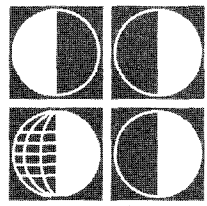
Human Sex Ratio
As It Relates to Caloric Availability



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ABSTRACT: **The relationship between human sex ratios at birth and caloric availability per capita was examined across different countries. Significant positive correlations were obtained between the amount of food a country had available and the percentage of male births. Furthermore, increases or decreases in a country's caloric availability were related to corresponding changes in that country's sex ratio. These results provide evidence of adaptive sex ratio biasing in humans. The physiological mechanism by which this effect operates is probably higher mortality rates for male embryos and fetuses as a result of nutritional deficiencies and associated stressors.**

Evolutionary theory suggests that many structural features and behaviors of an organism have adaptive significance by means of their ability either to increase that organism's ability to survive or to increase its reproductive output. Influencing the sex ratio of offspring is one way that some organisms can increase their reproductive success (Charnov, 1982; Maynard Smith, 1978; Williams, 1975). In polygynous systems where only the fittest males reproduce, parental investment in a son of good quality may yield greater returns than comparable investment in a daughter of good quality. A mother might therefore prefer to produce sons when she has the resources necessary to give them a better than average competitive ability, and daughters when she does not.

There is convincing evidence that invertebrates manipulate the sex ratio of their offspring so as to maximize their own fitness (Charnov, 1982). In haplodiploid species, mothers can directly influence the sex ratio by fertilizing eggs so they will develop into females and leaving unfertilized eggs to develop into males. Although the evidence is less consistent, and the magnitude of the effect tends to be smaller, there is evidence that sex ratio variation also occurs in some birds (Clutton-Brock, 1986) and some mammals (Clutton-Brock and Iason, 1986).

In humans, there has been very little study of whether adaptive variation in the sex ratio occurs. Nevertheless, many factors known to be associated with variations in the sex ratio at birth appear to have adaptive value. Fewer males are born with increasing birth order (James, 1987*a*; James and Rostron, 1985; Ruder, 1985) or multiple births (Bulmer, 1970; James, 1975), perhaps because of greater sibling competition for resources. Fewer males are born with increased paternal age, and, to a lesser extent, with increased maternal age (James, 1987*a*; James and Rostron, 1985; Ruder, 1985). More males are born in the spring and summer when food is more plentiful (Colombo, 1957; James, 1984*b*). More males are born during and after wars when there is decreased male-male competition for mates (James, 1987*a*; MacMahon

and Pugh, 1954). Fewer males are born to fathers with high levels of stress (Little, Rigsby, and Little, 1987; Schuster and Schuster, 1972). Couples with low coital rates are less likely to produce males (James, 1983; 1986; 1987*b*) (less fit males, either because of age or dominance status, are likely to have lower coital rates).

The above evidence suggests that adaptive variation of the human sex ratio does occur. The purpose of the present study is to determine whether human sex ratio variation also occurs as a function of caloric intake. Because there is a direct positive relationship between a mother's prepregnancy weight and the birth weight of her baby (Magnus et al., 1984; Peckham and Christianson, 1971), it might be expected that more males would be born to mothers with high caloric intake, and fewer males to mothers with low caloric intake. Although fertility and twinning rates in humans are related to the mother's percentage of body fat (Frisch, 1988; Campbell et al., 1974), the relationship between caloric intake and sex ratio has not been directly investigated.

The few studies relevant to this issue have not supported the prediction. No changes in the sex ratio occurred in the United States during the 1930's Depression (Ciocco, 1938), in Leningrad following the 1942 siege (Antonov, 1947), or in Holland following the famine of 1944–45 (Stein and Susser, 1978). On the basis of these studies, James (1987*a*), in his review of the factors affecting the sex ratio, concluded that nutrition did not likely have an effect. However, there is reason to reexamine this evidence. The fetus is extremely efficient at extracting calories in short-term periods of deprivation (Hytten, 1983). The famine in Leningrad lasted only six months and the one in Holland, seven months. Follow-up studies of children born during the Dutch famine show them to be "well grown" (Hytten, 1983) and with no intellectual deficits at age 18 (Stein et al., 1975), which is consistent with the possibility that these famines were of too short a duration to affect the sex ratio.

In any case, the effects of short-term famines in developed countries is only one way of investigating the relationship between caloric intake and sex ratio. The present paper reexamined this issue by looking at the relation between various country's caloric supply per capita and their sex ratio at birth. Since some countries consume twice as many calories per capita as other countries, this approach not only permits examination of whether malnourished countries have a lowered sex ratio, but also whether countries that overconsume have a higher sex ratio. Furthermore, because many of these consumption patterns are long-standing (i.e., Western overconsumption and Third World underconsumption), the potential for actual alteration in the sex ratio should be higher.

MATERIALS AND METHODS

Information on a country's caloric supply per capita (as a percentage of requirements) for the years 1975 to 1980 was obtained from the World Tables published by the World Bank (1983). For the years 1982 to 1984, this information was obtained from World Resources by the International Institute for Environment and Development and the World Resources Insti-

tute (1987). Information on the number of female and male live births from 1967 to 1986 was obtained from the United Nations Demographic Yearbook for 1986. All available countries were included in the analysis unless information on either caloric availability or sex ratio was not available, or if the country had fewer than six thousand births per year. Also, because birth records were of questionable accuracy in some developing countries, it was decided beforehand that sex ratio outliers ± 3 standard deviations from the mean would also be excluded (resulting in the exclusion of 5/222 countries).

Two types of calculations were done.

1. A Pearson product-moment correlation was calculated between the average caloric supply per capita for a two-year period and the percentage of male births for the second year. This procedure allowed for the possibility that sex ratio variation might occur either at the point of conception or by differential mortality during pregnancy. Three sets of years were examined: (*a*) caloric availability for 1976 and 1977 as it related to percentage of male births for 1977; (*b*) caloric availability for 1979 and 1980 as it related to percentage of male births for 1980; and (*c*) caloric availability for 1982 to 1984 as it related to percentage of male births for 1984.

2. The second calculation used a Pearson product-moment correlation to examine whether changes in a country's caloric availability were associated with changes in its sex ratio. Countries were included in this analysis only if they had a stable three-year period where their caloric supply varied by less than 5 per cent. The change in the average caloric supply from this three-year period to the subsequent two-year period was correlated with the change in the percentage of male births from the third year of this three-year period to the second year of the subsequent two-year period.

RESULTS

1. (*a*) A nonsignificant correlation coefficient of 0.140, $p > 0.05$ ($df = 59$) was obtained between average caloric availability for 1976 and 1977 and percentage of male births for 1977. (*b*) A significant correlation coefficient of 0.365, $p < 0.01$ ($df = 57$) was obtained between average caloric availability for 1979 and 1980 and percentage of male births for 1980. (*c*) A significant correlation coefficient of 0.369, $p < 0.01$ ($df = 45$) was obtained between average caloric availability for 1982 to 1984 and percentage of male births for 1984.

2. A significant correlation coefficient of 0.524, $p < 0.01$ ($df = 48$) was obtained when the change in caloric supply from a stable three-year period to the two subsequent years was correlated with change in percentage of male births from the third year of this three-year period to the second year of the subsequent two-year period. The data for this calculation are presented in Figure 1.

DISCUSSION

The results are largely consistent with predictions of adaptive sex ratio biasing. Countries with lower caloric availability or who experience a sudden decrease in caloric availability tend to have a lower percentage of male births. Countries with higher caloric

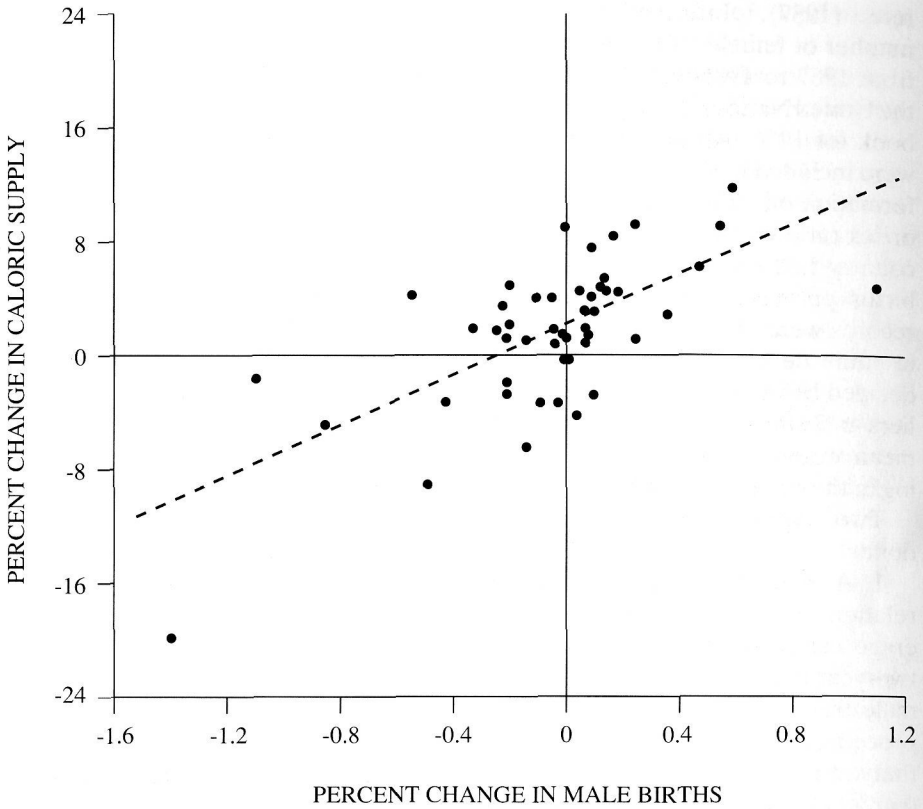

FIG. 1.—Relation between change in caloric supply from a stable three-year period to the two subsequent years, and change in percentage of male births from the third year of this three-year period to the second year of the subsequent two-year period. Each data point represents one country.

availability or that experience sudden increases in caloric availability tend to have a higher percentage of male births. Although deviations from the average percentage of 51.33 per cent are small (standard deviation of only 0.55 per cent), a small deviation translates into many thousands of excess male or female births in populous countries.

The percentage of variance accounted for by changes in caloric supply is less than 28 per cent. However, there are several confounds that may have diminished the magnitude of these correlations. One is the exclusion of many of the most impoverished countries because of the unavailability of birth and/or caloric supply data. Only 13 per cent of the countries included in the analysis had caloric supplies below 100 per cent of requirements, whereas the World Tables indicate that in 1980 this occurred in 36 per cent of all countries. A related problem concerns the overrepresentation of countries with caloric oversupply. Fifty-four per cent of countries included in the analysis had caloric supplies greater than 120 per cent of

requirements. Changes in caloric supply from 120 to 130 per cent might be expected to influence sex ratios less than a change from 80 to 90 per cent. Furthermore, gross obesity during pregnancy is a risk factor for birth and pregnancy complications that may decrease the likelihood of a live male birth (Peckham and Christianson, 1971; Gillmer, 1983). Another problem concerns the practice of female infanticide and failure to report female births that occurs in some developing countries (Repetto, 1972; Jeffery et al., 1984). A final issue concerns the problematic relationship between caloric availability and caloric intake. The availability of food within a country does not ensure equal distribution of the food, nor does it ensure consumption of the food.

The mechanism of this effect on sex ratio is uncertain. Although the effect could possibly be operating through a third variable such as parental age, parity, or race (James, 1984*a*; 1985), the evidence that changes in caloric supply are related to changes in the sex ratio within the same country argues against a mediating variable. By the same token, it is possible that caloric availability may be mediating the relationships that exist between sex ratio and parental age, parity, and race.

Although the physiological mechanism of this effect could theoretically operate at either the point of conception or during the pregnancy, the latter possibility seems more likely. Maynard Smith (1978) has argued that there does not exist a plausible physiological mechanism by which diploid species could alter their sex ratio at conception. Furthermore, Reiss (1987) points out that in diploid species maternal control over the sex ratio at conception is always going to be actively opposed by the sperm. Altruistic sperm that allowed themselves to be correctly identified by the mother as Y- or X-bearing will not be chosen as often as sperm that can disguise their identity and pass as either X- or Y-bearing. On the other hand, there is good evidence that males have a greater mortality rate during pregnancy (Hassold et al., 1983; Jakobovits et al., 1987; Kellokumpu-Lehtinen and Pelliniemi, 1984; McMillen, 1979), although there are dissenters from this view (Huisjes, 1984). Although difficult to estimate, the percentage of male births at conception may be as high as 54.5 per cent (McMillen, 1979) which declines to 51.4 per cent at birth. Furthermore, malnutrition is a prenatal risk factor known to increase the likelihood of pregnancy complications, abortion, and stillbirth (Brasel, 1978; National Centre for Health Statistics, 1986; Worthington-Roberts et al., 1985).

CONCLUSIONS

This study found that the amount of food a country has available had a significant positive correlation with that country's percentage of male births in two out of the three time periods examined. Furthermore, increases or decreases in a country's availability of food from a stable three-year period was found to be significantly related to corresponding changes in that country's sex ratio at birth.

These results provide evidence of adaptive sex ratio biasing in humans. The physiological mechanism by which this effect operates may be higher mortality rates for male embryos and fetuses as a result of nutritional deficiencies during gestation.

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