Prenatal sex selection and female infant mortality are more common in India after firstborn and second-born daughters

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ABSTRACT

Background The Indian sex ratio has become highly male-biased in recent decades. This may be attributed to prenatal sex selection (PSS) and excess female infant mortality. However, the question of whether these factors are related has not been adequately studied. Here we examine whether increased use of PSS may offset excess female infant mortality, by reducing the number of 'unwanted' daughters being born.

Methods We analyse the National Family Health Survey (NHFS) data sets for India, which contain nationally representative samples of birth histories for women aged 15–49, interviewed in 1992–1993, 1998–1999 and 2005–2006. We test for missing female births at the second and third birth order, by analysis of the frequencies of sibling sex combinations, and examine the mortality differential between male and female infants, controlling for household wealth and sex (es) of older siblings.

Results PSS was used most in wealthier households at the second and third birth order, when the firstborn, or firstborn and second-born, siblings were female. Having preceding female siblings was a significant risk factor for female infant mortality, but was not correlated with household wealth.

Conclusions PSS and female infant mortality increase with the presence of older female siblings, yet we find no evidence that increasing use of PSS prevents female infant mortality, because PSS and the proportion of female infant mortality attributable to having older sisters increased over the study period. Increased pressure on higher birth order females caused by the trend towards smaller family sizes may explain this.

INTRODUCTION

In India, there is a widespread cultural preference for sons. This is evident from larger family sizes in households with more daughters, which is due to families having more children in order to get the desired son or sons.[1–3] It is also evident from discrimination against daughters in terms of reduced childhood feeding, immunisation coverage, treatment seeking and nutritional status.[4–6] The cultural preference for sons has a socioeconomic and historical basis; but in particular, large dowry payments and a tradition of wives joining the extended family of the husband mean that daughters bring a lower future income to their parents.[7 8]

The sex ratio in India has become more male-biased in recent decades. This has been attributed to a high proportion of female infant deaths, resulting from high levels of neglect, abandonment and infanticide.[9–11] It has also been attributed to the use of prenatal sex selection (PSS) to get sons (typically involving abortion of female fetuses identified by an ultrasound scan).[12–15]

The contribution of PSS to the overall sex imbalance in India is related to socioeconomic status because the practice is more common in wealthier households. An analysis of National Family Heath Survey (NFHS data) found a significant and increasing excess of males among second births when the first birth was female, and a greater excess of males among third births when the first two births were female, between 1990 and 2005.[12] This was higher for mothers with 10 or more years of education and for the richest 20% of households. A study of the Indian National Sample Survey Organisation surveys (1983 and 2004–2005) similarly found that the odds of having a male infant aged 0–1 in the household was higher when the head of the household had a post-secondary qualification and when the household was in the top income quartile.[14]

It may be that wealthier families can afford the expense of PSS, for example, ultrasound scanning and abortion,[16] but it may actually be that the socially and economically disadvantaged couples want the highest proportion of sons.[2] However, there is no evidence that discrimination against females is higher among the poor,[10 17] although infant mortality overall is higher.[18]

Importantly for the Indian sex imbalance problem, the proportion of female infant mortality between the ages of 1 and 4 has been shown to have increased since the 1990s,[9] despite a decline in infant mortality overall. However, there has been a lack of research addressing this issue. In particular, the question of how excess female infant mortality varies with household wealth has not been sufficiently addressed.

There are several studies that have examined infant mortality risk according to the sex of previous siblings. First, a study of the 1992–1993 NHFS data found that having older sisters increased the risk of mortality for girls in some Indian states, though in other states, it was found that girls with older brothers were at greater risk.[3] This study excluded mortality in the first year of life, only studying mortality in children aged 1–5. Second, a demographic study of infant survival between the ages of 6 and 60 months in Matlab, Bangladesh, conducted in 1981–1982, showed that girls with two or more older sisters and boys with two older brothers had raised mortality (the effect was twice as high for girls), whereas children with siblings of the opposite sex had unusually low mortality.[19]

Third, analysis of the 2002–2004 Reproductive and Child Health Survey (RCH II) showed that female mortality between 1 and 60 months was lower after a male first birth than after a female first birth,[8] leading the author to conclude that a consequence of increasing use of PSS to get sons may be to reduce female infant mortality.

In this study, we use the available NFHS data to examine changes in the proportion of female infant mortality at the second and third birth order, from 1976 to 2005, between the ages of 0 and 12 months. We control for the sex(es) of previous siblings and household wealth and address three questions: (1) whether the proportion of female infant mortality depends on birth order and/or the sex of previous siblings, (2) whether it has changed over time and (3) whether any increase in PSS has resulted in a reduction in the proportion of female infant mortality. To examine the extent of PSS over the same period and also at the second and third birth order, we use a method of comparing the sex ratio of births against the binomial distribution, which allows a fine-grained statistical analysis of the effect of the sex of siblings and household wealth on the number of missing females.

METHODS

The 'birth's recode' data sets for the available NHFS data for India were downloaded from the Demographic and Health Surveys program website (http://dhsprogram.com/data/). The surveys were conducted in 1992–1993,[20] 1998–1999[21] and 2005–2006,[22] and provide a complete record of women's birth history, including information on the sex, health and survival of each child. An index of household wealth is also included, constructed from information on household assets and utility services and divided into quintiles, giving the richest, rich, middle, poor and poorest households.[23] In all analyses, mothers who had a multiple birth at the first, second or third pregnancy were excluded, because the sex ratio and infant mortality rate for multiple births differs from that of singletons.[24]

To compare sex ratios between groups, the expected proportion of each sibling sex combination was calculated according to the binomial distribution, for example,[25] but with the overall proportion of male births across all sex combinations determined from the proportion of male births at the first birth order, for the reason that the sex ratio of the first birth declined over the period, indicating that it was unaffected by PSS and therefore a good control (see figure 1). The difference between observed and expected values was tested using χ^2 goodness-of-fit tests.

We use the convention of reporting the sex ratio as the proportion of males, as this is most suited to statistical analysis.[26] This differs from the measure used by the Indian government, which is the number of females per 1000 males, and also differs from the MESH definition, which is the number of males per 100 females.

The influence of the sex of preceding siblings on the incidence of mortality (up to 12 months of age) for second-born and third-born males and females was tested using logistic regression analysis on the binary survival outcome, using the Generalized Linear Models (GLM) function in R (R Core Team. R: a language and environment for statistical computing. 2015). The interval between the focal and previous birth was controlled for, as short birth intervals are known to adversely affect infant survival, and our preliminary analyses indicated that birth intervals can differ according to the sex of previous children and household wealth (unpublished data, C. Gellatly).

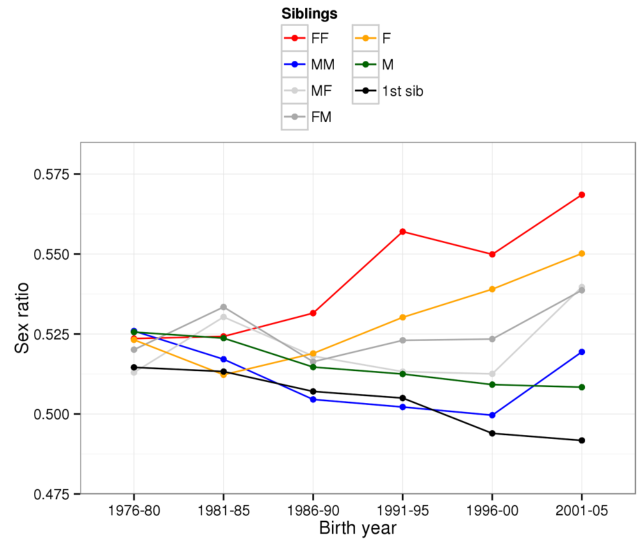

Figure 1 Sex ratio according to the sex(es) of older siblings. The first sibling sex ratio includes only firstborns to mothers with two or more children. The sex ratio of second-born and third-born children is shown according to the sex combination of their older siblings. Twins are excluded.

Individuals were included in the analysis only if older siblings were alive at the time of their birth because survival of children may be influenced by whether siblings are alive or dead.

The survival of infants was followed to 12 months of age. We did not examine infant mortality beyond this because we wanted to exclude the complicating factor of additional children being born into families. Individuals were only included in the analyses if they were born >12 months before the survey interview, to avoid data truncation.

RESULTS

Prenatal sex selection

The 1992–1993, 1998–1999 and 2005–2006 surveys were merged and families with twins removed, resulting in 168 169 families with firstborn and second-born children, and 101 705 families with firstborn, second-born and third-born children.

The sex ratio at the second and third birth order increased more between the early 1980s and mid-2000s if the preceding siblings were female (figure 1). Analysis of the first two births shows that there was a significant deviation from the binomial distribution by the 1986–1995 period, which had increased further by the 1996–2005 period (table 1). Inspection of the χ^2 residuals for the first two births shows that the deviation is driven by the higher-than-expected frequency of the female–male (FM) combination and the corresponding lower-than-expected frequency of the female–female (FF) combination, indicating that there were missing females among second births when the first birth was a female. In contrast, there is a negligible contribution to the χ^2 statistic of the MM and MF sex combination, indicating that no females were missing after a male first birth.

The magnitude of deviation from the binomial distribution is higher at the third birth order than at the second (table 2). The χ^2 residuals show that this is predominantly driven by the higher-than-expected frequency of the FFM combination and the corresponding lower-than-expected frequency of the FFF combination in the 1986–1995 and 1996–2005 periods. However, other combinations also make a significant

Table 1 Binomial goodness-of-fit tests for the first two births in families with two or more children

	Sex combinations					
	FF	FM	MF	MM	Total/χ^2	Sex ratio
1976–1985						
Observed	13 576	14 561	14 565	16 150	58 852	0.522
Expected	13 452	14 685	14 685	16 030	58 852	0.522
χ^2 residuals	1.14	1.04	0.98	0.90	4.05	
1986–1995						
Observed	17 508	19 244	18 955	19 976	75 683	0.516
Expected	17 847	18 905	18 905	20 026	75 683	0.514
χ^2 residuals	6.44	6.08	0.13	0.13	**12.77****	
1996–2005						
Observed	8596	10 118	9395	9676	37 785	0.514
Expected	9269	9445	9445	9626	37 785	0.505
χ^2 residuals	48.81***	47.89***	0.27	0.26	**97.24*****	

The expected values are calculated using the proportion of males in the first births. The χ^2 residuals are given at each sex combination and their significance calculated with 3 df and corrected for multiple testing using the Bonferroni method. The overall χ^2 statistic is calculated with 3 df and with no correction.
Significance codes: '**' < 0.01; '***' <0.001.

Table 2 Binomial goodness-of-fit tests for the first three births in families with three or more children

	Sex combinations									
	FFF	FFM	FMF	FMM	MFF	MFM	MMF	MMM	Total/χ^2	Sex ratio
1976–1985										
Observed	5001	5430	4887	5546	5044	5528	5472	5950	42 858	0.5157
Expected	4945	5212	5212	5495	5212	5495	5495	5792	42 858	0.5132
χ^2 residuals	0.64	9.09	20.31*	0.48	5.44	0.20	0.09	4.30	**40.55*****	
1986–1995										
Observed	6600	7695	6591	7175	6534	6941	6826	6913	55 275	0.5032
Expected	7232	7014	7014	6802	7014	6802	6802	6597	55 275	0.4923
χ^2 residuals	55.21***	66.20***	25.46**	20.47*	32.77***	2.85	0.09	15.18	**218.24*****	
1996–2005										
Observed	3047	3724	2857	3137	2783	3042	2721	2762	24 073	0.4909
Expected	3589	3180	3180	2817	3180	2817	2817	2495	24 073	0.4697
χ^2 residuals	81.92***	93.23***	32.72***	36.44***	49.46***	18.03	3.25	28.54**	**343.58*****	

The expected values are calculated using the proportion of males in the first births. The χ^2 residuals are given at each sex combination and their significance calculated with 7 df and corrected for multiple testing using the Bonferroni method. The overall χ^2 statistic is calculated with 7 df and with no correction.
Significance codes: '*' <0.05; '**' <0.01; '***' <0.001.

contribution to the overall deviation from the binomial distribution. In particular, FMF and MFF are lower than expected, whereas FMM and MMM are higher than expected. The significant deviation from the binomial distribution in the 1976–1985 period is primarily due to the lower-than-expected frequency of the FMF combination, which is somewhat unexpected given the pattern in later years, in which the biggest contribution to sex ratio deviation comes from the FFM combination.

In regard to household wealth and sex ratio at the second birth order, we see a significant percentage of missing females in the richest households by 1986–1995, which increased in magnitude by 1996–2005, when we also see a significant percentage of missing female births in the rich households (see online supplementary table S1). At the third birth order, we see a much higher percentage of missing female births spread more evenly across the household wealth categories (see online supplementary table S2). The major concentration of missing females is in the richest households, but the percentage of missing female births more than doubled in the middle, rich and richest households from 1986–1995 to 1996–2005, whereas there was possibly a decline in missing female births for the poor and poorest households over these periods.

Since PSS began to be widely practised in the 1980s, it seems there has been negligible use of the practice for first births. In fact, there was a significant overall decline in the sex ratio of first births (linear regression of sex on the year of birth between 1986 and 2005, in families with >1 child: b=−0.0038, R^2=0.121, F(1,93)=12.78, p<0.001) (figure 1).

Infant mortality

Infant mortality up to 12 months of age was significantly higher for second-born females in 1996–2005, when the firstborn child was female, as opposed to male (table 3). In contrast, the mortality hazard was significantly reduced for second-born males when the firstborn was female (p<0.01 in 1976–1985 and 1996–2005, p<0.1 in 1986–1995). Third-born females had significantly greater mortality hazard when the preceding siblings were both female, compared to when they were both male or mixed (1986–1995 and 1996–2005) (table 4). There is indication of a reduced mortality hazard for third-born males with two older female siblings in 1996–2005, as the overall factor

Table 3 Infant mortality hazard at the second birth order up to 12 months of age, according to the sex of the preceding sibling

Second-born	M				F			
Firstborn		F				F		
	M	Exp(B)	Sig.	n	M	Exp(B)	Sig.	n
76–85	1	0.8426	0.004**	26 731	1	1.0136	0.166	24 605
86–95	1	0.9030	0.087	33 996	1	0.9937	0.402	31 542
96–05	1	0.7971	0.006**	16 002	1	1.1996	0.015*	14 421

The model controlled for the interval between births. An exp(B)>1 indicates an increased hazard for second-born individuals when they have a female sibling, when compared with the reference category (male sibling). Significance codes: '*' <0.05; '**' <0.01.

Table 4 Infant mortality hazard at the third birth order up to 12 months of age, according to the sex of preceding siblings

Third-born	M					
Firstborn and second-born	MM		FF			
	Exp(B)	MM sig.	Exp(B)	FF sig.	Factor sig.	n
76–85	1.0664	0.401	0.8345	0.027*	0.064	16 919
86–95	1.0928	0.253	0.9515	0.510	0.383	21 790
96–05	1.1596	0.255	0.8030	0.090	0.034*	9105
Third-born	**F**					
Firstborn and second-born	**MM**		**FF**			
	Exp(B)	**MM sig.**	**Exp(B)**	**FF sig.**	**Factor sig.**	**n**
76–85	0.9522	0.560	0.955	0.580	0.629	15 370
86–95	0.9027	0.224	1.184	0.026*	0.003**	20 029
96–05	1.2600	0.094	1.349	0.019*	0.049*	8076

The model controlled for the interval between the second and the third birth. An exp(B)>1 indicates an increased hazard for third-born individuals when they have MM or FF siblings, when compared with the reference category (MF or FM combination). The factor significance gives the probability that the overall factor (ie, the sex combination of siblings) explains variance in infant mortality in the third birth. Significance codes: '*' <0.05; '**' <0.01.

(ie, sex combination of siblings) is significant ($p<0.05$), while the FF sex combination is close to significance ($p<0.1$). The effect of the birth interval was controlled for in these infant mortality tests because shorter birth intervals had a negative effect on survival of the next child (results not shown).

We tested the prediction that household wealth influenced the ratio of female to male infant mortality (see online supplementary tables S3 and S4). After correcting for multiple comparisons (Bonferroni method), the only significant result was an increase in the mortality hazard in middle-income families for second-born females after a firstborn female (exp(B)=1.51, $p<0.01$).

DISCUSSION

Here we show that the Indian sex ratio at birth became progressively imbalanced since about the early 1980s, due primarily to an increase in male births in the wealthiest households at the second and third birth order, when the firstborn or the firstborn and second-born siblings were female. It is likely that much of this was due to the use of PSS, as suggested in previous studies.[12–15] The magnitude of missing females was highest at the third birth order in the wealthiest households throughout the survey period, but was spreading across the spectrum of household wealth by the mid-2000s. At the second birth order, PSS was limited to the rich and richest households.

The existence of a firstborn or firstborn and second-born daughter significantly increased infant mortality for second-born and third-born females. The data do not allow for a breakdown of infant mortality by cause of death, but previous studies have highlighted neglect, abandonment and infanticide as causes of excess female infant mortality,[9–11] and it would seem that these are likely explanations for our findings. There is no obvious biological explanation for why females might suffer from the existence of preceding female rather than male siblings, other than if the birth interval is shorter after a female birth;[27] however, birth interval was controlled for in our statistical model, and does not explain the effect. The finding that infant mortality was lower for second-born and third-born males whose older living siblings were all female further indicates that sons, on average, receive preferential treatment over daughters, thereby enhancing their chance of surviving their first year. It should, nonetheless, be pointed out that males still suffer a higher rate of mortality during the first year in India, and this is common throughout the world, due to the inherent vulnerability of males.[28]

An international comparative study of the sex ratios of infant mortality found that India had the highest excess female mortality for children aged 1–4 years in 2012, while the estimated-to-expected childhood mortality rate for female infants was found to have increased between 1990 and 2012.[9] Here we find that the component of female infant mortality attributable to having older female siblings increased between the mid-1980s and mid-2000s, but we did not find any correlation between household wealth and the proportion of female infant mortality attributable to having sisters, which is in accordance with a previous study.[19] It has been suggested that preference for a son is higher in poorer households,[2] but the absence of any correlation between household wealth and excess female infant mortality and the high concentration of PSS in the wealthiest households may suggest otherwise. It should be pointed out, however, that our analyses stopped at the third birth order, and hence may not measure the effect of higher fertility in poorer households.

The upward trend in the use of PSS to get sons and the increase in the proportion of female infant mortality may be viewed in the context of the trend towards smaller family sizes in India over the past few decades, which has been driven by a combination of the demographic, economic and social changes that have occurred.[29] In the 1976–1985 period, we do not observe any effect of the sex of preceding siblings on infant mortality at the second or third birth order (except for lower mortality of second-born males who had a firstborn sister), but expectations of a larger family at that time may have meant that parents felt less pressure to have a son by the third (or even second) birth because they would have either expected, or felt able, to have a fourth or fifth child.

A critical assumption for our estimates of the number of missing female births (and thereby the magnitude of PSS) is that there was negligible use of PSS at the first birth order over the study period (because the proportion of males in first births was used to derive the expected frequencies of the sex combinations). An absence of PSS at the first birth was previously reported by Jha *et al.*[12] in the NHFS data, and we are also confident of this assumption because we see a marked decline in the sex ratio of the firstborn siblings over the study period (figure 1), which contrasts starkly with the increase in the sex ratio that we see at the second and third birth order when there are preceding female siblings.

It is interesting that the natural underlying sex ratio of the Indian population may have become more female-biased over the study period, given the decline in the sex ratio among first siblings (figure 1). This also indicates an advantage of the method we have used to evaluate missing female births, which does not make assumptions about what the natural sex ratio should be, for example, 950–975 girls per 1000 boys.[12] It is difficult to accurately state what the natural underlying sex ratio for a country should be, because it is known that the birth sex ratios of populations can undergo long-term fluctuations.[30]

A possible shortcoming in our results comes from the fact that they are based on retrospective interviews, which means that we cannot rule out the possibility of under-reporting of female births, particularly if they suffered infanticide. As such, there is some possibility that PSS is overestimated and that female infant mortality is underestimated and that this could also vary with household wealth. This type of bias has previously been reported for NFHS data.[31]

It has been shown that the introduction of legislation prohibiting PSS failed to prevent an increase in the practice in either India[14] or Nepal,[32] and it has been argued that certain policy directives aimed at preventing PSS are having the negative consequence of making it harder for women to access safe abortions.[33] Here we have shown that female infant mortality is higher under some of the same circumstances in which the use of PSS to get sons is most common, that is, after firstborn or firstborn and second-born daughters. This suggests that policies aimed at prevention of PSS must take into account potential adverse effects on female infants.

It was estimated in 2007 that 10000–12 000 women were dying each year in India from abortion-related complications.[34] It is likely that maternal deaths and ill-health caused by abortion-related complications have a greater impact on the survival of female than male infants, because the evidence tells us that the majority of sex-selective abortions involve women who have young daughters in their care. Inability of women to access safe abortion is therefore a potential cause of elevated female infant mortality.

What is already known on this subject

- There has been an increasing male bias in the Indian sex ratio over the past 50 years, and there is some evidence that the use of prenatal sex selection (primarily sex-selective abortion) and a high rate of female infant mortality are responsible. It is known that prenatal sex selection is most common among wealthier and better educated families and families who already have daughters. However, there has been a lack of research into whether excess female infant mortality is similarly correlated with either household wealth or the sex of preceding siblings. Moreover, the question of whether increased use of prenatal sex selection may have affected the extent of female infant mortality has not been sufficiently studied.

What this study adds

- Using data from the Indian National Family Health Surveys, we find that the proportion of female infant mortality and prenatal sex selection (as indicated by missing female births) increased over the study period (1970s to mid-2000s). We find no evidence that household wealth affected the proportion of female infant mortality, but find that prenatal sex selection was much more common in wealthier households with firstborn, or firstborn and second-born daughters. We find no direct demographic evidence that increased use of prenatal sex selection reduced the proportion of female infant mortality, because these both increased over the study period. We suggest that downward pressure on family sizes may have caused second-born and third-born daughters to become increasingly undervalued, because couples either planned to have fewer children or were unable to support a larger family, yet still had a strong desire to have a son.

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