demographic variables associated with the sex ratio, i.e., maternal age, paternal age, and birth order. With one exception, these race-specific trends also were observed within each of the nine regional divisions of states in the United States.

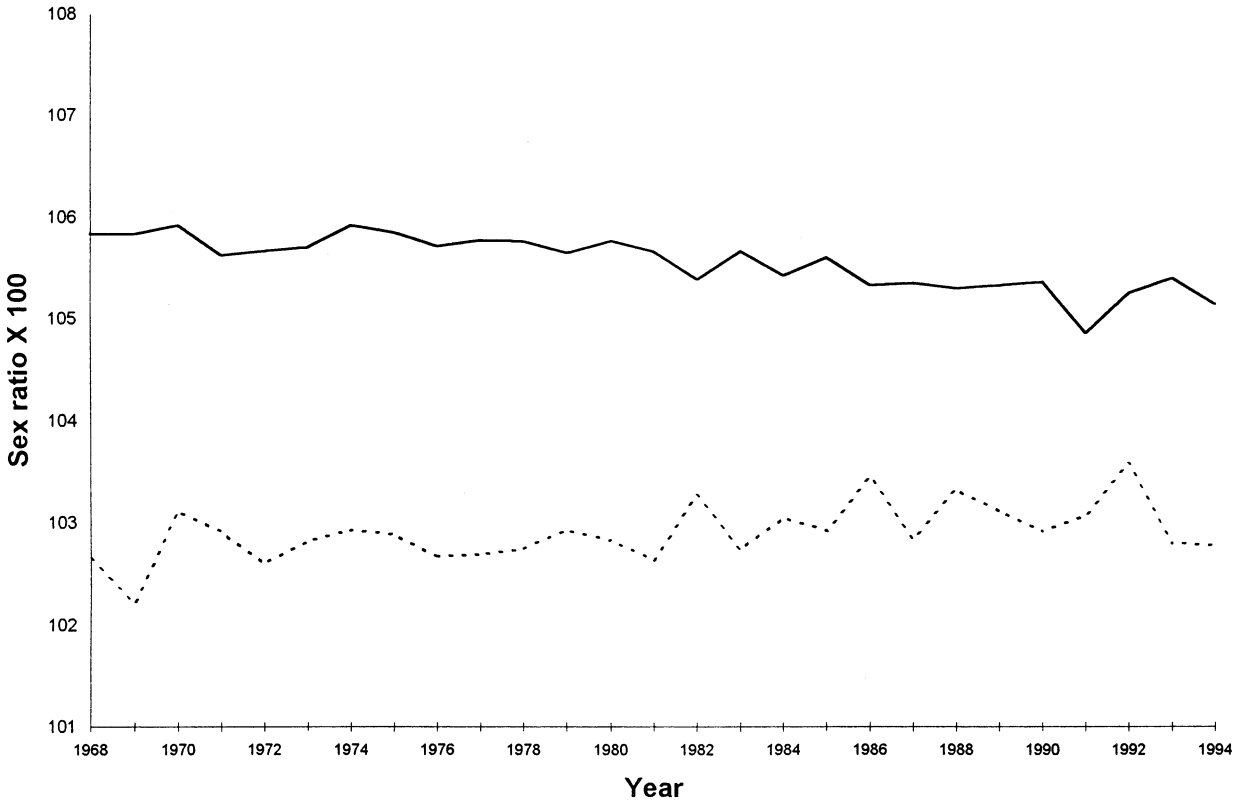
We explored the possibility that the decline in the sex ratio might be due to an increase in induced abortions. Because first births are more likely to be male than subsequent births, we considered the possibility that an increase in induced abortions of first births from 1969 to 1995 might explain some of the decline in sex ratio among whites during this time. If this were the case, then we would expect there to be an interaction between birth order and year because first births in later years would include a higher proportion of second pregnancies, less likely to be male. No such interaction was observed.

There are several biologic mechanisms by which a change in the sex ratio could occur. On the maternal side of the equation, the receptivity of the vaginal mucosa or the endometrium may differ for X-bearing sperm and Y-bearing sperm, or there may be selective survival of conceptuses of a particular sex (4). On the paternal side, the relative production or survival of sperm bearing X or Y chromosomes may have changed over time. Characteristics of sperm, such as survival time and motility, differ depending on which chromosome they bear, and these characteristics may interact with the maternal environment to alter the sex ratio over time.

We found that black mothers were less likely to have male offspring than white mothers during the entire period. There is some evidence that black women have higher estrogen levels during pregnancy (12) and when not pregnant (13). Black women also have higher testosterone levels during pregnancy (12). James (1) has argued that parental

FIGURE 1

Sex ratios for white and black live births, United States, 1969–1995. ——— white -------- black.



hormone levels influence the sex of their offspring, but there are very few human data to support or refute this hypothesis.

We found a convergence over time in the sex ratio of infants born to white mothers compared with the sex ratio of infants born to black mothers. One possible explanation for this convergence in sex ratios is a simple mixing effect. The proportion of births to parents of different races was only 1% in 1969 and had increased to 4% by 1992 (the most recent year for which these data were available). In 1992, approximately equal numbers of these interracial births were to white mothers (with black fathers) and to black mothers (with white fathers). Thus, we would expect the increase in sex ratio to be greater for black mothers than the decrease in sex ratio for white mothers because of the smaller number of births to black mothers. However, we found that the adjusted

TABLE 1

Odds ratios for the change in sex ratio among live births by race of mother, United States 1969–1995.

Race of mother	Average no. of live births	Odds ratio*	95% Confidence interval
White	2,949,359	0.9935	0.9919–0.9952
Black	579,470	1.0208	1.0162–1.0254
Other	123,134	1.0122	1.0035–1.0210

* Calculated for 27-year period; adjusted for maternal age, paternal age, and birth order.

TABLE 2

Odds ratios for the change in sex ratio among live births by race of mother and region, United States 1969–1995.

	Odds ratio*	
Region	White	Black
Pacific	0.9952	0.9922
New England	0.9927	1.0157
Middle Atlantic	0.9957	1.0205
East North Central	0.9898	1.0271
West North Central	0.9909	1.0243
South Atlantic	0.9971	1.0149
East South Central	0.9959	1.0382
West South Central	0.9941	1.0430
Mountain	0.9943	1.0106

* Calculated for 27-year period; adjusted for maternal age, paternal age, and birth order.

increase in the sex ratio for black mothers (OR 1.02) was smaller than the adjusted decrease in the sex ratio for white mothers (OR 0.994).

It has been suggested that the decline in the sex ratio noted in some European countries may be due to environmental exposures (14). A number of environmental exposures alter the sex ratio in humans. The offspring of pesticide-exposed men were less likely to be male than those of unexposed men (6, 7). Dioxin-exposed residents of Seveso, Italy, had a lower sex ratio than nonexposed Italian residents (8) and consistent with James' (1) hypothesis, male workers exposed to dioxin had decreased testosterone (15).

Because we found that in the United States the sex ratio declined only among white newborns and increased among black newborns, a pervasive environmental exposure is an unlikely explanation. However, because environmental exposures may be different among blacks and whites, an environmental contribution to these changes cannot be ruled out.

At present we must be satisfied with characterizing the presence of this phenomenon and speculating on its possible causes. Even so, it is worth evaluating the public health significance of these findings. On the surface it does not seem that a change in the sex ratio of <1 male per 100 females merits a great deal of concern. Yet even this small alteration in the sex ratio represents nearly 4,000 newborns per year for the United States as a whole. If the changes in sex ratio are a consequence of alterations in endocrine function, other hormone-dependent physiological processes may be affected. We hope these observations will stimulate additional research on the determination of sex ratios in humans.

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