Maternal undernutrition and the sex ratio at birth in Ethiopia: evidence from a national sample

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It has been suggested that maternal undernutrition results in facultative adjustment of the sex ratio at birth among humans, favouring females. We tested this hypothesis using data from the Demographics and Health Survey of Ethiopia for 2000. Our data provide at best limited support for the suggestion that maternal nutritional status is associated with the sex ratio at birth in humans.

Keywords: Ethiopia; sex ratios; humans; maternal nutrition

1. INTRODUCTION

Gibson & Mace (2003) recently suggested that maternal nutritional status, as measured by arm-muscle area (AMA) was associated with a preponderance of male offspring in a small ($n = 324$) series of births in the Arsi Zone, Oromiya Region, Ethiopia. They suggest that there is facultative sex-ratio adjustment related to the nutritional status of the mother. We sought to replicate their findings in other regions of Ethiopia, a country with wide regional variations in the prevalence of maternal undernutrition and subject to periodic food shortages.

2. MATERIAL AND METHODS

We analysed data from the Ethiopia Demographics and Health Survey (DHS), a large, nationally representative sample of women of reproductive age and their children under 5 years of age (Central Statistical Authority [Ethiopia], ORC Macro 2001). Fieldwork for the Ethiopia DHS was conducted in 2000. Heights and weights were measured using standard protocols, and a reproductive history was obtained by interview. A total of 15 367 women were studied, of which 15 228 had their height and weight measured and provided a reproductive history. This analysis is restricted to the 7223 women who reported at least one birth in the previous 5 years.

Following the protocol of Gibson & Mace (2003), we considered the sex of the most recent birth as the key outcome variable. First, we analysed the ecological relationship between the proportion of women with a body mass index (BMI) of less than 18.5 kg m^{-2} , a commonly used measure of chronic energy deficiency (WHO Expert Committee 1995), and the percentage of births that were male across the 11 regions of Ethiopia. We hypothesized that there would be an inverse association.

We also conducted individual-level logistic regression analyses, with the offspring sex as the dependent variable, and selected characteristics of the mother, namely:

- (i) BMI as a marker of current maternal nutritional status, categorized as less than 18.5, 18.5 to less than 20.0; 20.0 to less than 21.5 and greater than or equal to 21.5 kg m^{-2} ;
- (ii) the interval between the index pregnancy and the previous pregnancy as a marker of maternal depletion, categorized as less than 2 years, greater than or equal to 2 years, or first-born child;
- (iii) maternal height as an indicator of the mother's own nutrition in childhood, categorized as less than the 25th percentile or greater than or equal to the 25th percentile of the study sample; and
- (iv) maternal literacy (yes/no) and schooling (none, at least some primary) as indicators of her social standing and hence her ability to access resources during potential periods of deprivation.

We were unable to control independently for the effects of region and urban–rural residence, as the urban sample is almost exclusively from Addis Ababa, whereas the other regions are almost exclusively rural. All analyses were conducted in SPSS v. 11.0.

3. RESULTS

Figure 1 shows the percentage of births that were male across the regions. The prevalence of maternal undernutrition varied from 15% in the Addis region to upwards of 40% in the Gambela and Affar regions. A first-order linear regression suggests a very weak ($r^2 = 0.0057$), non-significant inverse relationship between the prevalence of BMI of less than 18.5 kg m^{-2} and the percentage of recent births that were male.

Table 1 shows the association between several putative nutritional stressors and the percentage of recent births that were male. For the national sample, there was no association between low BMI and the sex of the most recent child (odds ratio (OR) = 0.94; 95% confidence interval 0.84–1.04; $p > 0.05$). In the Oromiya and Amhara regions, but not in the other nine regions, low BMI was associated with reduced odds of the previous birth having been male.

Among possible nutritional stressors, having had a previous birth within 2 years, the present birth being the first, or being aged under 20 years or 35 years or over at interview were each associated with an increased odds of delivering a male child. The other factors were not associated with the sex of the index child. These trends were consistent in the Oromiya and Amhara regions, although the reduced sample size resulted in loss of formal statistical significance. Lack of any formal education was also associated with increased odds of delivering a male child in the Oromiya and in Amhara regions, but not elsewhere.

Adjustment for age and birth spacing made no difference to the size of the associations between BMI and offspring sex, both for the sample as a whole and within the Oromiya and Amhara regions (table 2).

4. DISCUSSION

Our data provide some limited support for the hypothesis that males are at higher risk of attrition *in utero* as a consequence of variation in maternal nutrition. However, our data, based on a much larger sample of Ethiopian births drawn using a randomized cluster approach, suggest much weaker effects than those reported by Gibson & Mace (2003), and marked local variation in the existence of any association. Of interest is that we did find an overall effect of low BMI on the sex ratio in the Oromiya region, which includes Arsi, the site of their study. Thus, although context may be important, the general relevance of the findings is suspect. We failed to replicate the finding of a relationship between current maternal nutritional status

Table 1. Association of selected markers of maternal nutrition with the proportion of males among recent births, Ethiopia 2000. (Notes: *n* refers to the number of individuals in each category. The reference categories are: BMI, greater than or equal to 18.5 kg m⁻²; first child or birth spacing, previous birth greater than or equal to 2 years prior; age, 25–29 years; height, greater than or equal to the 25th percentile; education, some. Each variable entered individually into logistic regression models. OR, odds ratio.)

	all of Ethiopia (<i>n</i> = 7223)			Oromiya region (<i>n</i> = 1341)			Amhara region (<i>n</i> = 1120)		
	<i>n</i>	OR	95% CI	<i>n</i>	OR	95% CI	<i>n</i>	OR	95% CI
BMI < 18.5 kg m ⁻²	1905	0.94	0.84–1.04	310	0.72	0.56–0.93	254	0.75	0.56–0.99
first child	1382	1.12	0.99–1.26	216	1.04	0.78–1.40	188	1.50	1.00–2.24
short birth spacing	1026	1.15	1.01–1.32	211	1.21	0.89–1.63	113	1.11	0.81–1.53
age < 20 years	429	1.28	1.04–1.58	77	1.51	0.91–2.48	90	1.46	0.90–2.35
age 20–24 years	1506	1.01	0.88–1.16	319	1.20	0.88–1.63	227	1.16	0.82–1.65
age 30–34 years	1414	1.05	0.92–1.21	260	1.03	0.74–1.43	194	1.23	0.86–1.78
age ≥ 35 years	1943	1.13	0.99–1.28	355	1.44	1.07–1.95	328	1.46	1.06–2.01
height < 25th percentile	1797	1.02	0.92–1.14	295	1.17	0.90–1.52	372	1.08	0.84–1.38
no education	5711	1.04	0.93–1.17	1110	1.24	0.93–1.64	982	1.32	0.93–1.89

Table 2. Association between maternal BMI at interview and the sex of her most recent delivery, Ethiopia, 2000, adjusted for potential determinants of maternal nutritional status.

(Notes: *n* refers to the number of individuals in each category. Adjusted for age (under 20, 20–24; 25–29; 30–34; 35 years or over); height (less than the 25th percentile; greater than or equal to the 25th percentile); birth spacing (first born, previous birth less than 2 years prior; previous birth greater than or equal to 2 years prior); education (some, none). OR, odds ratio.)

	all of Ethiopia (<i>n</i> = 7213)			Oromiya region (<i>n</i> = 1339)			Amhara region (<i>n</i> = 1119)		
	<i>n</i>	OR	95% CI	<i>n</i>	OR	95% CI	<i>n</i>	OR	95% CI
BMI < 18.5 kg m ⁻²	1905	0.98	0.86–1.12	309	0.74	0.54–1.02	254	0.71	0.50–1.02
18.5 ≤ BMI < 20.0 kg m ⁻²	1948	1.11	0.97–1.26	392	1.11	0.82–1.50	326	0.88	0.63–1.24
20.0 ≤ BMI < 21.5 kg m ⁻²	1698	1.05	0.92–0.20	326	0.99	0.72–1.35	303	1.03	0.73–0.46
BMI ≥ 21.5 kg m ⁻²	1665	1.00	(ref)	312	1.00	(ref)	236	1.06	(ref)

Figure 1. Percentage of most recent births that are male, by regional prevalence of BMI less than 18.5 kg m⁻² (Central Statistical Authority [Ethiopia], ORC Macro 2001).

and sex of the most recent live born in nine other districts of Ethiopia, many of which exhibit a prevalence of undernutrition of over twice that of the study sample of Gibson & Mace (2003). Furthermore, the results for BMI are in conflict with those of putative markers of maternal nutritional stress.

Our analysis was designed to take advantage of the heterogeneity in this much larger sample and enhanced generalizability of the DHS survey relative to the 324 mothers interviewed by Gibson & Mace (2003). One key difference between the two studies is that we did not have data on triceps skinfold thickness, as this was not measured in the DHS, and hence we could not calculate the AMA. We note that AMA is not widely used as a single indicator of nutritional status because it reflects both nutrition and exercise, but in lean populations it is associated with mid upper arm circumference and BMI (WHO Expert Committee 1995). Indeed, Gibson & Mace (2003) report that this measure was highly correlated with BMI in their sample, and that BMI was also inversely associated with prevalence of male offspring. Therefore, we do not consider this difference in the choice of measure of undernutrition to be critical to the interpretation.

Reasons for the discrepancy between our main results and those of Gibson & Mace (2003) remain unclear. One explanation might be chance. We note that the overall prevalence of chronic undernutrition in the Arsi population studied by Gibson & Mace (2003) was 20%, lower than that of the Ethiopian population in general (26%, range across regions of 15–40%), and that the ratio of male to female births was low overall, at 88 : 100, whereas the ratio for the country as a whole was 104.5 : 100. Hence, either that population is markedly anomalous, or

the sample analysed was unrepresentative. Several markers of nutritional stress, including both young and older age, and recent previous birth or first birth were associated with increased prevalence of male children. These findings run counter to any mechanistic explanation of facultative sex selection.

Both our study and that of Gibson & Mace (2003) suffer from the logical flaw that maternal nutrition was ascertained at up to 5 years after the index birth. Hence, both are susceptible to the counter-argument that in fact it is the sex of the offspring that affects maternal nutrition. As both studies followed the same protocol, this bias is common to both and cannot explain the divergent findings. Reviews of the available evidence show that the energetic costs of suckling may be greater for the mothers of male offspring in humans (Hrdy 1999) and other dimorphic mammals (Clutton-Brock 1991). Among some human population subgroups, male infants are breast-fed for longer (Koziel & Ulijaszek 2001) and it has been reported recently that women carrying male foetuses consume more calories (Tamimi *et al.* 2003).

We conclude that the strong association observed by Gibson & Mace (2003) may be unique, needs to be studied to understand the local context, is not characteristic

of births in Ethiopia and hence is likely not to be characteristic of humans in general. A modest association between poor maternal anthropometry and offspring sex ratio cannot be ruled out.

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