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Brief Communication

Maternal Preconception Diet and the Sex Ratio

J. S. CRAMER[1] AND L. H. LUMEY[2]

Abstract Temporal variations in the sex ratio, or the ratio of boys to girls at birth, have been widely studied and variously attributed to social changes, conditions of war, and environmental changes. Recently, Mathews et al. ["You are what your mother eats: Evidence for maternal preconception diet influencing fetal sex in humans," *Proc. R. Soc. Lond. B* 275:1661–1668 (2008)] studied the direct evidence of individual pregnancies and established an association between the sex at birth and the mother's preconception diet. We examined the hypothesis using new evidence from the wartime famine in Holland in 1944–1945 and failed to show an association between maternal diet in pregnancy and the sex ratio. This makes a causal link highly improbable.

In most human populations there is a small excess of boys over girls at birth, or a sex ratio slightly greater than 1 (Russell 1936). In several industrialized countries this sex ratio has been falling over a long period (James 2000; Parazzini et al. 1998), and the reasons for this decline are not well understood. Trends in Denmark since 1850 and in the Netherlands since 1950 have been interpreted in terms of increasing reproductive hazards, such as environmental estrogens, but long-term developments in Germany have been attributed to other factors, such as nutrition or social changes (Bromen and Jockel 1997; Moller 1996; van der Pal et al. 1997). In addition, a number of studies suggest an increase in male births in conditions of war (Graffelman and Hoekstra 2000; and for the Netherlands, van den Broek 1997). A recent report by Mathews et al. (2008) that links the sex ratio to the maternal preconception diet is therefore of particular interest, the more so as the investigators make use of direct evidence from individual pregnancies.

Mathews et al. (2008) interviewed women who attended an antenatal clinic in southern England in the 1990s and, using a food frequency questionnaire, collected 721 retrospective reports of the usual diet before conception. The preconception

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Table 1. Monthly Births by Conception Period for Amsterdam, 1938–1948

Period	*Date of Conception*	*Total Number of Births*	*Births per Day*	*Mean Sex Ratio (SD)*[a]	*Mean % Male (SD)*[a]
Prewar	April 1937 to April 1940	38,175	34.41	1.056 (0.011)	51.3 (0.3)
War, no famine	May 1940 to October 1944	62,500	38.06	1.065 (0.009)	51.5 (0.2)
War and famine	November 1944 to April 1945	4,860	26.41	1.077 (0.029)	51.8 (0.7)
Early postwar	May 1945 to October 1945	12,479	68.94	1.073 (0.013)	51.8 (0.3)
Later postwar	November 1945 to March 1948	46,677	52.86	1.058 (0.008)	51.4 (0.2)
Entire period	April 1937 to March 1948	165,231	41.15	1.061 (0.005)	51.4 (0.1)

a. Mean sex ratio and mean % male are means of monthly values for the indicated period; the standard deviations of these means have been derived from the variation of the monthly values.

dietary intake of women delivering a boy was higher than that of women delivering a girl (with averages of 2,413 and 2,283 kcal/day, respectively), and 45% of women in the lowest third of food intake had boys against 56% in the highest third. These differences are statistically significant. There was no association with diet in early pregnancy. Mathews and colleagues interpreted this association as a causal link and suggested among other things that the secular decline in the sex ratio in industrialized countries may be due to slimming diets of young women.

Here we examine the hypothesis that a mother's diet around the time of conception and during pregnancy has a direct effect on the sex ratio using new data for the Dutch famine during the winter of 1944–1945.

Data and Methods

We use new data for the Dutch hunger winter of 1944–1945, namely, the monthly birth statistics for the city of Amsterdam from January 1938 to December 1948, as published by the Municipal Bureau of Statistics of that city (Gemeente Amsterdam 1938–1948). The data represent a large population living under uniform (but varying) conditions, with between 1,000 and 1,200 monthly births in normal years and about 600 in the worst months of the famine. The study period includes the war years, in particular, the famine of the 1944–1945 winter, during the last months of the German occupation, when food rations in Amsterdam dropped dramatically to a level of only 500 kcal/day (Trienekens 2000).

To trace the effects of war and famine, we examined the monthly births in Amsterdam for five distinct periods of conception, reflected by births nine months later: the prewar period, the war period without famine (starting with the German invasion of the Netherlands in May 1940), the war period with famine (starting in November 1944), the early postwar period (starting with liberation in May 1945), and the later postwar period (starting 6 months later, in November 1945). The precise delimitation of these periods is given in Table 1. The monthly data on fertility

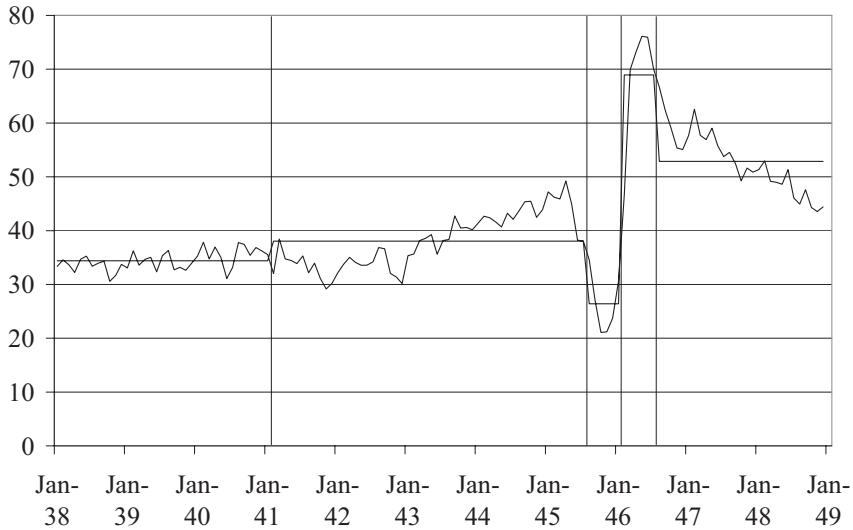

Figure 1. Daily number of births by month for five periods of conception for Amsterdam, 1938–1948 (see Table 1).

and the sex ratio are shown in Figures 1 and 2, and the mean values for the five periods are given in Table 1.

Results

Figure 1 shows a dramatic decline in fertility during the famine and an equally dramatic increase after the end of the war and of the German occupation. Although it is known that during the war conceptions responded to major events and the mood of the population (van den Brink 1949), the famine also caused widespread amenorrhea among women (Burger et al. 1948; Z. Stein et al. 1975).

Although the sex ratio is quite variable from month to month (as Figure 2 shows), its average level stays remarkably constant (as Table 1 shows) and is not affected by the condition of war or by the severe malnutrition of the famine months. It is easy to test the hypothesis that the sex ratio, or the proportion of male births, is the same for all five periods that we have distinguished. In each subperiod sample, given in the third column of Table 1, the number of male births has a binomial distribution, and this permits a likelihood ratio test of the hypothesis that the proportion of male births is the same for all five periods. This gives a test statistic of 0.64 for a chi-square distribution with 4 degrees of freedom. The hypothesis is maintained with flying colors.

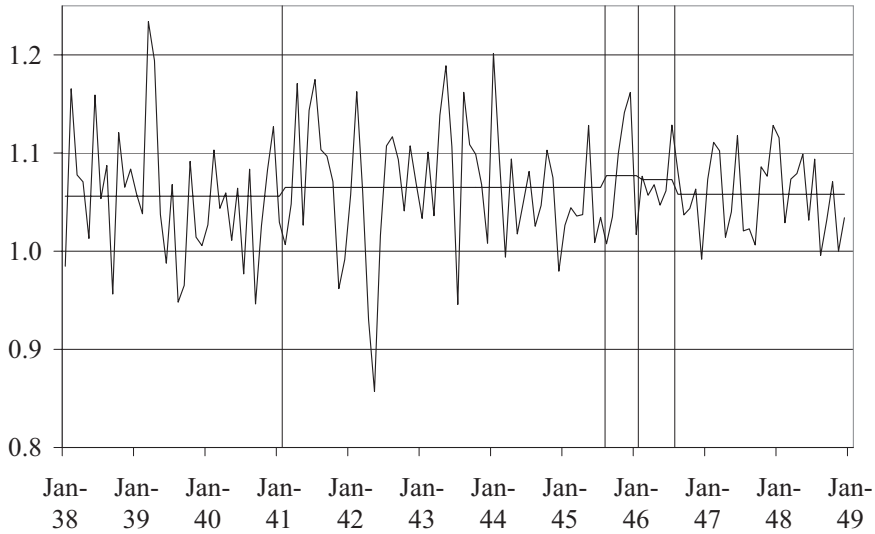

Figure 2. Sex ratio by month for five periods of conception for Amsterdam, 1938–1948 (see Table 1).

Discussion

Our results confirm the findings from two previous studies of the effects of the Dutch hunger winter, namely, the analysis of monthly birth data for six cities (Z. Stein et al. 1975, Appendix Table 1) and the study of 3,300 selected births in three birth clinics (A. D. Stein et al. 2004b). These results are also in line with recent findings from Africa (A. D. Stein et al. 2004a). In all these studies, the sex ratio is not affected by famine, in contradiction to Mathews's hypothesis. Nor is there any evidence of a war effect, as postulated by van den Broek (1997) for annual births in the entire Netherlands. We can therefore dismiss the hypothesis that the potential effects of malnutrition leading to a lower sex ratio could be offset by a contrary effect of war conditions.

These results do not invalidate the finding of Mathews et al. (2008); in their data there may be an association between maternal nutrition and the sex of the child. The results do, however, contradict any causal interpretation of that association.

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