Trends in missing females at birth in India from 1981 to 2016: analyses of 2·1 million birth histories in nationally representative surveys

Nandita Saikia, Catherine Meh, Usha Ram, Jayanta Kumar Bora, Bhaskar Mishra, Shailaja Chandra, Prabhat Jha

Summary

Background Half of the world's missing female births occur in India, due to sex-selective abortion. It is unknown whether selective abortion of female fetuses has changed in recent years across different birth orders. We sought to document the trends in missing female births, particularly among second and third children, at national and state levels.

Methods We examined birth histories from five nationally representative household surveys (National Family Health Surveys 1–4 and District Level Household Survey 2) to compute the conditional sex ratio (defined as the number of girls born per 1000 boys depending on previous birth sex) in India during 1981–2016. We estimated decadal variation in conditional sex ratio for 1987–96, 1997–2006, and 2007–16, and quantified trends in the numbers of missing female births for the states constituting >95% of India's population, as well as in 5-year intervals for each survey round. We used multivariate logistic regression to calculate the odds ratio of a second (or third) girl depending on the sex of the earlier child (or children), adjusting for education, wealth, religion, caste, and place of residence.

Findings We assessed 2·1 million birth histories across the five surveys. Applying the conditional sex ratios from the surveys to national births, we found that 13·5 million female births were missing during the three decades of observation (1987–2016), on the basis of a natural sex ratio of 950 girls per 1000 boys. Missing female births increased from 3·5 million in 1987–96 to 5·5 million in 2007–16. Contrasting the conditional sex ratio from the first decade of observation (1987–96) to the last (2007–16) showed worsening for the whole of India and almost all states, among both birth orders. Punjab, Haryana, Gujarat, and Rajasthan had the most skewed sex ratios, comprising nearly a third of the national totals of missing second-born and third-born females at birth. From about 1986, the conditional sex ratio for second-order or third-order births after an earlier daughter or daughters diverged notably from that after an earlier son or sons. From 1981 to 2016, the sex ratio for second-born children after an earlier daughter decreased from 930 (99% CI 869–990) to 885 (859–912), and that for third-born children after two earlier daughters decreased from 968 (866–1069) to 788 (746–830). The probability of missing girls was mostly determined by earlier daughters, even after considering wealth quintile and education levels. The conditional sex ratio among the richest and most educated mothers was most distorted compared with lower wealth and education groups, and generally decreased with time, until a modest improvement in 2007–16.

Interpretation In contrast to the substantial improvements in female child mortality in India, missing female births, driven by selective abortion of female fetuses, continues to increase across the states. Inclusion of a question on sex composition of births in the forthcoming census would provide local information on sex-selective abortion in each village and urban area of the country.

Funding None.

Lancet Glob Health 2021

Published Online
April 8, 2021
https://doi.org/10.1016/S2214-109X(21)00094-2

See Online/Comment
https://doi.org/10.1016/S2214-109X(21)00182-0

For the Hindi translation of the abstract see Online for appendix 1

Center for the Study of Regional Development, School of Social Science, Jawaharlal Nehru University, New Delhi, India (N Saikia PhD); **Centre for Global Health Research, Unity Health Toronto and Dalla Lana School of Public Health, University of Toronto, Toronto, ON, Canada** (C Meh MSc, S Chandra MSc, Prof P Jha DPhil); **Department of Public Health and Mortality Studies, International Institute for Population Sciences, Mumbai, India** (Prof U Ram PhD); **Indian Institute of Dalit Studies, New Delhi, India** (J K Bora MSc); **UNICEF, Dar es Salaam, Tanzania** (B Mishra MA)

Correspondence to:
Prof Prabhat Jha, Centre for Global Health Research, Unity Health Toronto and Dalla Lana School of Public Health, University of Toronto, Toronto, ON M5B2C8, Canada
prabhat.jha@utoronto.ca

Introduction

Missing female births have increased worldwide, from near zero per year in the late 1970s, to about 1·6 million per year by 2005–10.[1] Missing female births totalled around 30 million between 1980 and 2010, contributing to substantial deficits in the number of women.[1,2] India accounts for almost half of global missing female births. Daughters in India face more discrimination than sons[3,4] due to a combination of socioeconomic, cultural, and historical factors.[5,6] Selective abortion of female fetuses occurs within this context.[7,8] The Indian Government adopted the Pre-Conception and Prenatal Diagnostic Techniques Act in 1994, which banned use of prenatal diagnostic techniques that became widespread after around 1985 for sex-selective abortions,[9] but the Act is considered largely ineffective. Between the 2001 and 2011 censuses, sex-selective abortions appeared to have increased in nearly three-quarters of India's districts (small administrative areas, each with about 2 million people).[10,11] After widespread publicity about selective abortion of female fetuses from 2006 onward,[7] national and some state-level governments attempted to enforce

Research in context

Evidence before this study

We searched PubMed and Google Scholar using the search terms "conditional sex ratio," "sex ratio," "missing girls," "sex selection," "sex-selective abortion," and "India", for studies published from database inception up to Dec 26, 2020, without language restrictions. Only four studies had computed the number of missing female births in India. No previous studies discussed the trends in sex-selective abortion of female children at the subnational level.

Added value of this study

We focus on conditional sex ratios, defined as the number of girls born per 1000 boys measured by previous birth sex. From analysis of 2·1 million birth histories, we provide the total number of missing female births according to sex of previous children, across three decades and by Indian state or union territory. Applying the conditional sex ratios from these surveys to national birth totals, the total number of missing female births in India was 13·5 million during 1987–2016, increasing from 3·5 million in 1987–96 to 5·5 million in 2007–16, an increase of nearly 60%. Missing female births among second-born and third-born children (following an earlier daughter or daughters) contributed to more than half of total missing female births. Missing third-born girls were widespread, notably in states such as Gujarat, Maharashtra, and Uttar Pradesh. The contribution of Punjab, Haryana, and Maharashtra to missing girls among second-order and third-order births was approaching or greater than twice their share of total births in the country. Missing second-born and third-born girls was mostly determined by number of earlier daughters, even considering education, rural or urban residence, religion, wealth, caste, and state. Missing female births were more common in the richest wealth quintile and among women with higher literacy, although we observed some improvement in conditional sex ratios among the richest wealth quintile and high literacy groups in 2007–16.

Implications of all the available evidence

Selective abortion of female fetuses continues throughout India. Evidence-based interventions to reduce the practice are needed. To increase relevant local evidence, simple questions could be added to the 2022 census to document conditional sex ratios at birth in each village and urban area. Without reductions in sex-selective abortion, the profound demographic and social repercussions of missing girls at birth will continue.

the laws and expand existing cash transfer schemes for births of girls,[12] while civil society helped to raise awareness about the issue.

The overall sex ratio at birth, which is the primary statistic reported annually by the Government of India, stabilised briefly from about 2007 to 2012, but this overall sex ratio has decreased further since 2013.[13] This overall sex ratio is influenced by decreasing fertility rates and reduced family size, with a growing proportion of all births being first births, since selective abortion of girls occurs mostly among higher-order births. Thus, a more robust metric is the conditional sex ratio of second-order and higher-order births depending on previous birth sex.[7]

India has made rapid progress in reducing child mortality and narrowing excess mortality in girls, such that by 2015, numbers of deaths among girls and boys younger than 5 years were approximately equal.[14] Sex-selective abortion has been most common among the affluent and educated,[6,11,15] but whether this practice has changed among higher birth orders, and how missing females at birth are distributed among Indian states, remain unknown.

We sought to document the trends in missing female births, particularly among second and third order births (for which the most selective abortions after an earlier daughter or daughters occur[7]), at the national and state levels in India. We examined a nationally representative sample of birth histories over a period of 35 years, from 1981 to 2016, corresponding to four census periods starting with the 1981 census. Our aim was to quantify trends in sex-selective abortion and provide updated estimates of the absolute numbers of missing females at birth for each of the decades from 1990, 2000, and 2010. These analyses should enable more disaggregated and locally relevant collection of data on the girl and boy populations, and on birth histories, in the upcoming 2022 census.

Methods

Survey population

We analysed birth histories from five rounds of nationally representative household surveys: the first four rounds of the National Family Health Survey (NFHS; 1992–93, 1998–99, 2005–06, and 2015–16); and one round (the second round) of the District Level Household Survey (DLHS-2; 2002–04). Details of the sampling design and methodology for the NFHS and DLHS have been published.[16–20] The NFHS is a cross-sectional survey of Indian households providing information on health outcomes and health services. NFHS-1 (1992–93) interviewed 89 777 ever-married women aged 13–49 years in 25 states. Subsequent rounds interviewed women aged 15–49 years: NFHS-2 (1998–99) interviewed 90 303 women in 26 states; NFHS-3 (2005–06) interviewed 124 385 women in 29 states, and NFHS-4 (2015–16) interviewed 699 686 women in 36 states and union territories. DLHS-2 interviewed 507 622 women in 26 states. All rounds of NFHS and the DLHS-2 followed a stratified multistage sampling design. A census list of villages and urban enumeration blocks provide a

sampling frame to select rural and urban primary selection units, respectively. Units were selected with probability of selection proportional to their size. The surveys had a high mean response rate (in terms of number of completed interviews per 100 eligible women), at 96% in NFHS-1, 96% in NFHS-2, 95% in NFHS-3 and NFHS-4, and 87% in DLHS-2.[16–20]

We used DLHS-2 birth history data to evaluate the concordance in sex ratios at birth, by birth order, between DLHS and NFHS.[11] Other DLHS rounds had truncated birth histories or did not cover most states, and thus were unsuitable for this research. We restricted the analysis to birth histories up to a maximum of 15 years before each survey round to minimise recall bias, misreporting of birth dates, and under-reported births.[21]

Depending on the survey round, 61·2–68·4% of children ever born were born less than 15 years before the interview (data not shown). For periods when at least two rounds of survey data were available, we pooled the unit level data on births and computed the conditional sex ratio. We excluded multiple births from our analysis, as twins or higher order multiple births could be same-sex and dual-sex births. We combined the newly formed states (Chhattisgarh, Jharkhand, Telangana, and Uttarakhand) with their mother states since separate information for these states was not available in NFHS-1, NFHS-2, or DLHS-2. More than 95% of India's population was covered in the surveys. For reasons of statistical stability and completeness over time, we excluded small states with less than 7 million people as of 2021, union territories (including Delhi), and Jammu and Kashmir (from NFHS-1). For each survey, we applied the originally selected survey weights[16–20] to obtain national-level or state-level representative estimates, and used census published definitions of wealth index (based on ownership of consumer goods and household characteristics), religion, and education (with each variable according to similar definitions in the Indian Census).[11,13–16]

Statistical analysis

We pooled data from the national surveys into 5-year intervals, and focused the analyses on the three decades ending in 2016 and starting in 1987, as prenatal sex determination and selective abortion of female fetuses became common after about 1985.[7,9] We computed conditional sex ratio as the number of female births per 1000 male births measured by previous birth sex, by the equation: $[Pf/(1-Pf)\times 1000]$, where Pf is the proportion of female births to total births. Using a method developed previously,[7] we calculated the sex ratio separately by birth order: first born, second born (one older brother or sister), and third born (two older brothers or sisters or one of each). For each stratum, we compared observed ratios to the natural sex ratio of 950 (most conservative) to 975 (less conservative) girls per 1000 boys.[7,11,22] This natural sex ratio takes into account biological norms and is observed consistently in populations in which sex-selective abortion is uncommon, showing little variation by birth order (contrary to the idea that boys run in the family).[23] We attributed deviations from the natural sex ratio as due to selective abortion of girls (appendix 2 pp 3–5). We derived 99% CIs on the basis of the delta method with a variance of $Pf/[N\times(1-Pf)^3]$, where N is total births.[24]

See Online for appendix 2

We estimated the absolute number of missing female births by comparing the deviation of observed girl births from the natural sex ratio, calculated by applying the natural sex ratio at birth to observed male births. This method considers that total births in India already have a deficit of girls due to prenatal sex selection.[25] We derived total births from the Registrar General of India's Sample Registration System (SRS),[13] a demographic surveillance system providing annual state-specific and age-specific fertility data for women aged 15–49 years (the SRS draws from the respective census rounds from 1981–2011). We derived male births by applying the sex ratio at birth from the NFHS rounds 1–4 to total births in India. Observed female births were calculated as the difference between total births and male births. We assumed that no male sex-selective abortions had taken place in India.[7] We compared missing female births by birth order to state birth totals, using the SRS data.[13] A ratio greater than one indicated that the state had an excess contribution to missing female births compared with total births. We created forest plots showing conditional sex ratios by state and 99% CIs. Similar plots were used to contrast the first and last decades of interest.

We used a multivariate logistic regression model to calculate the odds ratio (OR) plus 99% CIs for having a girl in a second-order or third-order birth, given the sex of the earlier child or children, using NHFS-4, as the most recent dataset. We controlled for education (none, primary, secondary [up to grade 10], and higher education), wealth index quintile (poorest, poor, middle, rich, and richest), religion (Hindu, Muslim, Christian, Sikh, and others),[11,13–16] caste (scheduled caste, scheduled tribe, other backward class, and others),[16–20] and geographical variables (place of residence [rural or urban] and residing state or union territory of the mothers).

Role of the funding source

There was no funding source for this study.

Results

We assessed 2·1 million individual birth histories from 1981 to 2016, after exclusion of multiple births, which constituted 1·5% of the total births (data not shown). About 0·66 million (31·5%) of all births were first births (table). Around 0·29 million (13·9%) births were second-order births with one earlier son, and 0·28 million (13·4%) were second-order births with one earlier daughter. Decreasing fertility rates were evident: the proportion of all first-born births increased substantially between NFHS-1 and NFHS-4, from about a quarter to

	Survey year	Total women	Births within 15 years before the survey	First born	Second born, one earlier son	Second born, one earlier daughter	Third born, two earlier sons	Third born, two earlier daughters	Third born, earlier son and daughter	Fourth born and higher
Survey										
District Level Household Survey 2	2002–04	383 593	904 354	271 629	123 285	116 813	39 281	44 010	79 749	229 563
NFHS-1	1992–93	66 950	170 891	45 113	20 222	19 296	7753	7657	15 185	55 666
NFHS-2	1998–99	65 456	161 523	44 907	20 530	19 415	7141	7658	14 397	47 476
NFHS-3	2005–06	70 617	166 860	48 300	21 761	21 459	6781	8080	14 398	46 083
NFHS-4	2015–16	348 610	693 228	250 233	106 712	104 694	24 004	35 111	53 058	119 416
Totals										
n	..	935 226	2 096 856	660 182	292 510	281 677	84 960	102 516	176 787	498 204
Proportion of all births, %	..	..	100%	31·5%	13·9%	13·4%	4·1%	4·9%	8·4%	23·8%

Numbers may not sum due to rounding and the effects of sample weighting. NFHS=National Family Health Survey.

Table: **Sample description of women and births: 1981–2016**

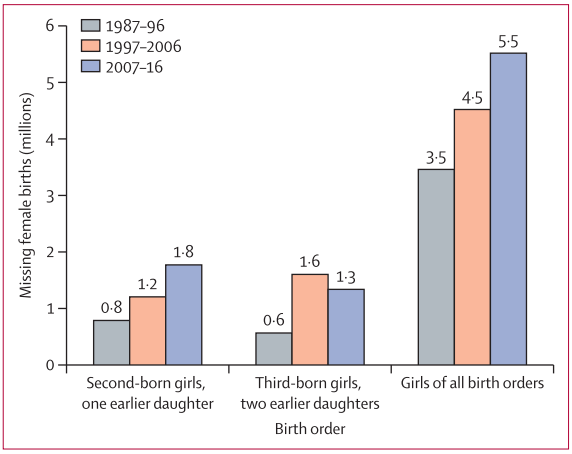

Figure 1: **Trends in the absolute number of missing female births in India, 1987–96, 1997–2006, and 2007–16**
Missing female births estimated from absolute male births by birth order, assuming a natural sex ratio of 950 girls per 1000 boys.

more than a third, whereas the share of fourth-order births and higher decreased from about a third to a sixth.

For our study, the most relevant births to document selective abortion were approximately 0·29 million births after a first son, 0·28 million births after a first daughter, 0·08 million births after two first sons, and 0·10 million births after two first daughters (table). About 18 000 fewer third-order births occurred after two earlier sons than after two earlier daughters.

Applying the conditional sex ratios from the surveys to national birth totals, we calculated the total number of missing female births from 1987 to 2016 in India to be 13·5 million, on the basis of the conservative value of a natural sex ratio of 950 girls per 1000 boys (figure 1, appendix 2 pp 6–7). Missing female births increased from 3·5 million in 1987–96 to 4·5 million in 1997–2006 and to 5·5 million in 2007–16, indicating an annual mean of 0·55 million sex-selective abortions in the latest decade. Missing female births increased in nearly all Indian states (appendix 2 pp 8–28).

We observed a deficit of girls at all birth orders, including the first (figure 1, appendix 2 pp 6–7). However, more than half of missing female births were second-order and third-order births following an earlier daughter or daughters, averaging 0·24 million per year from 1987 to 2016. The conditional sex ratio from the first decade of observation (1987–96) to the last (2007–16) showed worsening for the whole of India and almost all states, among both birth orders (figure 2). Gujarat, Punjab, Rajasthan, and Haryana had the most skewed sex ratios, comprising nearly a third of the national totals of missing second-born and third-born girls at birth. For these two birth orders from 1987 to 2016, around 720 000 missing female births occurred in Gujarat, 580 000 in Punjab, 530 000 in Rajasthan, 480 000 in Haryana, and 1·4 million in the most populous state of Uttar Pradesh (including Uttarakhand). Considering the two most recent decades from 1997, conditional sex ratios were lower for third-order births than second-order births; however, the absolute number of missing third-born girls after two earlier daughters decreased modestly from 1·6 million in 1997–2006 to 1·3 million in 2007–16 (appendix 2 pp 6–7), probably due to a decrease in total third-order births. State-level estimates of missing female births are in appendix 2 (pp 8–28). Applying a natural sex ratio of 975 girls per 1000 boys to our estimates of total births yielded 22·1 million missing female births in 1987–2016 (appendix 2 pp 6–7).

Figure 3 presents the trends and magnitude of changes in the most relevant conditional sex ratios at birth in India during 1981–2016, with each ratio representing the preceding 5 years, grouped according to survey round. The sex ratios for first-born children were within the natural range (950–975 girls per 1000 boys) or slightly lower, particularly during the early 2000s. The sex ratios of second-order or third-order births after an earlier son or sons were generally within the natural range or slightly higher, in no particular pattern. By contrast, the sex ratio deviated downward from the natural range among second-order births after an earlier daughter, and this trend was pronounced among third-order births after two earlier

1987–2016: Second or third born, one earlier daughter or two earlier daughters

	Female births	Male births	Missing female births (thousands)	Missing female births (% of total second and third births)	Conditional sex ratio (99% CI)
Second born, one earlier daughter					
Punjab	3318	4804	350	4·8	691 (651–731)
Haryana	3970	5285	280	3·9	751 (710–792)
Gujarat	4464	5640	450	6·2	791 (750–832)
Rajasthan	7868	9232	340	4·7	852 (818–886)
Uttar Pradesh and Uttarakhand	18485	21489	890	12·2	860 (838–882)
Maharashtra	6374	7271	450	6·2	877 (838–916)
Madhya Pradesh and Chhattisgarh	13786	15492	340	4·7	890 (863–917)
Tamil Nadu	5387	6017	170	2·3	895 (852–938)
Andhra Pradesh and Telangana	4292	4762	210	2·9	901 (852–950)
Himachal Pradesh	2461	2706	10	0·1	909 (844–974)
Kerala	2543	2772	70	1·0	917 (852–982)
Orissa	6180	6637	40	0·6	931 (889–973)
Bihar and Jharkhand	14033	15009	120	1·7	935 (907–963)
Karnataka	5272	5540	0*	0·0	952 (905–999)
West Bengal	3770	3943	0*	0·0	956 (900–1012)
Assam	4734	4926	0*	0·0	961 (911–1011)
India subtotal	**125982**	**142544**	**3760**		**884 (875–893)**
Third born, two earlier daughters					
Punjab	985	1901	230	3·2	518 (466–570)
Haryana	1318	2233	200	2·8	590 (537–643)
Himachal Pradesh	830	1283	40	0·6	647 (573–721)
Maharashtra	2111	3016	520	7·2	700 (649–751)
Gujarat	1592	2190	270	3·7	727 (665–789)
Rajasthan	3098	3816	190	2·6	812 (761–863)
Uttar Pradesh and Uttarakhand	7418	8901	480	6·6	833 (799–867)
Assam	1616	1922	60	0·8	841 (768–914)
Tamil Nadu	1366	1606	110	1·5	851 (770–932)
Andhra Pradesh and Telangana	1177	1383	120	1·7	851 (764–938)
Karnataka	1654	1899	50	0·7	871 (795–947)
Bihar and Jharkhand	5771	6539	230	3·2	883 (842–924)
Madhya Pradesh and Chhattisgarh	5566	6251	120	1·7	890 (848–932)
West Bengal	1235	1368	120	1·7	903 (812–994)
Orissa	2282	2469	40	0·6	924 (855–993)
Kerala	489	498	0*	0·0	982 (821–1143)
India subtotal	**43739**	**53494**	**3510**		**818 (804–832)**
India: second born and third born	**169721**	**196038**	**7270**		**866 (858–873)**

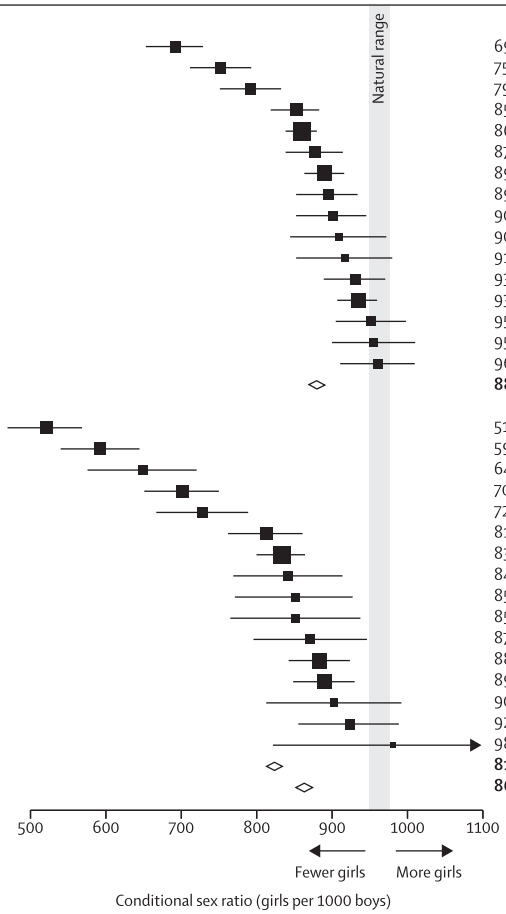

Figure 2: **Conditional sex ratio of second-order and third-order births with one earlier daughter or two earlier daughters in India and its major states, 1987–2016**
Missing second-order and third-order girls were estimated from absolute male births. Missing female births in thousands are given for each state and birth order; percentage missing are missing births divided by the national total of missing second-order and third-order female births. India totals include smaller states and union territories not graphed. The newly formed states of Chhattisgarh, Jharkhand, Telangana, and Uttarakhand were combined with their mother states. The natural range is 950–975 girls per 1000 boys. Square sizes represent the sample size of each state. *By definition the states with conditional sex ratios within or higher than the natural range do not have any missing girls.

daughters. In the NFHS rounds, the conditional sex ratio of second-born children after an earlier daughter was 930 (99% CI 869–990) in 1979–83, decreasing to 848 (825–870) in 2007–11, and increasing marginally to 885 (859–912) in 2012–16. The sex ratio of third-born children after two earlier daughters decreased considerably, from 968 (866–1069) in 1979–83 to 744 (709–779) in 2007–11, and then increased marginally to 788 (746–830) in 2012–16. After about 1986, the sex ratio after an earlier daughter or daughters notably diverged from that after an earlier son or sons (figure 3, appendix 2 p 29).

Sex ratios decreased with time in the richest quintile and among mothers with grade 10 or higher education, but with a marginal increase in 2007–16 (figure 4). Among these income and education groups, decreases in sex ratio were further pronounced for third-order births after two earlier daughters. We found no clear trends during 1981–2016 in conditional sex ratios for second-born children among the poorest quintile or with mothers who could not read or write (appendix 2 p 29).

Logistic regression analyses of 157931 second births in NFHS-4 (appendix 2 p 30) showed that the odds of a second birth being a girl were reduced if the first born was a girl (OR 0·59 [99% CI 0·57–0·61]), as compared with a first-born boy, after adjustment for urban or rural residence, mother's education, wealth quintile, caste, and state. For 106867 third-order births, two earlier daughters also reduced the likelihood of a third girl (OR 0·40 [0·38–0·42]) compared with two earlier sons. The odds of a second-born or third-born girl were less affected by

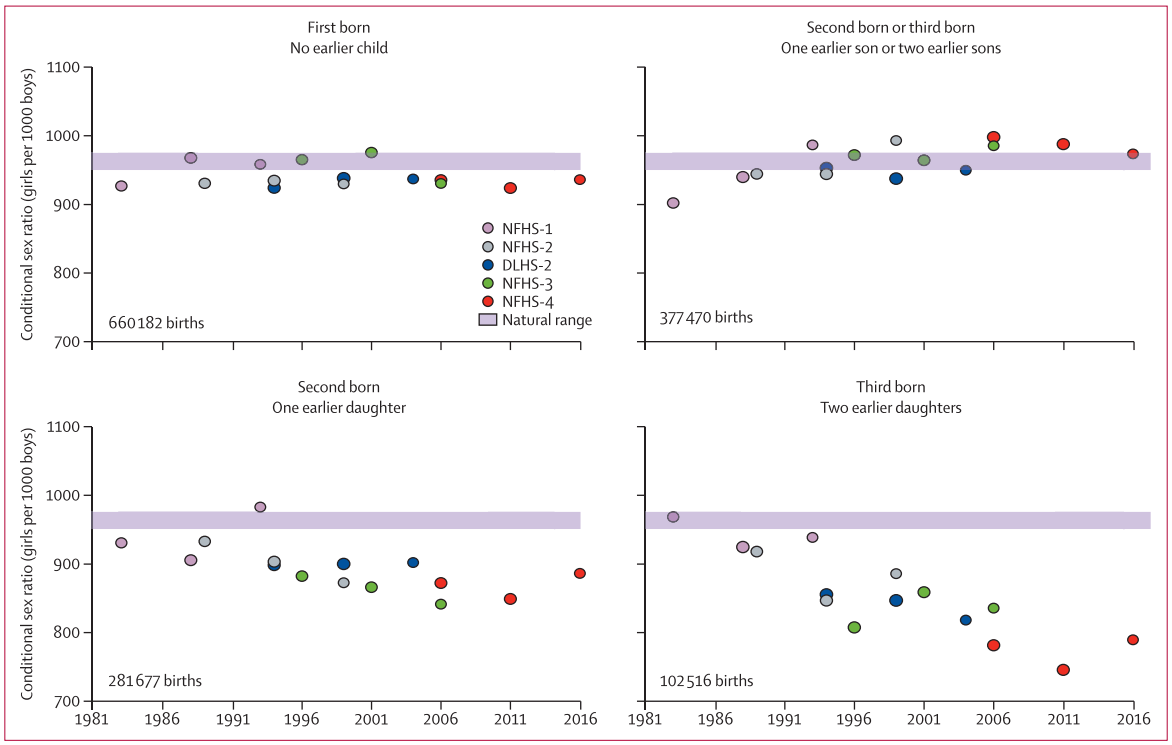

***Figure 3*: Trends in conditional sex ratio by birth order in India, 1981–2016**

Each datapoint represents conditional sex ratio for five years preceding the corresponding timepoint on the x-axis. The natural range is 950–975 girls per 1000 boys. The separate conditional sex ratios for second births after an earlier son and third births after two earlier sons are shown in appendix 2 (p 29). NFHS=National Family Health Survey. DLHS=District Level Household Survey.

location of residence, mother's education, wealth quintile, religion, caste, or state, showing an earlier daughter or daughters to be the dominant determinant of a second-born or third-born girl. A higher level of education in mothers increased the likelihood of a second-born or third-born girl, but the counteracting effect of having an earlier daughter or daughters was more dominant.

We observed considerable variation in the conditional sex ratio after one earlier daughter or two earlier daughters across the major states throughout 1987–2016 (figure 2). For second-born children after an earlier girl, the sex ratio was substantially lower than the natural range in nearly all states, and was lowest in Punjab, Haryana, Gujarat, Rajasthan, Uttar Pradesh (including Uttarakhand), Maharashtra, and Madhya Pradesh (including Chhattisgarh). The sex ratio for third-born children after two earlier girls was lower than that for second-born children after an earlier girl in every state, except for Kerala. For Madhya Pradesh (including Chhattisgarh) and Orissa, the differences in conditional sex ratio for second and third births were minimal. The sex ratio for second-order births was within the natural range only in Assam, Karnataka, and West Bengal, with all other states having ratios lower than the natural range. Punjab had the lowest sex ratio for second-born children (691 [99% CI 651–731]) and third-born children (518 [466–570]).

Between the decades 1987–96 and 2007–16, annual births in India increased modestly from 24·4 million to 24·7 million (appendix 2 pp 6–7), most likely to be due to the counteracting effects of population growth and rapidly decreasing fertility rates. The ratios of state contributions to missing female births for second-born and third-born children after an earlier daughter or daughters, compared with contribution to total births (1987–96, 1997–2006, and 2007–16), are shown in appendix 2 (p 30). A ratio greater than 1 for second-born children, indicating that the state has an excess contribution to missing female births compared with total births, was observed in Haryana, Punjab, Maharashtra, Gujarat, Rajasthan, Uttar Pradesh (including Uttarakhand), and Madhya Pradesh (including Chhattisgarh) in 2007–16. The contribution of Haryana, Punjab, and Maharashtra to missing second-born and third-born girls was approaching or greater than twice their share of total births in the country. Haryana, Punjab, Maharashtra, Gujarat, Tamil Nadu, and Himachal Pradesh had missing female births in excess of their contribution to third-born births.

The state-specific contrast in sex ratio for second-born and third-born children with earlier daughters from the first decade of observation (1987–96) to the last (2007–16) is shown in figure 5. The sex ratio worsened for the whole of India and almost all states, among both birth orders. We observed slight improvements in the sex ratio of

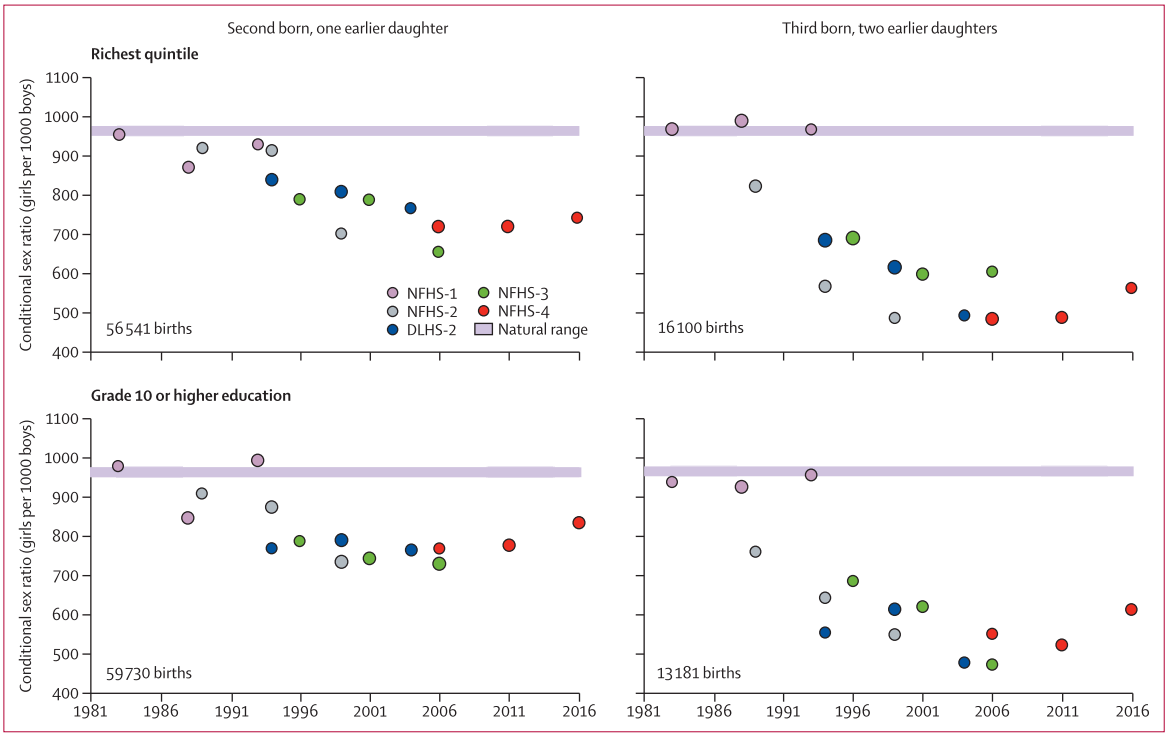

Figure 4: **Effects of the richest wealth quintile and higher education on sex ratio in second-born and third-born daughters, 1981–2016**
Each datapoint represents conditional sex ratio for five years preceding the corresponding timepoint on the x-axis. The natural range is 950–975 girls per 1000 boys. NFHS=National Family Health Survey. DLHS=District Level Household Survey.

second-born children in Himachal Pradesh, Assam, West Bengal, Andhra Pradesh (including Telangana), Gujarat, and Tamil Nadu. Improvements in sex ratios for third-born children were evident in Kerala, Karnataka, and Jammu and Kashmir.

Discussion

Missing female births are increasing in India and conditional sex ratios are worsening across the states. The most cogent explanation for missing female births is prenatal sex determination followed by selective abortion. Various factors, including infections, smoking, and hormonal and social factors, could also reduce overall sex ratios (appendix 2 pp 3–5). However, such factors are unlikely to account for the marked discrepancies in sex ratios for second-order and third-order births and changes with time.[7] Previous analyses[7,11] suggest that female infanticide, which is now rare, has little or no role in explaining the overall gap in missing girls of age 0–6 years.

Our findings are in contrast to claims that the rate of sex-selective abortion of girls in India is slowing.[26,27] Conservative estimates of missing female births, assuming 950 girls per 1000 boys as the natural ratio, revealed 13·5 million missing female births in 1987–2016, increasing from 3·5 million in 1987–96 to 5·5 million in 2007–16, an increase of nearly 60%. Our estimates on missing female births are consistent with estimates in previous studies.[1,28,29] The preliminary reports from 22 states in the NFHS-5 also document worsening sex ratio at birth in eight states.[30]

The increase in missing female births occurred in almost all Indian states. Sex-selective abortion appeared to be more pronounced for third-order births than for second-order births after an earlier daughter or daughters. Sex-selective abortion continued to be more common in richer and more educated families than in poorer and less educated families, in contrast to differences in childhood survival and health-care access. The main determinant of missing female births in second-order and third-order births was an earlier daughter or daughters. The unfavourable trends in missing female births are in marked contrast to the substantial improvement in female child mortality in the past two decades in India.[14]

The reduction in absolute number of missing third-born girls, which decreased from 1·6 million to 1·3 million between 1997–2006 to 2007–16, is attributable to decreasing fertility, considering that conditional sex ratios for third-born girls worsened. Fewer third-order births after two earlier sons than two earlier daughters will have contributed to an overall decrease in fertility, and is consistent with the observation that families stop having more children when boys are born.[31] Missing third-born girls have become more geographically widespread in India than missing second-born girls, suggesting that the use of sex-selective abortion is as widespread as the preference for sons.[5] Even Assam, Tamil Nadu, and

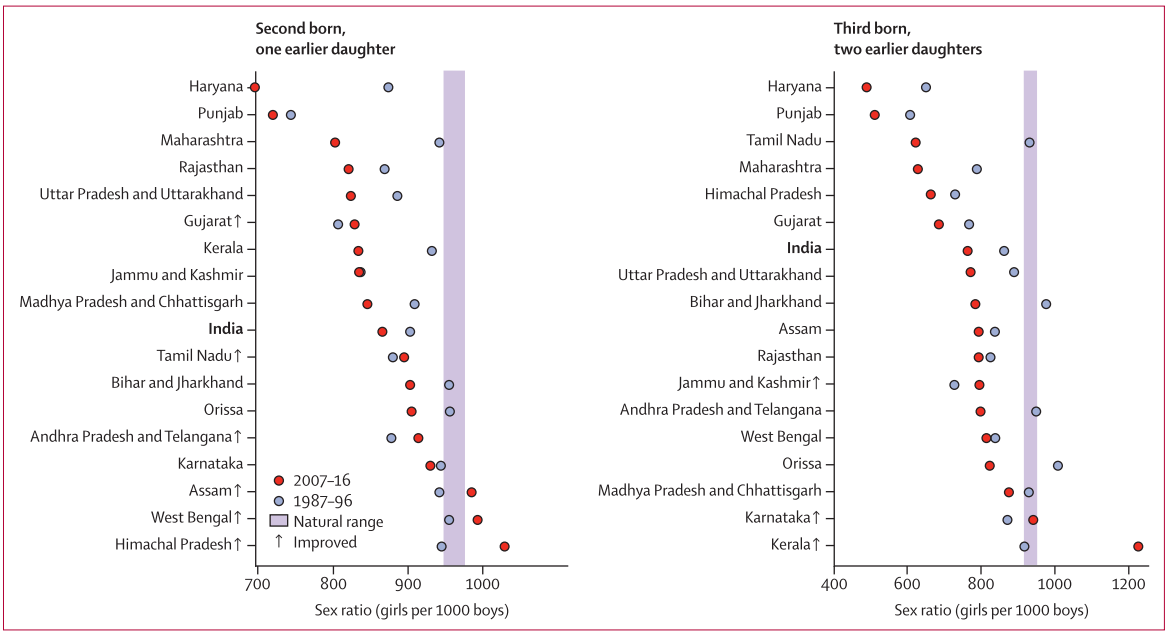

Figure 5: **Change in conditional sex ratio for second-order and third-order births after an earlier daughter or two earlier daughters in India and its major states, 1987–96 and 2007–16**

The upward arrow represents states that showed an improvement in selective abortion of girls. The remaining states showed a worsening in selective abortion of girls. The natural range is 950–975 girls per 1000 boys. States and India total are ordered according to 2007–16 conditional sex ratio. The newly formed states of Chhattisgarh, Jharkhand, Telangana, and Uttarakhand were combined with their mother states.

Andhra Pradesh (including Telangana), where abortion of girls is believed to be less common,[10,12] showed skewed ratios particularly for third-born children. Almost all states, and not only those widely known for sex-selective abortion, now face possible large deficits of missing female births. Indeed, Maharashtra had a near natural sex ratio in 1987–2006, but has since emerged as having widespread selective abortion, particularly among third-order female births.

Platforms for addressing the issue already exist. India's large maternal and child health programmes could identify pregnant women with earlier daughters as being particularly at risk of selective abortion and design incentive programmes for these families. Due to the COVID-19 pandemic, the 2021 census has been postponed to 2022, and offers a unique opportunity to document the national-level, state-level, and even village-level patterns of sex-selective abortion. Identifying such patterns would involve reporting the number of children aged 0–6 years (which has been done in past censuses), sex ratios at birth, and conditional sex ratio for second-order and third-order births. Inclusion of simple questions on the sex composition of previous children (appendix 2 p 32) in the census could provide important local information on sex-selective abortion in rural and urban regions of the country. Reliable local reporting of sex-selective abortion will allow local debates on the consequences of son preference. Concomitant discussion in the media and civil society, and even mention in the entertainment sector, might yield benefits. Indeed, the modest improvement in conditional sex ratios in 2007–16 among the richest and most educated groups might be in response to the widespread media and social discussion of missing girls from 2006 onward.[7,32]

Our study has a few limitations. First, small sample sizes for particular states and years might reduce representativeness of the national surveys. For this reason, we relied mostly on pooled estimates for 10-year periods to ensure an adequate sample size. Second, birth histories have temporal variation and reporting biases.[21] As in a previous analysis,[11] we minimised misreported date of birth, under-reporting of births (particularly female children), and sample implementation errors by restricting our analysis to a maximum of 15 years before each survey, combining NFHS and DLHS survey samples for overlapping periods, presenting ratios from individual surveys by 5-year intervals, and excluding states with insufficient numbers for analysis. Analyses of shorter recall periods for birth histories (5 years) showed similar trends to those we present (data not shown). Furthermore, although routine registration of births is limited by lower reporting of girls, this bias is smaller in the household surveys than in other birth registration systems in India (appendix 2 p 33). Stillbirths are not likely to have biased our results, as a previous report documented higher stillbirths among boys than girls, and found the number of stillbirths to be much lower than the number of missing female births.[7] Finally, we might have underestimated the true extent of missing female births by applying the conservative natural ratio of 950 girls per 1000 boys. The use of a natural ratio of 975 girls per 1000 boys[7,11]

yielded more than 22 million missing girls at birth. The stratifications by education and demographic groups are subject to some biases,[33] but these biases are unlikely to have changed substantially with time.

Our analyses document the numbers and causes of missing female births, but not the consequences. Selective abortion of girls is one of the most severe forms of gender discrimination, contributing to an excess of men who would like to find a partner but are unable to, and increasing violence against women.[3–5] Evidence-based strategies that include consideration of social determinants, such as equal inheritance laws for women, and emphasis on effective implementation of policies, are urgently needed to reduce sex-selective abortion.[34,35] Without a reduction in sex-selective abortion, the demographic distortion might have repercussions for decades.[36,37]

Contributors

NS and PJ conceived and designed the study. NS, CM, and PJ analysed data. NS and CM reviewed the literature. NS and PJ wrote the initial draft, and all authors were involved in commenting on subsequent revisions. NS and PJ are the guarantors who accessed and verified all data used in the study. All authors had full access to all relevant data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

The NHFS and DLHS surveys are all open-access public use files and free to request online.

Acknowledgments

No funding was provided for this study. NS was an early career scholar in the Queen Elizabeth Advanced Scholars Program—Statistical Alliance for Vital Events, funded by the Government of Canada. PJ holds a Canada Research Chair and is a professor at the University of Toronto. We thank Erica Di Ruggiero and Hellen Gelband for their comments.

References

1 Bongaarts J, Guilmoto CZ. How many more missing women? Excess female mortality and prenatal sex selection, 1970–2050. *Popul Dev Rev* 2015; **41:** 241–69.
2 Sen A. Missing women—revisited. *BMJ* 2003; **327:** 1297–98.
3 Das Gupta M. Selective discrimination against female children in rural Punjab, India. *Popul Dev Rev* 1987; **13:** 77–100.
4 Pande RP. Selective gender differences in childhood nutrition and immunization in rural India: the role of siblings. *Demography* 2003; **40:** 395–418.
5 Murthi M, Guio A, Drèze J. Mortality, fertility, and gender bias in India: a district-level analysis. *Popul Dev Rev* 1995; **21:** 745–82.
6 Guilmoto CZ, Depledge R. Economic, social and spatial dimensions of India's excess child masculinity. *Population* 2008; **63:** 91–117.
7 Jha P, Kumar R, Vasa P, Dhingra N, Thiruchelvam D, Moineddin R. Low male-to-female sex ratio of children born in India: national survey of 1·1 million households. *Lancet* 2006; **367:** 211–18.
8 Guilmoto CZ, Saikia N, Tamrakar V, Bora JK. Excess under-5 female mortality across India: a spatial analysis using 2011 census data. *Lancet Glob Health* 2018; **6:** e650–58.
9 Tabaie S. Stopping female feticide in India: the failure and unintended consequence of ultrasound restriction. *J Glob Health* 2017; **7:** 010304.
10 Diamond-Smith N, Saikia N, Bishai D, Canudas-Romo V. What has contributed to improvements in the child sex ratio in select districts of India? A decomposition of the sex ratio at birth and child mortality. *J Biosoc Sci* 2020; **52:** 27–36.
11 Jha P, Kesler MA, Kumar R, et al. Trends in selective abortions of girls in India: analysis of nationally representative birth histories from 1990 to 2005 and census data from 1991 to 2011. *Lancet* 2011; **377:** 1921–28.
12 Sekher TV. Ladlis and Lakshmis: financial incentive schemes for the girl child. *Econ Polit Wkly* 2012; **47:** 58–65.
13 Office of the Registrar General and Census Commissioner, India. Sample registration system statistical report 2017. New Delhi, 2017. http://censusindia.gov.in/vital_statistics/SRS_Reports_2017.html (accessed May 6, 2020).
14 Million Death Study Collaborators. Changes in cause-specific neonatal and 1–59-month child mortality in India from 2000 to 2015: a nationally representative survey. *Lancet* 2017; **390:** 1972–80.
15 Echávarri RA, Ezcurra R. Education and gender bias in the sex ratio at birth: evidence from India. *Demography* 2010; **47:** 249–68.
16 International Institute for Population Sciences. National Family Health Survey (NFHS-1), 1992–93. 1995. https://www.dhsprogram.com/pubs/pdf/FRIND1/FRIND1.pdf (accessed Dec 16, 2020).
17 International Institute for Population Sciences and ORC-Macro. National Family Health Survey (NFHS-2), 1998–99. 2000. https://dhsprogram.com/pubs/pdf/frind2/frind2.pdf (accessed Dec 16, 2020).
18 International Institute for Population Sciences and Macro International. National Family Health Survey (NFHS-3), 2005–06. 2007. https://dhsprogram.com/pubs/pdf/frind3/frind3-vol1andvol2.pdf (accessed Dec 16, 2020).
19 International Institute for Population Sciences and ICF. National Family Health Survey (NFHS-4), 2015–16. 2017. https://dhsprogram.com/pubs/pdf/FR339/FR339.pdf (accessed Dec 16, 2020).
20 International Institute for Population Sciences. District Level Household Survey (DLHS-2), 2002–04. 2006. http://rchiips.org/pdf/rch2/National_Report_RCH-II.pdf (accessed Dec 16, 2020).
21 Schoumaker B. Quality and consistency of DHS fertility estimates, 1990 to 2012. Rockville, MA: ICF, 2014.
22 Hesketh T, Xing ZW. Abnormal sex ratios in human populations: causes and consequences. *Proc Natl Acad Sci USA* 2006; **103:** 13271–75.
23 Rodgers JL, Doughty D. Does having boys or girls run in the family? *Chance* 2001; **14:** 8–13.
24 Miller RG Jr. Survival analysis, 2nd edn. Hoboken, NJ: Wiley, 2011.
25 Kulkarni PM. Estimation of missing girls at birth and juvenile ages in India. New Delhi: United Nations Population Fund India, 2007.
26 Patel T, ed. Sex selective abortion in India: gender, society and new reproductive technologies. New Delhi: Sage Publications, 2007.
27 The Economist. Gendercide—the war on baby girls winds down. Jan 21, 2017. https://www.economist.com/international/2017/01/21/the-war-on-baby-girls-winds-down (accessed Dec 16, 2020).
28 Chao F, Gerland P, Cook AR, Alkema L. Systematic assessment of the sex ratio at birth for all countries and estimation of national imbalances and regional reference levels. *Proc Natl Acad Sci USA* 2019; **116:** 9303–11.
29 Kulkarni PM. Sex ratio at birth in India: recent trends and patterns. New Delhi: United Nations Population Fund, 2020.
30 International Institute for Population Sciences. Fact sheets. Key indicators: 22 states/UTs from phase-I. National Family Health Survey-5 (2019–20). 2020. http://rchiips.org/NFHS/NFHS-5_FCTS/NFHS-5%20State%20Factsheet%20Compendium_Phase-I.pdf. (accessed Dec 16, 2020).
31 Clark S. Son preference and sex composition of children: evidence from India. *Demography* 2000; **37:** 95–108.
32 Diamond-Smith N, Bishai D. Evidence of self-correction of child sex ratios in India: a district-level analysis of child sex ratios from 1981 to 2011. *Demography* 2015; **52:** 641–66.
33 Bassani DG, Corsi DJ, Gaffey MF, Barros AJ. Local distributions of wealth to describe health inequalities in India: a new approach for analyzing nationally representative household survey data, 1992–2008. *PLoS One* 2014; **9:** e110694.
34 Kumar S, Sinha N. Preventing more "missing girls": a review of policies to tackle son preference. *World Bank Res Obs* 2020; **35:** 87–121.
35 Guo Z, Das Gupta M, Li S. 'Missing girls' in China and India: trends and policy challenges. *Asian Popul Stud* 2016; **12:** 135–55.
36 Guilmoto CZ. Sex imbalances at birth: current trends, consequences and policy implications. Bangkok: United Nations Population Fund Asia and Pacific Regional Office, 2012.
37 Chao F, Guilmoto CZ, Samir KC, Ombao H. Probabilistic projection of the sex ratio at birth and missing female births by state and union territory in India. *PLoS One* 2020; **15:** e0236673.

For the **data request forms of the NHFS and DLHS surveys** see https://www.iipsindia.ac.in/content/data-request