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

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Summary

Background **India's 2011 census revealed a growing imbalance between the numbers of girls and boys aged 0–6 years, which we postulate is due to increased prenatal sex determination with subsequent selective abortion of female fetuses. We aimed to establish the trends in sex ratio by birth order from 1990 to 2005 with three nationally representative surveys and to quantify the totals of selective abortions of girls with census cohort data.**

Methods **We assessed sex ratios by birth order in 0·25 million births in three rounds of the nationally representative National Family Health Survey covering the period from 1990 to 2005. We estimated totals of selective abortion of girls by assessing the birth cohorts of children aged 0–6 years in the 1991, 2001, and 2011 censuses. Our main statistic was the conditional sex ratio of second-order births after a firstborn girl and we used 3-year rolling weighted averages to test for trends, with differences between trends compared by linear regression.**

Findings **The conditional sex ratio for second-order births when the firstborn was a girl fell from 906 per 1000 boys (99% CI 798–1013) in 1990 to 836 (733–939) in 2005; an annual decline of 0·52% (p for trend=0·002). Declines were much greater in mothers with 10 or more years of education than in mothers with no education, and in wealthier households compared with poorer households. By contrast, we did not detect any significant declines in the sex ratio for second-order births if the firstborn was a boy, or for firstborns. Between the 2001 and 2011 censuses, more than twice the number of Indian districts (local administrative areas) showed declines in the child sex ratio as districts with no change or increases. After adjusting for excess mortality rates in girls, our estimates of number of selective abortions of girls rose from 0–2·0 million in the 1980s, to 1·2–4·1 million in the 1990s, and to 3·1–6·0 million in the 2000s. Each 1% decline in child sex ratio at ages 0–6 years implied 1·2–3·6 million more selective abortions of girls. Selective abortions of girls totalled about 4·2–12·1 million from 1980–2010, with a greater rate of increase in the 1990s than in the 2000s.**

Interpretation **Selective abortion of girls, especially for pregnancies after a firstborn girl, has increased substantially in India. Most of India's population now live in states where selective abortion of girls is common.**

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For the **2011 Indian census** see http://censusindia.gov.in

See **Online** for webappendix

Introduction

The 2011 Indian census revealed about 7·1 million fewer girls than boys aged 0–6 years, a notable increase in the gap of 6·0 million fewer girls recorded in the 2001 census and the gap of 4·2 million fewer girls recorded in the 1991 census. The overall child sex ratio of girls per 1000 boys at ages 0–6 years fell by 1·9% (from 945 to 927) in the decade starting in 1991 and by 1·4% (from 927 to 914) in the decade starting in 2001. More girls than boys die at ages 1–59 months, but this is mostly offset by more boys than girls dying in the first month of life.[1] The most plausible explanation for the gap in the number of girls in the 2011 census is prenatal sex determination with subsequent selective abortion of female fetuses. In most high-income countries, only slightly more boys than girls are born, with recorded sex ratios at birth of 950–975 girls per 1000 boys.[2–4] This sex ratio varies little by birth order, or by the sex of previous births.[4–6] By contrast, in India the sex ratio for the second birth, when the firstborn is a girl, is much lower than if the firstborn is a boy.[7,8]

The mean number of children per Indian woman fell from 3·8 in 1990 to 2·6 in 2008,[9] and households continue to prefer a son over a daughter (webappendix p 1).[10] Fetal ultrasound has become more available over the past decade. However, it is uncertain to what extent ultrasound is being used to monitor fetal health or for sex determination with subsequent selective abortion of female fetuses.[11,12]

We assess the trends in sex ratio by birth order from 1990 to 2005 with three nationally representative surveys and assess how any changes might have varied by education or wealth. We further assess cohorts of children from the 1991–2011 censuses to estimate the absolute numbers of selective abortions in the past three decades.

Methods

Survey population

We derived annual birth histories and child mortality rates for 1990–2005 from three rounds of the National

Family Health Survey (NFHS), a large-scale, nationally representative survey of rural and urban Indian households.[10,13,14] NFHS-1, done in 1992–93, interviewed 89 777 ever-married women aged 13–49 years in 25 states. Sample selection for NFHS-1 in rural areas used the 1981 census, with the exception of Assam, Delhi, and Punjab, which used the 1991 census. Urban sampling for NFHS-1 used the 1991 census. NFHS-2, done in 1998–99, interviewed 89 199 ever-married women aged 15–49 years in 26 states and used the same sampling as NFHS-1. NFHS-3, done in 2005–06, interviewed 124 385 women aged 15–49 years in 29 states. Both rural and urban areas used the 2001 census for sample selection. Details of the NFHS sampling strategy and other details of methods, including the generally high completeness of birth histories have been published elsewhere.[10,13,14]

The Indian census is a complete enumeration of all living persons in the country, irrespective of nationality, and was done over 3 weeks in February of 1991, 2001, and 2011. After a detailed house-listing procedure, more than 2 million trained surveyors enumerated all individuals in each home and on the street (for the homeless). Full details on census procedures and completeness (for the 2001 census)[15] are published elsewhere. We used provisional 2011 census results. The 2001 provisional and final totals differed by only 0·17%.[15]

Procedures

Female interviewers obtained a complete birth history from every woman surveyed in each NFHS, including the date of birth, sex, birth order, and mortality for all of her children, as well as her religion and education level. We used principal component analysis to create state-specific wealth quintiles based on the assets available in the household for rural and urban regions in each state (data not shown). The census enumerates the date of birth for each person—usually by interviewing the head of the household. Strict field instructions aimed to enumerate girls and boys equally and to minimise age misclassification.[16]

Statistical analysis

Overall sex ratios at birth are less reliable in the estimation of selective abortions because they might mask conditional sex ratios at higher-order births.[7–9] Thus, our main statistic was the conditional sex ratio of second-order births after a firstborn girl. We calculated the sex ratio as the total number of female births per 1000 male births ($Pf/[1-Pf]\times1000$); where Pf is the proportion of female to total births (N). We took 950–975 girls per 1000 boys to be the natural variation of sex ratio, on the basis of ranges reported in most high-income countries where social pressures for fewer girls do not exist.[2–6] NFHS-1, NFHS-2, and NFHS-3 included information about births during the periods from 1990 to 1992, 1990 to 1998, and 1995

	Sex of previous children	1990	1991	1992	1993	1994	1995	1996	1997
1	..	943 (867–1019)	934 (861–1007)	967 (913–1022)	973 (898–1048)	901 (828–973)	958 (880–1035)	958 (878–1037)	963 (885–1041)
2	Male	952 (842–1062)	1017 (900–1135)	918 (840–996)	927 (823–1031)	899 (796–1002)	897 (789–1004)	973 (854–1091)	968 (852–1083)
	Female	906 (798–1013)	918 (808–1027)	961 (879–1042)	870 (765–975)	873 (773–972)	862 (758–966)	891 (780–1003)	861 (756–967)
3	Both male	1034 (831–1237)	961 (772–1149)	971 (838–1105)	942 (766–1117)	1079 (886–1292)	1083 (864–1302)	952 (749–1154)	1032 (881–1253)
	Both female	882 (717–1048)	902 (730–1074)	896 (777–1014)	731 (595–868)	820 (665–975)	847 (680–1013)	820 (649–991)	776 (623–929)
	1 male, 1 female	995 (862–1129)	936 (807–1066)	930 (839–1022)	850 (735–964)	960 (831–1089)	870 (746–994)	900 (763–1037)	918 (782–1054)
4+	..	932 (856–1007)	926 (848–1003)	940 (885–994)	940 (867–1014)	986 (907–1064)	926 (848–1004)	971 (885–1058)	925 (843–1007)
All	..	942 (902–982)	940 (900–980)	946 (905–986)	919 (881–956)	927 (889–966)	919 (879–959)	942 (899–984)	928 (887–969)

We calculated years 1990–92 by taking the weighted average of NFHS-1 and NFHS-2. We used only NFHS-2 for years 1993–94, and the weighted average of NFHS-2 and NFHS-3 for years 1995–98, and only NFHS-3 for years 1999–2005.

Table 1: **Sex ratio at birth, conditional on sex of previous birth (99% CIs) by birth order from 1990–1997**

		1998	1999	2000	2001	2002	2003	2004	2005
1	..	919 (846–992)	1010 (929–1092)	950 (874–1026)	966 (888–1044)	987 (906–1067)	917 (842–992)	939 (862–1015)	966 (889–1042)
2	Male	907 (801–1013)	887 (778–996)	1031 (905–1156)	988 (863–1113)	972 (853–1091)	938 (822–1053)	1003 (879–1126)	1013 (891–1136)
	Female	881 (775–988)	899 (789–1008)	786 (689–884)	863 (753–974)	851 (744–957)	840 (737–943)	858 (751–964)	836 (733–939)
3	Both male	1051 (819–1282)	1046 (826–1266)	1026 (805–1247)	995 (757–1233)	883 (672–1095)	867 (653–1082)	1000 (756–1244)	895 (667–1123)
	Both female	874 (702–1047)	908 (727–1089)	875 (702–1048)	717 (560–873)	887 (700–1074)	699 (548–850)	877 (690–1065)	768 (606–930)
	1 male, 1 female	942 (805–1079)	908 (774–1042)	1015 (860–1171)	811 (675–946)	909 (762–1057)	960 (805–1116)	809 (671–948)	990 (822–1157)
4+	..	903 (825–980)	924 (848–1001)	923 (842–1003)	894 (812–976)	932 (846–1017)	914 (829–998)	881 (793–970)	970 (876–1065)
All	..	913 (873–952)	943 (902–984)	934 (893–975)	912 (870–954)	936 (894–979)	898 (856–939)	911 (868–954)	942 (899–986)

We calculated years 1990–92 by taking the weighted average of NFHS-2 and NFHS-3. We used only NFHS-2 for years 1993–94, and the weighted average of NFHS-2 and NFHS-3 for years 1995–98, and only NFHS-3 for years 1999–2005.

Table 2: **Sex ratio at birth, conditional on sex of previous birth (99% CIs) by birth order from 1998–2005**

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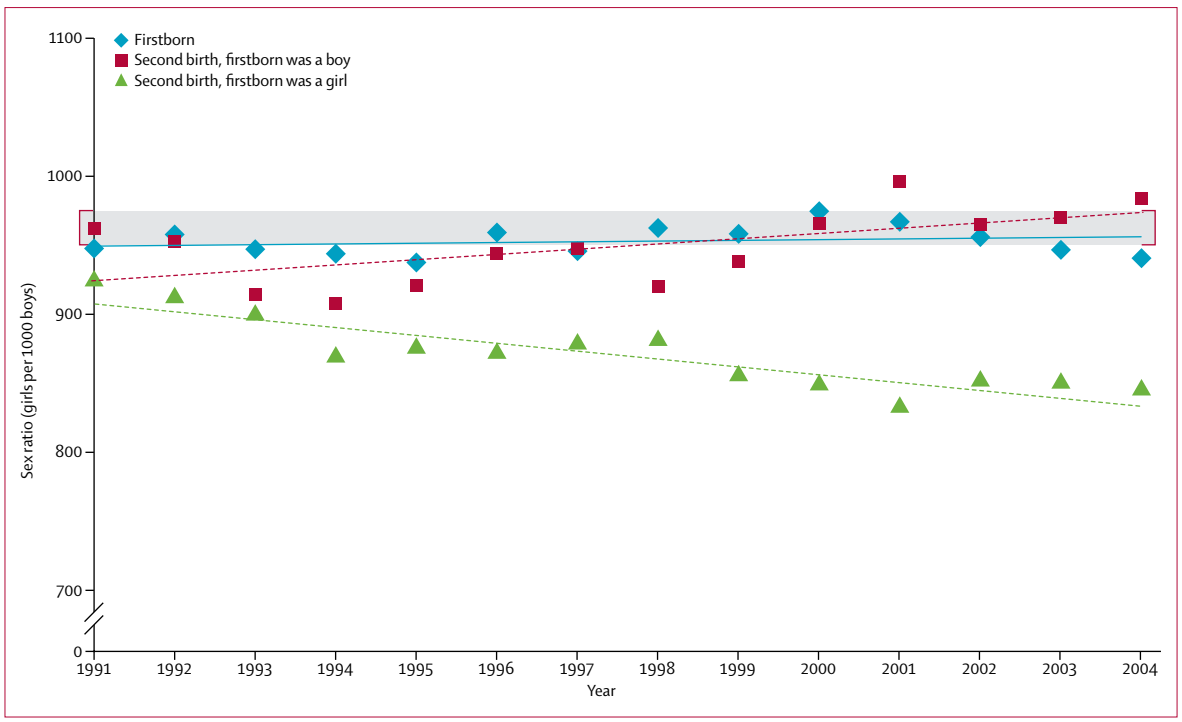

Figure 1: **Sex ratio (girls per 1000 boys) of first-order and second-order births, conditional on sex of firstborn, from 1990–2005**
Red brackets show the natural sex ratio range of 950–975 girls per 1000 boys. Tests for trend: any firstborn, p=0·152; second birth, firstborn was girl, p=0·002; second birth, firstborn was boy, p=0·023. The numbers of births for each figure are provided in the webappendix (p 3). We used 3-year rolling averages, with the midpoint shown (eg, 1991, 2004).

to 2005, respectively. We used a weighted average of two datapoints for overlapping years. The results for sex ratios weighted and unweighted for sampling probability were similar (data not shown), and we present only the latter. We used the delta method to calculate 99% CIs, with a variance of $Pf/(N\times[1-Pf])$.[17] We used 3-year rolling averages to test for trends, with differences between trends compared by linear regression.

We estimated the absolute totals of missing girls from the 7 years of children at ages 0–6 years in the 1991, 2001, and 2011 censuses (corresponding to children born in 1984–90, 1994–2000, and 2004–2010, respectively). For each of these 21 cohort years, we calculated the expected number of girls with a sex ratio at birth of 950–975 girls per 1000 boys.[2–4] Girls at ages 0–4 years have higher mortality rates than boys per birth and these girl-to-boy relative risks have widened over time, even though child mortality has fallen sharply (webappendix p 1).[10] However, because more boys than girls were born every year, the absolute number of annual boy deaths exceeded the absolute number of girl deaths through most of the 1990s. We adjusted for the extra girl deaths at ages 0–6 years that would be expected had more girls been born. Our estimate of excess girl deaths was based on annual infant mortality rates for girls and boys at ages 0–1 years from the UN.[18] Yearly infant mortality rates were combined with a constant proportionate age-specific and sex-specific mortality at ages 2–6 years, as derived from a nationally representative mortality survey in 2001–03.[1] We excluded emigration, because net migration at all ages from India is less than 0·2% of the population.[19] We did all analyses in STATA (version 10.0).

Role of the funding source

The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

We assessed 35 530 births from 1990 to 1992 (NFHS-1), 108 550 births from 1990 to 1998 (NFHS-2), and 121 436 births from 1995 to 2005 (NFHS-3). 78 449 first-order, 70 321 second-order, and 48 243 third-order births were recorded in these surveys.

The conditional sex ratio for second-order births, if the firstborn was a girl, had an annual mean decline of 0·52% between 1990 and 2005 (p for trend=0·002; table 1, table 2, and figure 1). The sex ratio for third-order births, if the two previous births were girls, was even lower, but the declines between 1990 and 2005 were not statistically significant (p=0·18; data not shown). This lack of statistical significance is partly due to the smaller absolute numbers of higher-order births than first-order or second-order births. The sex ratio for any firstborns or for second-order

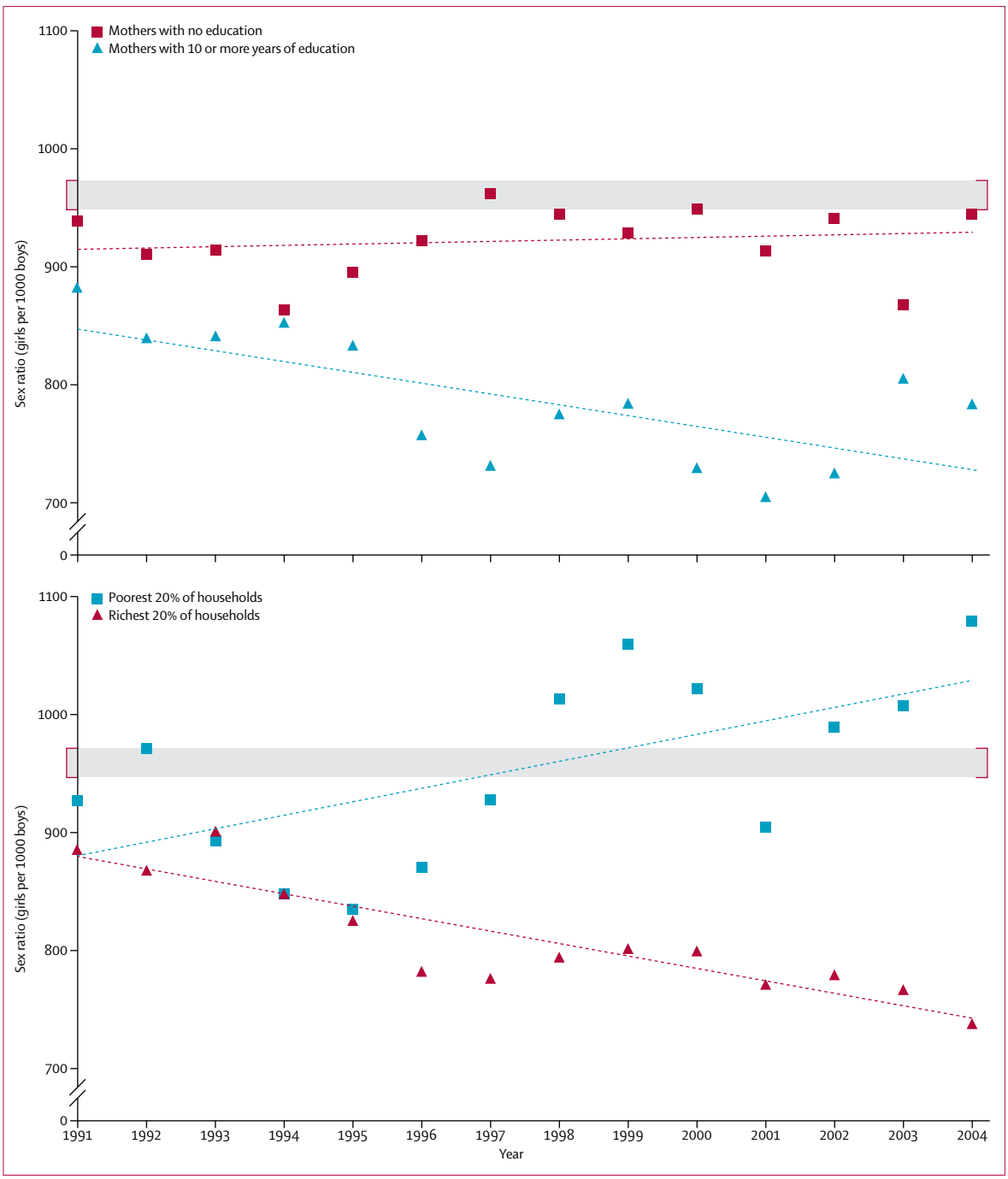

Figure 2: **Sex ratio (girls per 1000 boys) of second-order births, if firstborn was a girl, by mother's level of education and household wealth index, from 1990–2005**
Red brackets show the natural sex ratio range of 950–975 girls per 1000 boys. Test for trend: illiterate, p=0·347; grade 10 or higher, p=0·014; poorest 20%, p=0·026; richest 20%, p=0·002.

births, if the firstborn was a boy, did not change between 1990 and 2005 (p for trend=0·70 and 0·023, respectively), staying near the natural range of 950–975 girls per 1000 boys. The overall sex ratio for any births, irrespective of birth order, declined between 1990 and 2005 (p for trend=0·009), but that reported between 2000 and 2007 by the Registrar-General of India did not (webappendix p 1).[9] The conditional sex ratio of the second-order births if the firstborn was a girl or a boy differed significantly (p for test for differences <0·0001).

The conditional sex ratio for second-order births if the firstborn was a girl fell for mothers with 10 or more years

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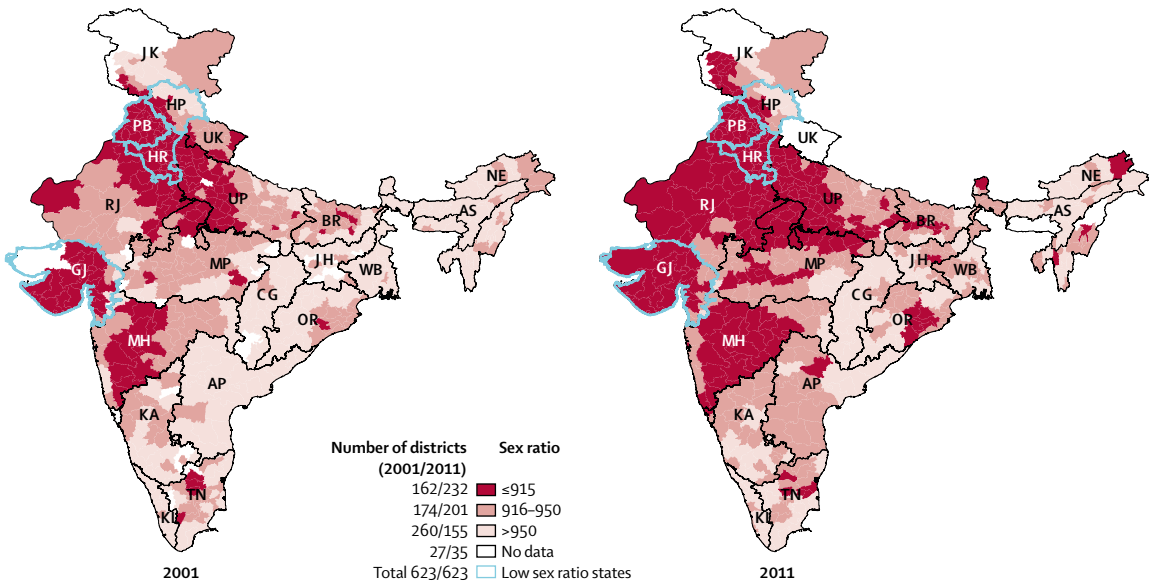

Figure 3: **Child sex ratio of girls to boys at ages 0–6 years in 2001 and 2011, by district**
Of the 623 districts, data were available for 596 in the 2001 census and 588 in the 2011 census. The blue highlighted states are Gujarat, Haryana, Himachal Pradesh, and Punjab, which have shown consistently lower child sex ratios at ages 0–6 years in the last three censuses. State names are Andhra Pradesh (AP); Assam (AS); Bihar (BR); Chattisgarh (CG); Gujarat (GJ); Haryana (HR); Himachal Pradesh (HP); Jammu and Kashmir (JK); Jharkhand (JH); Karnataka (KA); Kerala (KL); Maharashtra (MH); Orissa (OR); Punjab (PB); Rajasthan (RJ); Tamil Nadu (TN); Uttarakhand (UK); Uttar Pradesh (UP); West Bengal (WB); and Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura (collectively NE).

	Actual gap in girls to boys at ages 0–6 years (ratio of girls per 1000 boys)	Gap in girls to boys with the natural sex ratio at birth adjusted for higher girl mortality*		Estimated annual number of selective abortions of girls (low, high)	Actual number of children surveyed in each census (total, boys, girls)
		Low (950)	High (975)		
Born 1984–90 (1991 census)	4·23 (945)	0	1·38	0, 0·20	150·41, 77·32, 73·09
Born 1994–2000 (2001 census)	5·96 (927)	0·81	2·86	0·12, 0·41	157·86, 81·91, 75·95
Born 2004–10 (2011 census)	7·11 (914)	2·14	4·20	0·31, 0·60	158·79, 82·95, 75·84

*These hypothetical natural ranges of sex ratios at birth are adjusted for the number of excess girl deaths at ages 0–6 years that would have resulted with a higher number of girls born (the excess of girl deaths based on annual infant mortality rates calibrated to the ratio of deaths at older ages were [in millions] 0·42, 0·67, and 0·59 for a sex ratio of 950 for the 1991, 2001, and 2011 censuses, respectively, and 0·67, 0·88, and 0·75 for a sex ratio of 975 for the 1991, 2001, and 2011 censuses, respectively). These effectively alter the sex ratio of 950–975 girls per 1000 boys at birth to about 933–968 per 1000 at ages 0–6 years.

Table 3: **Estimates of annual gaps in girls to boys at ages 0–6 years due to selective abortion of female fetuses, in millions by birth year**

of education, but was unchanged for mothers with no education (p for test for differences=0·002; figure 2). The conditional sex ratios fell sharply in the 20% of the richest households by contrast with a non-significant increase in the 20% poorest households (p for test for differences <0·0001; figure 2). Declines in the conditional sex ratio were slightly greater in urban than in rural regions, but declines did not differ between Hindu and Muslim households (data not shown).

Figure 3 shows the changes in the child sex ratios at ages 0–6 years between the 2001 and 2011 censuses. The number of districts (local administrative areas within each state) with child sex ratios greater than 950 girls per 1000 boys fell from 260 to 155. Of the 563 districts common to both censuses and reporting data as of May 12, 2011, 405 districts (72%) had declines in the child sex ratio and 278 (49%) had declines greater than the national average decline of 1·4%. Only 158 districts (28%) had no change or increases in the child sex ratio (webappendix p 4).

	Low	High	Mean
1981–90 subtotals	0	1·97	0·98
1991–2000 subtotals	1·15	4·08	2·62
2001–10 subtotals	3·06	6·00	4·53
30-year totals	4·21	12·04	8·13

*Based on sex ratios at birth of 950–975 girls per 1000 boys, adjusted for excess mortality in girls.

Table 4: **Estimates of decennial gaps in girls to boys at ages 0–6 years due to selective abortion of female fetuses, in millions**

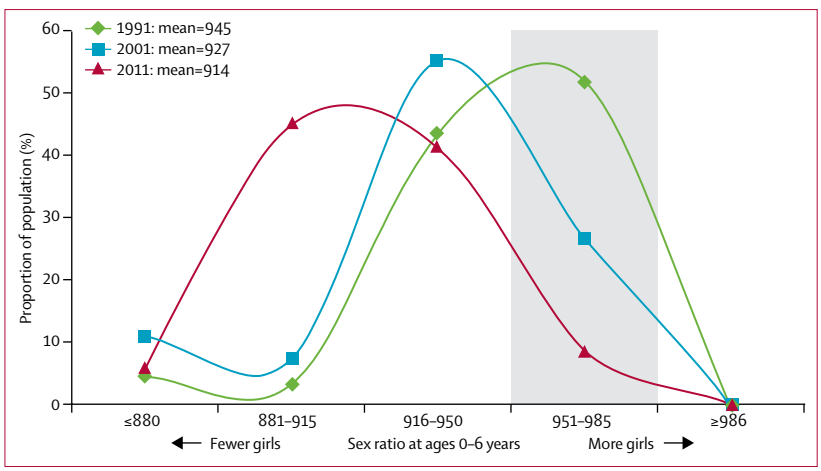

Figure 4: **Distribution of the total population living in states with varying child sex ratios (girls per 1000 boys at ages 0–6 years), 1991, 2001, and 2011**

Mean national values for each of the censuses are shown. The vertical grey bar represents a natural sex ratio at birth of 950–975 girls per 1000 boys, where the distribution of child sex ratios at ages 0–6 years would be centred in the hypothetical absence of selective abortion of girls and equal girl and boy child mortality rates.

Table 3 and table 4 list our estimates of the contribution of selective abortions of girls to the 1991, 2001, and 2011 census cohorts of living children. In the hypothetical case of no selective abortion of girls and equal death rates for boys and girls, the expected imbalance in the child sex ratio at ages 0–6 years would be much smaller than that noted. However, some imbalance would remain because the natural range of sex ratios at birth is 950–975 girls per 1000 boys.[2–4] After adjusting these natural sex ratios at birth for the excess deaths of girls (arising from more girls being born), selective abortion of female fetuses probably accounts for most, if not all, of the remaining gap between recorded and expected girls aged 0–6 years.

Our estimated annual total of selective abortions of girls rose from 0–0·20 million in the 1991 census, to 0·12–0·41 million in the 2001 census, and to 0·31–0·60 million in the 2011 census. Therefore the total number of selective abortions of girls rose from 0–2·0 million (mean 1·0 million) in the 1980s, to 1·2–4·1 million (mean 2·6 million) in the 1990s, and to 3·1–6·0 million (mean 4·5 million) in the 2000s. At 2010 birth rates and child mortality rates, every 1% drop in the child sex ratio at ages 0–6 years implies about 1·2–3·6 million additional selective abortions. Overall, there were between 4·2 million and 12·1 million selective abortions of girls from 1980 to 2010.

Discussion

Our findings show that selective abortion of girls in India has grown in the past two decades and accounts for most of the large and growing imbalance between the number of girls to boys aged 0–6 years. Sex ratios for births after a firstborn girl fell sharply from 1990 to 2005. By contrast, sex ratios for births after a firstborn boy did not change. Increases in selective abortion of girls are probably because of persistent son preference[10] combined with decreases in fertility: third-order or higher births as a proportion of all births fell from 49% in 1990 to 38% in 2005 in our study (and to 32% in 2008;[9] webappendix p 1). Son preference varies little by education or income,[10] but selective abortion of girls is more common in educated or richer households, presumably because they can afford ultrasound and abortion services more readily than uneducated or poorer households. Recent increases in literacy and Indian per-person income[19] might have thus contributed to increased selective abortion of girls.

Although large in absolute terms, selective abortion of female fetuses still accounts for only a minority of all annual female pregnancies (about 2–4%, or roughly 0·3–0·6 million, of the expected 13·3–13·7 million pregnancies in 2010 carrying a girl). Women with a first-order or second-order girl are most clearly at risk of aborting subsequent female fetuses. We did not yet see any clear evidence of selective abortion of firstborn female fetuses. This is partly because India does not enforce a one-child policy, which led to the selective abortion of firstborn female fetuses in China.[20] However, selective abortions of first-order girls might increase if fertility drops further, particularly in urban areas.

Although our birth data were only until 2005, a district-based household survey from 2005 to 2007 found similar conditional sex ratios for births after a firstborn girl.[21] Thus, selective abortion remains common in the most recent cohorts of children captured in the 2011 census. Figure 4 shows a remarkable shift in the population living in states where the child sex ratios at ages 0–6 years are below 915 girls per 1000 boys; rising from 10% in 1991, to 27% in 2001, and 56% in 2011. Thus, we conclude that most of India's population now lives in states where selective abortion of girls is common.

The Indian Government implemented a Pre-Natal Diagnostic Techniques Act in 1996 to prevent the misuse of techniques for the purpose of prenatal sex determination leading to selective abortion of girls.[22] It is unlikely that this Act has been effective nationally because few health providers have been charged or convicted.[23] We are not surprised by this lack of prosecution given that most primary care is with unregulated private providers.[24] More than twice the number of districts showed declines in the child sex ratio between 2001 and 2011 censuses compared with the number of districts with no change or increases in the child sex ratio. However, the 170% rate of increase in selective abortions of girls from 2001 to 2011 is slower than the 260% rate of increase from 1991 to 2001. Indeed, the 2011 census noted the child sex ratios at ages 0–6 years had increased somewhat in the states of Haryana and Punjab, and had stabilised in Gujarat (webappendix p 4). It might be that the Pre-Natal Diagnostic Techniques Act, plus the recent public attention to selective abortion of girls, has reduced the practice in some settings. Our results are consistent with reports that ultrasound and abortions are far more common in second-order and third-order births than in firstborns (panel).[26,27] However,

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Panel: Research in context

Systematic review

In a systematic review with the search terms "female" [all fields] AND "abortion" [all fields] AND "trends" [all fields] AND "India" [all fields], we identified 35 studies, of which 22 were published after 1990. Only one, a small hospital-based study in Gujarat, noted an increase in abortions from 1983 to 2003.[25] No studies were available that provided nationally representative data on trends for India.

Interpretation

Our study is the first to assess trends over time in selective abortion of girls in India at the national level with nationally representative data. We compared the sex ratios of second-order births after firstborn girls with the second-order sex ratios after firstborn boys. We note a sharp decline in the girl-to-boy sex ratio for second-order births when the firstborn was a girl, with a mean fall of about 0·5% annually between 1990 and 2005. These declines are greater in educated and in richer households than in illiterate and poorer households. Since family size in India has fallen substantially, it seems that selective abortion of girls is increasingly being used for second-order births or higher if the firstborn was a girl, to ensure at least one boy in the household. The total of about 4–12 million selective abortions of girls from 1980 to 2010 is consistent with other estimates that used other methods. The data also suggest that selective abortion has spread from a handful of states to most parts of the country. Thus, most of India's population now live in states where selective abortion of girls is common.

our method based on conditional birth histories is unlikely to be biased by misreporting of ultrasound use.[26]

Our study has some limitations. First, the sex ratios in the NFHS are based on birth histories, which vary substantially from year to year. This is in part due to random variation from only a few hundred or thousand births, as well as possible systematic underenumeration of girls and recall biases for birth histories in retrospective surveys.[10,28] However, our key analysis was of trends over several years, where the yearly variation is less important. We therefore relied on actual enumerated children in the censuses to calculate absolute totals of missing girls rather than the NFHS birth histories. The census omission rates are low, and do not vary greatly by sex,[15] which might have otherwise resulted in spurious sex ratios. Second, our annual estimates of selective abortions of girls relying on the census are, by necessity, crude. Our study estimates are notably more conservative than those estimated from birth histories in the Sample Registration System (a large, continuous, nationally representative demographic survey of more than 1 million homes).[9] Specifically, Sample Registration System-based estimates of annual selective abortions of girls were 0·59–0·74 million in 1997[7] and 0·48–0·67 million during 2001–03[8] (webappendix p 2). However, the 4–12 million estimate of selective abortions of girls from 1980 to 2010 is consistent with our earlier (cruder) estimate of about 10 million selective abortions of girls from 1985 to 2005,[7] as well as other estimates of 8–18 million selective abortions of girls from 1981 to 2006.[29] Third, the exact contribution of selective abortion of girls to the measured sex imbalance at ages 0–6 years in the censuses also depends on child mortality rates. However, only in recent years did slightly more girls die compared with boys,[1] and we adjusted our estimates for higher girl mortality had more girls been born. Fourth, the sex ratio range at birth of 950–975 girls per 1000 boys is based on findings in Europe and North America, and might not apply to Asian populations for unknown biological reasons.[30] However, such sex ratios at birth were documented in some Indian states as recently as 1991. Although unmeasured biological factors, such as infections, might reduce or increase overall sex ratios at birth, they are unlikely to be conditional on birth order.[4] Finally, we identified, as in earlier reports[7,8] and in unpublished data on birth histories in Indian diasporas (data not shown), a small and presently inexplicable excess of third girls after the birth of two earlier boys.

The selective abortion of female fetuses, usually after a firstborn girl, has increased in India over the past few decades, and has contributed to a widening imbalance in the child sex ratio. Reliable monitoring and reporting of sex ratios by birth order in each of India's districts could be a reasonable part of any efforts to curb the remarkable growth of selective abortions of girls.

Contributors

JKB was the Registrar-General of India responsible for implementing and publishing the 2001 census. PJ and the academic partners in India (RGI-CGHR Collaborators) planned the Million Death Study in close collaboration with the Office of the Registrar General of India. MAK and PJ did the statistical analyses. All authors were involved with data interpretation, critical revisions of the paper, and approved the final version; PJ is its guarantor.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

The Registrar-General of India first established the ongoing national census in 1881, and is presently collaborating with several of the authors on the Million Death Study. External funding is from the Fogarty International Centre of the US National Institutes of Health (grant R01 TW05991–01]), International Development Research Centre (grant 102172), Canadian Institute of Health Research (CIHR; IEG-53506), and the Li Ka Shing Knowledge Institute at St Michael's Hospital and University of Toronto (CGHR support). PJ is supported by the Canada Research Chair programme. The opinions expressed in this report are those of the authors and do not necessarily represent those of the Government of India. We thank Rahim Moineddin and Wilson Suraweera for statistical help, Vicky Hsiao and Brendon Pezzack for graphics, and Daniel Rosenblum and Ansely Wong for comments.

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Can India achieve a balance of sexes at birth?

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The masculine nature of the Indian population, as indicated by the lower than normal sex ratio (defined as female-to-male ratio in India), has been a matter of concern since the first Indian census in 1871.[1] Almost a century and a half later, the sex ratio in children aged 0–6 years in India—of 915 girls to 1000 boys—is the lowest ratio recorded since data became available in 1961.[2] The steady decline in the ratio is surprising, and counterintuitive, in view of India's progress in recent decades in improving the levels of female literacy and increases in income per person. In *The Lancet*, Prabhat Jha and colleagues[3] present a timely analysis of trends in sex ratio at birth in India, and show that the ratio for second-order births, conditional on the first born being a girl, fell from 906 girls per 1000 boys in 1990, to 836 girls per 1000 boys in 2005. On the basis of this finding, the investigators estimate that there have been between 3·1 and 6 million abortions of female fetuses in the past decade.

In view of the unverifiable assumptions that are needed to derive statistical estimates of sex-selective abortions, the value of the analysis by Jha and colleagues is mainly independent confirmation of two important aspects of the sex ratio in India that have been reported previously with different data.[4,5] The first is that sex imbalance at birth seems to be particularly concentrated in households with high education and wealth. This pattern suggests that dominance of the son-preference norm is unlikely to be offset, at least in the short term, by socioeconomic development. Second is that the overall problem of sex imbalance seems to arise throughout India, including in Kerala,[4,5] which has often been characterised as a model state for social development and gender equality.[6] The problem of sex imbalance seems to be a function of socioeconomic status, not geography.

The abnormal sex ratio in children was initially attributed to gender discrimination in the allocation of health-related resources within households—indicative of the strong societal norm of son preference—leading to excess mortality in girls.[7] Recent declines in the child sex ratio, however, are thought to be driven largely by medical technologies to determine the sex of fetuses, followed by selective abortion of girls.[8] Although the implementation of the Pre-Natal Diagnostic Techniques Act[9] makes it illegal to identify the sex of a fetus, there is little evidence that the law is accomplishing its goal.[4] Rather, it seems that states with increased availability, per person, of registered prenatal diagnostic facilities have lower child sex ratios than states where this equipment is less available. This finding suggests either increased demand for such services in states with populations with a high son preference, or that the presence of these facilities is actively contributing to the lowering of sex ratios through sex determination and sex-selective abortion (figure).

Can India balance its distribution of sexes at birth? The prospects seem grim. The demand for sons among wealthy parents is being satisfied by the medical community through the provision of illegal services of fetal sex-determination and sex-selective abortion. The financial incentive for physicians to undertake this illegal activity seems to be far greater than the penalties associated with breaking the law. The market for sex determination and selective abortion has been

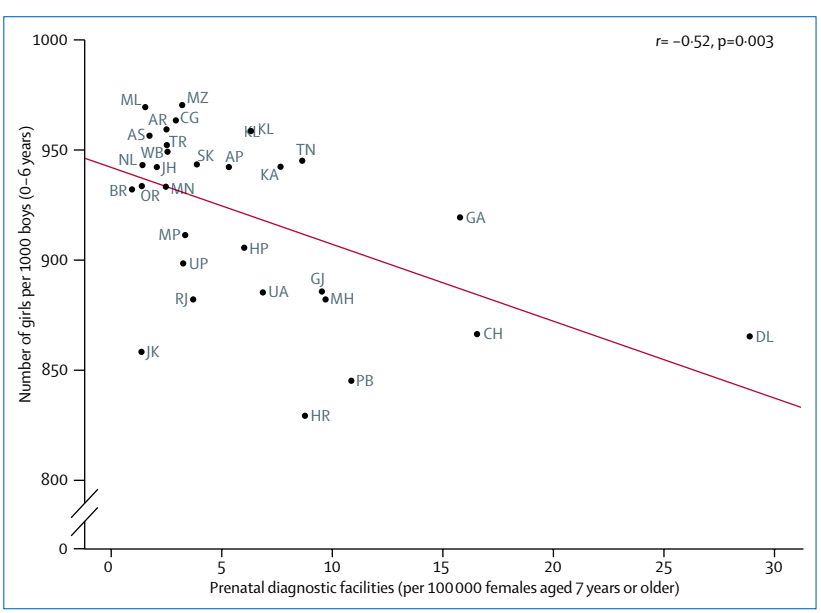

Figure: **Number of girls per 1000 boys (2011) by per-person availability of prenatal diagnostic facilities (2006) across states in India**

Child female-to-male ratio at ages 0–6 years from 2011 Census of India.[2] Prenatal diagnostic facilities calculated as per 100 000 women (age 7 years and older), based on number of facilities registered by state through 2006.[9] Facilities include genetic counselling centres, genetic laboratories, genetic clinics, ultrasound clinics and imaging centres, mobile clinics (vehicles), and in-vitro fertilisation and infertility centres. State names: Andhra Pradesh (AP), Arunachal Pradesh (AR), Assam (AS), Bihar (BR), Chandigarh (CH), Chhattisgarh (CG), Delhi (DL), Goa (GA), Gujarat (GJ), Haryana (HR), Himachal Pradesh (HP), Jammu and Kashmir (JK), Jharkhand (JH), Karnataka (KA), Kerala (KL), Madhya Pradesh (MP), Maharashtra (MH), Manipur (MN), Meghalaya (ML), Mizoram (MZ), Nagaland (NL), Orissa (OR), Punjab (PB), Rajasthan (RJ), Sikkim (SK), Tamil Nadu (TN), Tripura (TR), Uttar Pradesh (UP), Uttarakhand (UA), and West Bengal (WB).

estimated to be worth at least US$100 million per year,[8] and the pervasive nature of the low sex ratio at birth suggests that this is not a consequence of a minority of errant physicians in a few states. Therefore the medical establishment must be held accountable on moral, social, and legal grounds. Although there have been efforts to increase the penalty for non-compliance on the part of technicians and physicians, the sluggishness of the Indian judicial system, and the absence of systematic record-keeping of births, will remain a major hurdle for effective implementation of the Pre-Natal Diagnostic Techniques Act. For example, 800 court cases against doctors in 17 states have resulted in only 55 convictions.[10]

India does not record how many children are born every day. Immense challenges exist to register every birth, but sample survey data based on a mother's recall of her entire birth history, as used by Jha and colleagues, are far from ideal. The decadal frequency of the census limits its usefulness for frequent monitoring and surveillance of the proportion of sexes at birth. Any meaningful progress towards achieving a balance of sexes at birth, therefore, has to start by enumerating every child at birth.

Public policy efforts thought to have helped normalise sex ratios at birth in South Korea,[11] together with calls for effective implementation of the Pre-Natal Diagnostic Techniques Act, raise hope for a possible turnaround in India. However, son-biased sex ratios were found for second and higher births in Indians living in the USA, with no such biases found in the ratios for whites at all birth orders.[12] In this natural experiment of sorts, whereby the social norms that facilitate son preference are removed, son-biased sex ratios persist. This finding raises a difficult and provocative question for public policy: if no male biases are noticeable for the first born, as is the case in India,[3] should medical technology and services be allowed to play a part in letting a family plan their desired composition, especially when there is an active public policy effort to voluntarily limit family size to replacement level?

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Web table 1: Percentage of women in India, aged 15-49, reporting on gender and family size preference.

Indicator	1992-3	1998-9	2005-6
Mean no. of ideal sons	1.6	1.4	1.2
Mean no. of ideal daughters	1.1	1.0	0.9
Mean no. of ideal either sex	0.2	0.3	0.4
% want more sons than daughters	41.4	33.2	25.4
% want more daughters than sons	2.6	2.2	2.4
% want at least one son	90.0	85.1	80.7
% want at least one daughter	84.6	80.1	74.7

Source: Reference 11

Web table 2: SRS sex ratio at birth, sex ratio age 0-4 years, and percent first and second birth order, in India.

	2000	2001	2002	2003	2004	2005	2006	2007
India								
Sex ratio at birth	894	892	883	882	880	892	901	904
Sex ratio 0-4		907	905	905	907	908	914	915
% birth order-1st	33.4	33.3	33.7	35.1	35.5	35.0	36.7	37.0
% birth order-2nd	27.0	27.5	27.9	25.1	27.9	28.9	28.8	29.8

Source: Reference 10

Web table 3: NFHS male/female death rates ages 0-4 years, in India.

Survey	Boys	Girls	Girl/Boy relative ratio	Girl-Boy absolute difference
Child mortality rates				
NHFS-1, 1992-3	115.4	122.4	1.06	7.00
NHFS-2, 1998-9	97.90	105.2	1.07	7.30
NFHS-3, 2005-6	69.70	79.2	1.14	9.50
No. of deaths in thousands				
NHFS-1, 1992-3	1,559.6	1,490.2	0.96	-69.33
NHFS-2, 1998-9	1,324.5	1,282.2	0.97	-42.28
NFHS-3, 2005-6	960.7	973.8	1.01	13.04

Source: Reference 11, 14, 15

Web table 4: Observed, expected and missing female births in India (in millions) in 1997 and 2001-03 by birth order and sex of previous children in the SRS.

1997

Birth order	Sex	Births in millions (% of all births)	Observed female births (Millions)	Expected female births (Millions)		Missing female births in millions (% of missing female births)	
				Female-to-Male Ratio		Female-to-Male Ratio	
				950	975	950	975
1st		8.1	3.8	3.9	4.0	0.17 (30%)	0.23 (31%)
2nd	Male	3.7	1.9	1.8	1.8	-	-
	Female	3.8	1.6	1.8	1.9	0.21 (36%)	0.23 (32%)
3rd	Male	1.2	0.6	0.6	0.6	-	-
	Female	1.4	0.6	0.7	0.7	0.10 (17%)	0.11 (15%)
	One male, one	2.4	1.1	1.2	1.2	0.03 (5%)	0.04 (6%)
4+		7.4	3.5	3.6	3.7	0.08 (13%)	0.12 (17%)
All		28.0	13.1	13.6	13.8	0.59 (100%)	0.74 (100%)

2001-2003

Birth order	Sex	Births in millions (% of all births)	Observed female births (Millions)	Expected female births (Millions)		Missing female births in millions (% of missing female births)	
				Female-to-Male Ratio		Female-to-Male Ratio	
				950	975	950	975
1st		8.5	4.0	4.2	4.2	0.14 (25%)	0.19 (29%)
2nd	Male	4.0	1.9	2.0	2.0	-	-
	Female	3.7	1.7	1.8	1.8	0.15 (27%)	0.17 (26%)
3rd	Male	0.9	0.5	0.5	0.5	-	-
	Female	1.2	0.5	0.6	0.6	0.09 (16%)	0.09 (14%)
	One male, one	1.9	0.9	0.9	0.9	0.06 (11%)	0.07 (11%)
4+		4.3	2.0	2.1	2.1	0.11 (20%)	0.14 (21%)
All		24.6	11.4	12.0	12.1	0.55 (100%)	0.66 (100%)

*1997 data reproduced from Reference 9

Web table 5: Number of live births for the manuscript figures, using three year rolling averages.

Figure 1: Number of firstborn and second order births, conditional on sex of firstborn, by year, in India.

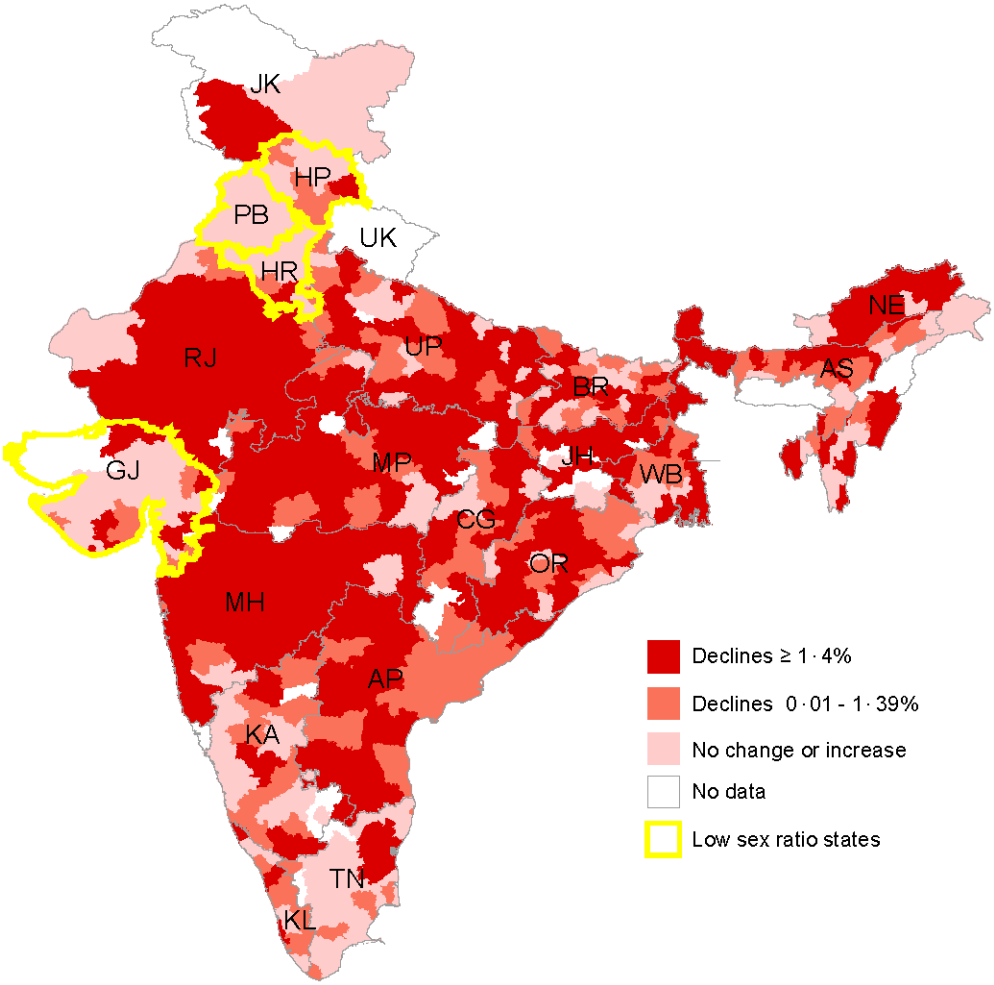
Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Firstborn	3494	3611	3538	3493	3313	3290	3354	3402	3434	3383	3358	3311	3305	3383
Second birth, firstborn was a girl	1546	1533	1592	1596	1556	1480	1483	1509	1506	1447	1423	1427	1460	1481
Second birth, firstborn was a boy	1637	1638	1659	1671	1578	1530	1551	1546	1516	1432	1430	1430	1454	1465

Figure 2A: Number of second order births, if firstborn was a girl, by year and literacy, in India.

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Illiterate	824	810	835	802	733	658	635	640	604	539	496	474	460	432
Primary or below grade 10	479	484	519	545	554	535	544	559	560	554	552	579	597	622
Grade 10 or higher	243	239	239	249	269	287	303	310	342	353	375	374	403	427

Figure 2B: Number of second order births, if firstborn was a girl, by year and wealth index, in India.

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Poorest 20%	290	298	323	328	313	286	286	285	282	265	261	252	249	237
Richest 20%	319	313	319	318	317	305	308	300	311	303	320	322	331	340



Web figure 1: Relative changes (in percent) in the child sex ratio of girls to boys at ages 0-6, between 2001 and 2011, for the districts of India.

Average national decline from 2001-2011 (including the 110 districts whose data are not shown here) was 1•4%. Mean values among the 513 reporting districts were as follows: mean decline=-3•1% among the 251 districts showing declines greater than the national average; mean decline=-0•7% among the 119 districts showing declines less than the national average; and mean increase=2•4% among the 143 districts showing no change or increases.

*The red highlighted states are Gujarat, Haryana, Himachal Pradesh, and Punjab, which have shown consistently lower child sex ratios at ages 0-6 years in the last three censuses.[1]

State names: Andhra Pradesh (AP); Assam (AS); Bihar (BR); Chattisgarh (CG); Gujarat (GJ); Haryana (HR); Himachal Pradesh (HP); Jammu & Kashmir (JK); Jharkhand (JH); Karnataka (KA); Kerala (KL); Maharashtra (MH); Orissa (OR); Punjab (PB); Rajasthan (RJ); Tamil Nadu (TN); Uttarakhand (UK); Uttar Pradesh (UP); West Bengal (WB); and Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura (collectively NE).