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

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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 secular 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.

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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.11 India accounts for almost half of global missing female births. Daughters in India face more discrimination than sons14 due to a combination of socioeconomic, cultural, and historical factors.16 Selective abortion of female fetuses occurs within this context.17 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,11 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).19,20 After widespread publicity about selective abortion of female fetuses from 2006 onward,19 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, 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. 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.

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.4 Sex-selective abortion has been most common among the affluent and educated, 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), 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.5–9 The NFHS is a cross-sectional survey of Indian households providing information on health outcomes and health services. NFHS-1 (1992–93) interviewed 89777 ever-married women aged 13–49 years in 23 states. Subsequent rounds interviewed women aged 15–49 years: NFHS-2 (1998–99) interviewed 90303 women in 26 states; NFHS-3 (2005–06) interviewed 124385 women in 29 states, and NFHS-4 (2015–16) interviewed 699686 women in 36 states and union territories. DLHS-2 interviewed 507622 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-2.36-38

We used DLHS-2 birth history data to evaluate the concordance in sex ratios at birth, by birth order, between DLHS and NFHS.39 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.39

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 (Ghatsisgarh, Jharkhand, Telangana, and Uttar Pradesh) 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 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).40-44

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 1985.45 We computed conditional sex ratio as the number of female births per 1000 male births measured by previous birth sex, by the equation: \[ \frac{Pf}{1-Pf} \times 1000 \], where Pf is the proportion of female births to total births. Using a method developed previously,46 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.47-48 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).49 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 \( Pf / [N \times (1-Pf)] \), where N is total births.45

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.50 We derived total births from the Registrar General of India’s Sample Registration System (SRS),51 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.52 We compared missing female births by birth order to state birth totals, using the SRS data.53 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 NFHS-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), caste (scheduled caste, scheduled tribe, other backward class, and others), 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
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 72,000 missing female births occurred in Gujarat, 58,000 in Punjab, 53,000 in Rajasthan, 48,000 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 sons.
### 1987–2016: Second or third born, one earlier daughter or two earlier daughters

<table>
<thead>
<tr>
<th></th>
<th>Female births</th>
<th>Male births</th>
<th>Missing female births (thousands)</th>
<th>Missing female births (% of total second and third births)</th>
<th>Conditional sex ratio (99% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Second born, one earlier daughter</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punjab</td>
<td>3378</td>
<td>4004</td>
<td>350</td>
<td>48</td>
<td>6.90 (6.51–7.31)</td>
</tr>
<tr>
<td>Haryana</td>
<td>2979</td>
<td>3585</td>
<td>380</td>
<td>3.9</td>
<td>7.52 (7.07–7.93)</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>7868</td>
<td>9232</td>
<td>340</td>
<td>4.7</td>
<td>8.52 (8.18–8.86)</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>18,485</td>
<td>21,489</td>
<td>890</td>
<td>12.2</td>
<td>8.60 (8.38–8.82)</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>63,928</td>
<td>77,211</td>
<td>450</td>
<td>6.2</td>
<td>8.77 (8.59–8.95)</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>7,786</td>
<td>9,492</td>
<td>340</td>
<td>4.7</td>
<td>8.90 (8.65–9.17)</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>5737</td>
<td>6,017</td>
<td>120</td>
<td>2.3</td>
<td>9.17 (8.82–9.53)</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>47,922</td>
<td>4,972</td>
<td>210</td>
<td>2.9</td>
<td>9.23 (9.07–9.41)</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>2,661</td>
<td>2,706</td>
<td>10</td>
<td>0.1</td>
<td>9.09 (8.66–9.44)</td>
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<tr>
<td>Kerala</td>
<td>7,543</td>
<td>7,772</td>
<td>10</td>
<td>0.1</td>
<td>9.17 (8.82–9.53)</td>
</tr>
<tr>
<td>Odisha</td>
<td>5,180</td>
<td>6,637</td>
<td>30</td>
<td>0.6</td>
<td>9.31 (8.99–9.64)</td>
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<tr>
<td>Bihar and Jharkhand</td>
<td>14,033</td>
<td>15,099</td>
<td>120</td>
<td>1.7</td>
<td>9.35 (9.06–9.67)</td>
</tr>
<tr>
<td>Karnataka</td>
<td>5270</td>
<td>5,580</td>
<td>0*</td>
<td>0.0</td>
<td>9.52 (9.05–9.98)</td>
</tr>
<tr>
<td>West Bengal</td>
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<td>3,943</td>
<td>0*</td>
<td>0.0</td>
<td>9.56 (9.00–10.12)</td>
</tr>
<tr>
<td>Assam</td>
<td>4,934</td>
<td>4,986</td>
<td>0*</td>
<td>0.0</td>
<td>9.65 (9.11–10.13)</td>
</tr>
<tr>
<td><strong>India: second born and third born</strong></td>
<td>125,982</td>
<td>143,544</td>
<td>3,760</td>
<td></td>
<td>8.84 (8.57–9.10)</td>
</tr>
</tbody>
</table>

### 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 Uttaranchal were combined with their mother states. The natural range is 950–955 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.

dughters. 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 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 157,931 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 106,867 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
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 ratio 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...
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. Previous analyses 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. 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.

The preliminary reports from 22 states in the NFHS-5 also document worsening sex ratio at birth in eight states. 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.

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. 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. Even Assam, Tamil Nadu, and
Andhra Pradesh (including Telangana), where abortion of girls is believed to be less common, 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. Including 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.

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. As in a previous analysis, 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. Finally, we might have underestimated the true extent of missing female births by applying the conservative natural ratio of 295 girls per 1000 boys. The use of a natural ratio of 975 girls per 1000 boys...
yielded more than 22 million missing girls at birth. The stratifications by education and demographic groups are subject to some biases, 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. 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. Without a reduction in sex-selective abortion, the demographic distortion might have repercussions for decades.

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 NHHS and DLHS surveys are all open-access public-use files and freely request online.

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