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Changing patterns of social inequalities in anaemia among women in India: cross-sectional study using nationally representative data

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ABSTRACT

Objectives: To examine the patterns of social inequalities in anaemia over time among women of reproductive age in India.

Design: Repeated cross-sectional study using nationally representative data from the 1998/1999 and 2005/2006 National Family Health Surveys of India. Multivariate modified Poisson regression models were used to assess trends and social inequalities in anaemia.

Setting: India.

Population: 164 600 ever-married women aged 15–49 years (n=79 197 in 1998/1999 and n=85 403 in 2005/2006) from 25 Indian states.

Main outcome measure: Anaemia status defined by haemoglobin level (<12 g/dl in non-pregnant women, haemoglobin<11 g/dl for pregnant women).

Results: Over the 7-year period, anaemia prevalence increased significantly from 51.3% (95% CI 50.6% to 52%) to 56.1% (95% CI 55.4% to 56.8%) among Indian women. This corresponded to a 1.11-fold increase in anaemia prevalence (95% CI 1.09 to 1.13) after adjustment for age and parity, and 1.08-fold increase (95% CI 1.06 to 1.10) after further adjustment for wealth, education and caste. There was marked state variation in anaemia prevalence; in only 4 of the 25 states did anaemia prevalence significantly decline. In both periods, anaemia was socially patterned, being positively associated with lower wealth status, lower education and belonging to scheduled tribes and scheduled castes. In this context of overall increasing anaemia prevalence, adjusted relative and absolute socioeconomic inequalities in anaemia by wealth, education and caste have narrowed significantly over time.

Conclusions: The significant increase in anaemia among India's women during this recent period is a matter of concern, and in contrast to secular improvements in other markers of women's health and nutritional status. While socioeconomic inequalities in anaemia persist, the relative and absolute inequalities in anaemia have decreased over time. Future research should explore the causes for these changing patterns, and inform the policy and programmatic response to address anaemia and its inequalities in this vulnerable population.

ARTICLE SUMMARY

Article focus

- Anaemia is a major global health issue, primarily affecting women of reproductive age and children. In India, more than half of women of reproductive age are anaemic.
- While anaemia disproportionately affects disadvantaged groups, it is not known how patterns of inequalities in anaemia have changed over time.

Key messages

- India's prevalence of anaemia among women of reproductive age has increased significantly over a recent 7-year period, even after adjustment for age, parity, wealth, education, caste and residence.
- Socioeconomic inequalities in anaemia (by wealth, education and caste), using both absolute and relative metrics, have decreased over time.
- Future studies, which explore the causes for narrowing inequalities in anaemia and explore why trends in anaemia are increasing, are needed to guide the policy response.

Strengths and limitations of this study

- Used large population-based nationally representative data with haemoglobin testing.
- Measured both relative and absolute inequalities across different dimensions of social inequalities to assess changing patterns over time.
- Unable to distinguish between the different causes of anaemia that may explain the changing patterns of inequalities.
- Used repeated cross-sectional surveys standardised across the two time periods.

INTRODUCTION

Anaemia persists as a significant public health problem affecting 1.62 billion of the world's population.¹ The burden falls predominantly on Asia and Africa with the complex interplay of dietary factors, infectious disease, genetics and other factors determining anaemia status.² Anaemia contributes to almost 120 000 maternal deaths

globally; in low and middle income countries, 18% of maternal mortality is attributed to iron deficiency.³ Several adverse health outcomes have been associated with anaemia including maternal morbidity and mortality, perinatal and neonatal mortality, low birth weight and poor cognitive development.⁴ Women of reproductive age are physiologically more vulnerable to anaemia because of recurrent menstrual loss and the demands of pregnancy and repeated childbearing; global estimates suggest that the prevalence of anaemia is 41.8% among pregnant women and 30.2% among non-pregnant women.¹

South Asia suffers from some of the highest rates of anaemia worldwide,⁵ and in India, more than half are anaemic and around one-third of women of reproductive age are underweight.⁶ In this region burdened by high maternal mortality,⁷ around 13% of maternal deaths are attributable to anaemia.⁸ Given the importance of addressing the nutritional and health needs of women of reproductive age, understanding the trends and patterns of anaemia within this population is important for meeting Millennium Development Goal 5, which pertains to improving maternal health.

While several small epidemiological studies have focused on determining the prevalence and causes of anaemia among specific subpopulations of Indian women,^{9–14} population-based surveys such as the National Family Health Surveys (NFHS) and District Level Household and Facility Surveys (DLHS) have been more useful in monitoring the national burden of anaemia.^{15–20} Understanding the social patterning of anaemia and heterogeneity among different groups and across states, and exploring the changing patterns of anaemia distribution over time may help elucidate which factors drive these changes, and identify interventions to address this significant health burden.

Therefore, we set out to examine the national and state trends in anaemia prevalence and examine how social inequalities in anaemia among women of reproductive age have changed over time during a recent 7-year period. This study adds to the existing literature in several ways: first, by using nationally representative data of 164 600 women from two repeated cross-sectional surveys to examine trends in social inequalities over time; second, by using both relative and absolute metrics to capture different dimensions of social inequalities over time; third, by conducting analyses at both the national and state levels to investigate anaemia trends over time and fourth, by using modified Poisson regression models to more accurately estimate prevalence ratios.

METHODS

Data sources

We used data from the NFHS of India carried out in 1998/2009 (NFHS-2) and 2005/2006 (NFHS-3).²¹ These nationally representative cross-sectional surveys collect

detailed information relating to population, health and nutrition. The surveys use a stratified cluster multistage sampling design, with generally two stages in rural areas and three stages in urban areas. In brief, in rural areas, in the first stage, primary sampling units (PSU) are selected using a probability proportional to population size; in the second stage, households are systematically selected for inclusion in the survey. In urban areas, in the first stage, wards are selected using a probability proportional to population size; in the second stage, a census enumeration block is selected randomly from each ward; and in the third stage, households are selected randomly from each census enumeration block for inclusion in the survey. More details of the sampling methodology are described elsewhere.²¹ NFHS-2 was restricted to ever-married women aged 15–49 years, whereas NFHS-3 included all women aged 15–49 years.

Both surveys were carried out by trained fieldworkers using standardised questionnaires and methodologies, and the household response rate was greater than 95% in both surveys. NFHS-2 surveyed 90 303 ever-married women from 92 486 households from the 26 states; NFHS-3 surveyed 124 385 women from 109 041 households in all 29 states of India (between the time of the surveys, three new states were formed: Jharkhand was created out of Bihar, Uttaranchal (Uttarakhand) from Uttar Pradesh and Chhattisgarh from Madhya Pradesh).

Ethical review

Informed consent was obtained from participants at the time of interview, and further consent was obtained prior to blood testing. All survey participants received an informational leaflet at the time of anaemia testing; women diagnosed with severe anaemia were asked if they could be referred to local health services. This analysis was approved by the Institutional Review Board of the Harvard School of Public Health.

Study population

In NFHS-2, 80 851 (89.5%) agreed to haemoglobin (Hb) testing, 3252 (3.6%) refused and 6200 (6.9%) were not sampled. Of those women who agreed to testing, Hb measurements were available for 80 672 women (99.8%) (89.3% of the total sample). In NFHS-3, Hb was measured on 90.6% of women surveyed (n=112 714): anaemia (and HIV) testing was not conducted in the state of Nagaland due to local opposition (3.13%; n=3 896); in the other states, 4.45% (n=5538) refused, 0.86% (n=1069) were not present for testing and in 0.94% (n=1168), Hb was not measured for other reasons. Extreme and physiologically implausible measurements (Hb<4g/dl and >20g/dl) were excluded (n=84 in NFHS-2; n=69 in NFHS-3). A further 674 in NFHS-2 and 376 in NFHS-3 were excluded due to missing data on other covariates used in this analysis.

In order to ensure comparability between the surveys, state boundaries from the time of the earlier survey were used, and the state of Nagaland was excluded from the

analysis as it was not represented in the later survey, thus yielding a total of 25 states. The sample was restricted further to ever-married women to ensure comparability between the two surveys. Therefore, the final analytical sample consisted of 164 600 ever-married women from 25 states in India; with 79 197 women from NFHS-2 and 85 403 women from NFHS-3.

Dependent variable

The main outcome variable was Hb level measured in g/dl, operationalised as a categorical variable by predefined cut-off points for mild, moderate and severe anaemia recommended by the WHO for women above age 15 years. For non-pregnant women, any anaemia was defined as Hb<12 g/dl, and for pregnant women as <11 g/dl: this included the categories of mild, moderate and severe anaemia. Mild anaemia was defined as 10–11.9 g/dl for non-pregnant women and 10–10.9 g/dl for pregnant women. Moderate/severe anaemia was defined as Hb<10 g/dl.²² Both non-pregnant and pregnant women were included in the analysis. Hb levels were adjusted for altitude and smoking status.²³

Anaemia testing was conducted by specially trained personnel who were part of the survey team. The finger prick tests were carried out in the homes of the respondents, and blood samples were tested immediately using a portable hand-held HemoCue testing system. In NFHS-2, the HemoCue B-Hb system was used, whereas the newer HemoCue Hb 201+ analyser was used in NFHS-3.

Independent variables

The demographic, socioeconomic, cultural and behavioural covariates included in the analysis were age, marital status, parity, religion, caste, place of residence, wealth, education, occupation, body mass index (BMI), contraceptive use, vegetarianism and alcohol consumption, based on a review of the existing literature.

We focused on wealth, education and caste as key measures of socioeconomic status, based on previous work on social patterning of disease in India.²⁴ We constructed a new wealth index from the 24 household asset data and household characteristics available in both surveys, and used this to categorise individuals into wealth quintiles (poorest, poorer, middle, rich, richest). Principal components analysis was used to assign each of the 24 assets and housing characteristics a factor score or weight derived from a covariance matrix. These weights were then used to estimate an asset score for each household.^{25 26} Households were ranked on their asset score for each survey, and individuals were then ranked according to their household.

Education was categorised based on years of schooling into none, 1–5 years, 6–10 years, 11–12 years, >=13 years, representing milestones in educational attainment. Caste was classified in to scheduled caste (SC), scheduled tribe (ST), other backward caste, general, other/missing, reflecting the categories most routinely used for

population-based monitoring.²⁷ Caste represents a social stratification based on hereditary status in Indian society, although such classification masks substantial heterogeneity within these groups.²⁸ Place of residence was defined as either urban or rural.

Age was categorised into 5 years age groups. Parity, defined as the number of children ever born, was categorised as 0, 1, 2, 3, 4, 5 or more. Religion was categorised into Hindu, Muslim, Christian, Sikh, Buddhist and other/missing. BMI (kg/m²) was categorised using standard WHO classification into underweight <18.5 kg/m², normal 18.5–24.9 kg/m², overweight 25.0–29.9 kg/m² and obese ≥30.0 kg/m².²⁹ Contraceptive use was categorised as no use, use of contraceptive pills, use of intrauterine device, female sterilisation or other. Vegetarianism (yes/no) was based on a self-report of never eating fish or meat products. Any alcohol consumption (yes/no) was based on a self-report of drinking alcohol.

Statistical analysis

We estimated the weighted prevalences of any anaemia and moderate/severe anaemia for each of the covariates using the survey-specific sample weights clustered at the PSU level for both surveys taking into account the survey design.

Trends in anaemia

We examined both relative and absolute changes in anaemia prevalence. We estimated adjusted prevalence ratios and 95% CIs from modified Poisson regression models, using the time of the first survey as the reference group. Given that the outcome of anaemia was not rare (>10%), the use of logistic models is less appropriate as the resultant ORs are a poor approximation of the prevalence ratio.^{30 31} Alternative approaches for estimating the prevalence ratio include log-binomial models or modified Poisson models. Owing to the failure of the log-binomial model to converge, we adopted a modified Poisson regression approach, although this approach is less efficient. Poisson models are considered appropriate for modelling rare events over time; however, when applied to binomial data, they can overestimate the error-term associated with the prevalence ratio. Therefore, the alternative approach of modified Poisson models, using a robust error variance procedure to more accurately estimate the SEs, was adopted.³² In these modified Poisson models, we first adjusted for age and parity, and then additionally controlled for wealth, education, caste and place of residence to estimate relative change. We estimated absolute change in anaemia prevalence and 95% CIs from linear regression models, using the time of the first survey as the reference group, adjusting for the same covariates. These modelling procedures were then carried out independently (25 models) for each state to examine the anaemia trends for each state.

Patterns of socioeconomic inequalities in anaemia

We first examined the correlates of anaemia for the covariates listed above using multivariable multilevel Poisson regression models, for each survey separately and then for the pooled sample. Adjusted prevalence ratios and 95% CIs for each covariate were estimated from these models.

We measured socioeconomic anaemia patterns using wealth, education and caste, making the normative judgement that these are important social constructs which influence the distribution of opportunities and, therefore, access to goods and services which can reduce exposure to the determinants of anaemia.³³ Wealth, education and caste have shown to be important axes of stratification in Indian society,²⁴ with independent associations with nutrition outcomes in this context.³⁴ In unadjusted analysis, we assessed inequalities by wealth (poorest vs richest (reference)), education (no education vs most educated ≥ 13 years (reference)) and caste (ST vs general (reference)) for both surveys. Trends in relative and absolute inequalities over time were calculated using $((\text{rate ratio (RR)}_{2005} - \text{RR}_{1998}) / ((\text{RR}_{1998} - 1)))$ and $((\text{rate difference (RD)}_{2005} - \text{RD}_{1998}) / ((\text{RD}_{1998} - 1)))$, respectively.³⁵ In adjusted analysis, we applied the modified Poisson regression modelling method described above to pooled data from both surveys and tested for interactions between wealth, education and caste and the survey year, each in separate models, using Wald tests.

For the continuous variable of Hb, we then estimated the independent effects of wealth, education and caste on Hb level from multivariable multilevel linear regression models to see whether these associations have changed over time. (This analysis was restricted to non-pregnant women due to the variation in Hb during pregnancy.) Again, this was carried out for the pooled sample including interaction terms between socioeconomic variables and the survey year.

In sensitivity analyses, we also used an alternate stepwise modelling approach, using the significance level of $p < 0.05$, to justify the inclusion of covariates into the regression models.

Statistical significance was considered at $p < 0.05$; all tests were double-sided. Survey sample weights were applied. Regression models included a random effect at the PSU level to account for clustering at the PSU and state fixed effects. Analyses were carried out using STATA: Release V.10 (StataCorp LP, CollegeStation, Texas, USA).

RESULTS

Table 1 shows the weighted distributions of anaemia prevalence among women of reproductive age in India for both surveys. Between 1998/1999 and 2005/2006, the prevalence of all severities of anaemia increased among ever-married women in India. The prevalence of any anaemia increased from 51.3% (95% CI 50.6% to 52.0%) in 1998/1999 to 56.1% (95% CI 55.4% to 56.8%) in 2005/2006. The prevalence of mild anaemia

increased from 35.0% (95% CI 34.4% to 35.5%) to 38.9% (95% CI 38.3% to 39.5%), while the prevalence of moderate/severe anaemia increased from 16.3% (95% CI 15.9% to 16.8%) to 17.2% (95% CI 16.8% to 17.7%). The prevalence of anaemia among pregnant women increased from 49.2% (95% CI 47.5% to 51.0%) in 1998/1999 to 57.8% (95% CI 56.1% to 59.6%) in 2005/2006, and among non-pregnant women, it increased from 51.4% (95% CI 50.7% to 52.2%) in 1998/1999 to 56.0% (95% CI 55.3% to 56.7%) in 2005/2006.

After adjustment for age and parity, the prevalence of anaemia increased 1.11-fold, (95% CI 1.09 to 1.13), and 1.08-fold (95% CI 1.06 to 1.10) after further adjustment for wealth, education and caste. Correspondingly, between the two periods, there was a significant decline in the mean Hb of women of reproductive age ($p < 0.001$) from 11.7 (95% CI 11.7 to 11.7) to 11.5 g/dl (95% CI 11.5 to 11.6) among non-pregnant women ($p < 0.001$), and from 10.9 (95% CI 10.8 to 10.9) to 10.6 (95% CI 10.5 to 10.6) g/dl among pregnant women ($p < 0.001$).

Next, we examined the changes in the prevalence of anaemia (table 2; see online supplementary figure S1) and changes in Hb level by state (see online supplementary table S1). We found marked regional variation in anaemia prevalence, ranging in 2005/2006 from 69.4% in Assam, 68.7% in Bihar and 67.5% in Tripura, to 32.7% in Kerala, 38.4% in Punjab and 38.8% in Goa. In 14 of the 25 states, there was a significant increase in the adjusted relative risk of anaemia over time, with a significant increase in the adjusted absolute difference in 13 states. In the states of Himachal Pradesh, Manipur, Sikkim, Andhra Pradesh and Kerala, the adjusted absolute difference in prevalence between the two surveys was over 10% points. Only in the four states of Punjab, Arunachal Pradesh, Meghalaya and Mizoram did the relative prevalence of anaemia decrease and absolute prevalence of anaemia decrease significantly over this 7-year period.

We analysed the correlates of anaemia for both surveys (table 3; see online supplementary table S2). Adolescent girls (age 15–19 years) had the highest prevalence of anaemia compared with the other age groups. Anaemia was positively associated with increasing parity (adjusted p for trend < 0.001). Muslims and Christians were significantly less likely to have any anaemia, in comparison to Hindus. There was a negative association between BMI and any anaemia (adjusted p for trend < 0.001).

At both timepoints, the prevalence of anaemia was positively associated with decreasing relative wealth and decreasing educational level (adjusted p for trend < 0.001). Members of STs and SCs were more likely to have any anaemia, even after controlling for wealth and education. The wealth gradient in anaemia was consistently the strongest of these socioeconomic correlates.

Examining the inequalities in anaemia over time, in unadjusted analyses, both relative and absolute inequalities in anaemia status decreased over time for wealth

Table 1 Descriptive characteristics of any anaemia and moderate/severe anaemia prevalence among ever-married women aged 15–49 years from the 1998/1999 and 2005/2006 NFHS surveys

			Any anaemia				Moderate/severe anaemia			
	1998	2005	1998		2005		1998		2005	
	N	N	n	Per cent	n	Per cent	n	Per cent	n	Per cent
Overall	79197	85403	39302	51.3	45238	56.1	12113	16.3	13298	17.2
Age (years)										
15–19	5997	4541	3309	55.6	2770	62.9	1156	19.3	951	21.3
20–24	13880	13570	7254	53.5	7700	59.2	2471	18.7	2548	19.8
25–29	16057	16604	7996	50.9	8825	55.8	2474	16.1	2536	17.0
30–34	14023	15593	6713	50.0	7913	53.6	1946	15.3	2178	15.7
35–39	12127	14492	5773	49.6	7435	54.7	1682	15.3	2092	16.3
40–44	9644	11736	4739	51.2	6053	54.7	1421	15.6	1753	16.4
45–49	7469	8867	3518	48.6	4542	55.1	963	13.7	1240	15.5
Marital status										
Currently married	74494	80144	36805	51.1	42349	55.9	11320	16.2	12403	17.1
Formerly married	4703	5259	2497	54.6	2889	58.9	793	17.9	895	19.5
Parity										
0	8143	8372	3851	49.5	4289	54.4	1286	16.8	1406	18.2
1	11588	13627	5805	51.8	7172	56.3	1889	17.3	2104	17.8
2	17212	22459	8264	49.8	11445	54.1	2435	15.4	3239	16.2
3	15589	17135	7563	50.2	9057	55.6	2232	15.5	2647	17.2
4	10941	10546	5567	52.2	5793	57.8	1698	16.7	1700	17.3
5+	15724	13264	8252	53.8	7482	59.2	2573	16.8	2202	17.6
Religion										
Hindu	62214	64873	31502	52.0	35235	56.6	9689	16.6	10415	17.3
Muslim	8989	10976	4299	48.8	5774	55.7	1347	14.9	1686	17.1
Christian	4006	4992	1700	47.1	2168	51.2	540	16.2	613	18.6
Sikh	1929	1969	774	39.8	789	39.3	250	13.0	231	12.1
Buddhist	871	1174	392	47.2	603	51.4	132	17.0	172	15.8
Other/missing	1188	1419	635	58.2	669	61.7	155	18.6	181	19.1
Caste										
SC	13583	14720	7273	55.7	8261	58.5	2373	18.5	2623	19.0
ST	9303	9716	5450	65.0	5698	69.2	1788	23.2	1853	24.5
OBC	23412	28195	11679	50.3	15112	55.3	3589	16.0	4487	16.7
General	32474	29009	14658	46.9	14294	51.9	4277	14.0	3800	14.7
Other/missing	425	3763	242	55.5	1873	56.3	86	19.4	535	17.7
Employment										
Not working	49655	49555	24165	50.0	25863	54.8	7308	15.5	7495	16.3
Non manual	4394	9039	1806	44.4	4365	51.4	493	13.9	1145	14.6
Agricultural	18152	18928	9734	55.1	10734	59.5	3211	18.8	3381	19.5
Manual	6996	7881	3597	52.4	4276	57.7	1101	16.2	1277	18.1
Residence										
Rural	54534	49357	28320	53.4	27389	58.1	9044	17.4	8363	18.0
Urban	24663	36046	10982	45.4	17849	51.4	3069	13.4	4935	15.4
Wealth										
1 Poorest	15563	19669	9617	61.3	12278	63.0	3324	21.2	4006	20.3
2	15618	17998	8452	54.5	10156	58.6	2756	17.7	3163	18.5
3	15989	16493	7826	49.6	8502	53.0	2434	15.8	2486	16.3
4	16044	15684	7108	44.7	7601	49.6	2021	13.4	2043	14.0
5 Richest	15983	15559	6299	40.1	6701	44.0	1578	10.4	1600	11.2
Education (years)										
None	39161	34204	21303	55.4	19743	60.1	7062	18.7	6221	19.3
1–5	13405	13416	6651	51.4	7272	56.4	2049	16.1	2199	17.6
6–10	19339	25443	8616	45.9	12841	53.1	2378	13.3	3697	16.0
11–12	3426	5410	1341	39.4	2432	46.3	316	9.7	557	11.3
≥13	3866	6930	1391	36.9	2950	43.0	308	9.1	624	9.3
BMI										
Underweight	24775	22800	13690	56.3	13939	62.7	4632	19.3	4467	20.3
Normal	44942	47017	22222	50.8	24729	55.4	6713	15.9	7373	17.3

Continued

Table 1 Continued

			Any anaemia				Moderate/severe anaemia			
	1998	2005	1998		2005		1998		2005	
	N	N	n	Per cent	n	Per cent	n	Per cent	n	Per cent
Overweight	7437	11902	2656	36.4	5018	43.8	611	8.6	1135	10.0
Obese	2043	3684	734	36.9	1552	43.9	157	8.2	323	9.7
Contraceptive use										
Not using	41494	36693	21938	54.3	20452	59.6	7475	18.9	6787	20.3
CP	1853	3208	815	44.8	1359	43.5	189	10.2	265	9.0
IUD	1716	1794	766	45.0	919	52.0	197	11.6	229	14.4
Female sterilisation	25387	30641	11694	47.6	15722	53.8	3155	13.5	4308	15.3
Other	8747	13067	4089	49.3	6786	54.3	1097	13.7	1709	14.6
Vegetarian										
No	53818	60049	27653	53.4	32525	58.2	8478	17.0	9520	17.9
Yes	25379	25354	11649	46.5	12713	51.6	3635	14.8	3778	15.7
Alcohol										
No	76923	82587	37964	51.1	43503	55.8	11747	16.3	12761	17.1
Yes	2274	2816	1338	61.0	1735	66.5	366	19.1	537	21.9

Survey sample weights applied to obtain weighted percentages.

Definitions: Any anaemia: non-pregnant women Hb ≤ 12 g/dl, pregnant women ≤ 11 g/dl.

Moderate/severe anaemia (both non-pregnant and pregnant women): Hb < 10 g/dl.

BMI, body mass index; CP, contraceptive pills; Hb, haemoglobin; IUD, intrauterine device; NFHS, National Family Health Surveys; OBC, other backward caste; SC, scheduled castes; ST, scheduled tribes.

(by 19% and 11%, respectively), education (by 21% and 8%, respectively) and by caste groups (see online supplementary table S3). This pattern was also observed in adjusted analyses. Relative inequalities in anaemia had decreased over time by wealth (p for interaction ≤ 0.001), education (p for interaction=0.0013) and caste (p for interaction=0.0001) (see online supplementary table S4) The adjusted differential in Hb between women in the highest and lowest wealth quintiles was greater in 1998/1999 (0.35 g/dl) than in 2005/2006 (0.25 g/dl), and the differential between the most educated and least educated was 0.16 g/dl in 1998/1999 compared with 0.11 g/dl in 2005/6 (see online supplementary table S5).

DISCUSSION

Principal findings

The prevalence of anaemia among women of reproductive age has increased significantly during a recent 7-year period in India. This increase was apparent across socio-economic groups. There was geographical variation in anaemia trends, with a significant increase seen in 14 of the 25 states and significant decrease in four states. Anaemia remains socially patterned; however, both relative and absolute inequalities in anaemia, along the axes of wealth, education and caste, have decreased over this time.

Comparison with existing studies

Trends in anaemia prevalence

The increasing trends are of concern, more so as, since the mid-1980s, the anaemia burden was predicted to

improve in India.³⁶ Based on an interpolation from regression models, the predicted change in anaemia prevalence was -0.38% points/year for non-pregnant women and -0.36% points/year for pregnant women³⁶ between 1995 and 2000. However, extrapolating from our analysis, the anaemia prevalence in India is increasing by 0.65% points/year for non-pregnant women and 1.23% points/year for pregnant women. Moreover, this increase in anaemia prevalence has occurred in the context of a comprehensive anaemia policy framework that has existed in India since the 1970s (see online supplementary table S6), as well as rapid economic development and increased investment in health through national health initiatives.

Furthermore, over this time period, there have been improvements in several indicators relating to women's nutrition and health, such as increasing BMI, increasing utilisation of antenatal care and iron and folic acid supplementation, increasing use of contraception, as well as increased age at marriage and decreased total fertility rate.²⁷ However, such a pattern of anaemia increase is consistent with studies from other transitional countries³⁷ and from other developing countries where Demographic and Health Surveys have been carried out.²¹

Social inequalities in anaemia

We demonstrated that anaemia continues to be socially patterned, and such findings build on and are consistent with other studies from India. For example, Bharati *et al*^{19 20}, have highlighted the higher prevalence of anaemia in women with lower education, lower wealth and for select caste groups. This picture has also been

Table 2 Weighted anaemia prevalence by state, and adjusted relative and absolute changes in anaemia prevalence over time

	1998	2005	1998		2005		Relative risk (adjusted)		Absolute difference (adjusted)	
	N	N	Per cent	95% CI	Per cent	95% CI	RR	95% CI	AD	95% CI
All India	79197	85403	51.3	50.6 to 52.0	56.1	55.4 to 56.8	1.08	1.06 to 1.10	4.0	3.1 to 5.0
North										
Delhi	2158	1819	40.0	37.2 to 42.8	43.2	40.1 to 46.3	1.09	0.99 to 1.19	3.4	-0.5 to 7.3
Haryana	2726	2190	46.9	44.5 to 49.3	56.5	54.0 to 59.0	1.21	1.13 to 1.30	9.9	6.5 to 13.3
Himachal Pradesh	2950	2260	33.0	29.5 to 36.5	42.8	38.5 to 47.1	1.36	1.20 to 1.54	11.4	6.6 to 16.3
Jammu & Kashmir	2545	1976	48.3	45.4 to 51.2	53.6	50.4 to 56.8	1.20	1.08 to 1.32	9.5	4.3 to 14.8
Punjab	2612	2633	41.4	38.9 to 44.0	38.4	36.0 to 40.8	0.90	0.82 to 0.99	-4.0	-7.7 to -0.4
Rajasthan	6015	3156	48.0	46.1 to 49.9	53.7	50.6 to 56.8	1.11	1.04 to 1.20	5.5	1.7 to 9.3
Central										
Madhya Pradesh(C)	6528	8099	54.1	51.3 to 56.8	57.6	55.5 to 59.7	1.04	0.98 to 1.10	2.1	-1.0 to 5.2
Uttar Pradesh(U)	5510	10401	48.2	46.0 to 50.3	50.9	49.2 to 52.7	1.05	1.00 to 1.12	2.6	-0.2 to 5.4
East										
Bihar(J)	6191	5242	63.2	61.1 to 65.4	68.7	66.8 to 70.6	1.07	1.03 to 1.12	4.7	1.8 to 7.5
Orissa	4264	3289	62.8	60.4 to 65.2	62.7	60.2 to 65.2	1.01	0.96 to 1.06	0.4	-2.7 to 3.5
West Bengal	3835	5108	62.6	60.0 to 65.2	63.8	61.5 to 66.1	1.02	0.97 to 1.08	1.6	-1.7 to 4.9
Northeast										
Arunachal Pradesh	1077	1163	54.9	49.8 to 60.0	50.3	45.0 to 55.6	0.85	0.73 to 0.98	-8.4	-16.0 to -0.8
Assam	2822	2669	69.6	65.8 to 73.4	69.4	66.5 to 72.3	1.02	0.96 to 1.10	1.6	-3.1 to 6.3
Manipur	1357	2727	27.1	23.7 to 30.4	39.4	36.9 to 41.9	1.42	1.24 to 1.62	11.4	7.2 to 15.6
Meghalaya	767	1192	59.9	53.1 to 66.7	48.7	43.6 to 53.7	0.84	0.72 to 0.98	-9.6	-17.7 to -1.4
Mizoram	1006	1185	45.1	40.4 to 49.7	40.2	35.6 to 44.9	0.84	0.73 to 0.96	-7.4	-12.8 to -1.9
Sikkim	972	1378	47.2	43.7 to 50.7	58.0	53.8 to 62.2	1.24	1.11 to 1.38	11.1	5.3 to 16.9
Tripura	1015	1414	57.9	53.8 to 62.0	67.5	64.4 to 70.6	1.15	1.06 to 1.24	8.6	3.7 to 13.5
West										
Goa	1186	2136	36.4	33.2 to 39.5	38.8	36.4 to 41.1	1.12	1.01 to 1.24	4.2	0.2 to 8.2
Gujarat	3455	2898	46.1	43.6 to 48.6	55.4	52.7 to 58.1	1.20	1.13 to 1.28	9.3	6.0 to 12.5
Maharashtra	4989	5998	48.0	45.6 to 50.3	49.0	47.0 to 51.0	1.01	0.95 to 1.08	0.7	-2.2 to 3.6
South										
Andhra Pradesh	3846	5139	49.4	46.6 to 52.1	62.6	60.3 to 65.0	1.26	1.18 to 1.35	12.9	9.3 to 16.5
Karnataka	4108	4201	42.3	39.8 to 44.8	51.9	49.8 to 54.0	1.20	1.12 to 1.28	8.6	5.5 to 11.6
Kerala	2713	2690	22.6	20.4 to 24.8	32.7	30.0 to 35.5	1.49	1.31 to 1.70	11.0	7.4 to 14.6
Tamil Nadu	4550	4440	55.4	52.4 to 58.4	53.7	51.1 to 56.3	0.96	0.90 to 1.02	-2.3	-5.8 to 1.3

Survey sample weights applied to obtain weighted percentages and 95% CI (LCI, UCI) Changes in states over time: Madhya Pradesh in 1998/1999 and Madhya Pradesh and Chhattisgarh in 2005/2006; Uttar Pradesh in 1998/1999 and Uttar Pradesh and Uttaranchal (Uttarakhand) in 2005/2006; Bihar in 1998/1999 and Bihar and Jharkhand in 2005/2006. Adjusted relative risk and 95% CI estimated from modified Poisson regression models, adjusting for age, parity, wealth, education, caste and rural/urban residence.

Table 3 Adjusted socioeconomic correlates of anaemia among ever-married women aged 15–49 years in 1998/1999 and 2005/2006

Covariates	1998/1999		2005/2006		Pooled	
	N		N		N	
	79197		85403		164600	
	Adjusted		Adjusted		Adjusted	
	PR†	95% CI	PR†	95% CI	PR†	95% CI
Wealth index						
Richest	1.00		1.00		1.00	
Richer	1.05**	(1.02 to 1.08)	1.05**	(1.02 to 1.08)	1.05**	(1.03 to 1.07)
Middle	1.08**	(1.05 to 1.11)	1.06**	(1.03 to 1.09)	1.07**	(1.05 to 1.10)
Poorer	1.13**	(1.09 to 1.17)	1.09**	(1.06 to 1.13)	1.11**	(1.09 to 1.14)
Poorest	1.20**	(1.16 to 1.24)	1.14**	(1.10 to 1.18)	1.17**	(1.14 to 1.20)
<i>p for trend‡</i>	<0.001		<0.001		<0.001	
Education						
≥13	1.00		1.00		1.00	
11–12	1.04	(0.99 to 1.10)	1.01	(0.97 to 1.05)	1.02	(0.98 to 1.05)
6–10	1.10**	(1.05 to 1.15)	1.06**	(1.02 to 1.10)	1.06**	(1.04 to 1.09)
1–5	1.12**	(1.07 to 1.18)	1.06**	(1.03 to 1.11)	1.08**	(1.05 to 1.11)
None	1.12**	(1.07 to 1.18)	1.06**	(1.03 to 1.11)	1.08**	(1.05 to 1.11)
<i>p for trend‡</i>	<0.001		0.002		<0.001	
Caste						
General	1.00		1.00		1.00	
SC	1.03*	(1.00 to 1.05)	1.03*	(1.00 to 1.05)	1.03**	(1.01 to 1.05)
ST	1.13**	(1.10 to 1.17)	1.13**	(1.10 to 1.17)	1.14**	(1.11 to 1.17)
OBC	1.00	(0.98 to 1.02)	1.00	(0.98 to 1.02)	1.00	(0.99 to 1.02)
Other/missing	1.08	(0.99 to 1.18)	0.98	(0.94 to 1.02)	0.99	(0.95 to 1.03)
Survey year						
1998/1999					1.00	
2005/2006					1.10**	(1.09 to 1.12)

* p<0.05.

**p<0.01.

†Adjusted prevalence ratios (PR) from multivariable modified Poisson regression models with any anaemia as the outcome, adjusted for age, parity, religion, residence, occupation, contraceptive use, BMI, alcohol use, vegetarianism; clustered SE and state fixed effects.

‡From a variable representing the ordinal categories of the predictor introduced into the model as continuous. Pooled includes both 1998/1999 and 2005/2006 surveys, with a dummy variable introduced for the survey year.

BMI, body mass index; OBC, other backward caste; SC, scheduled castes; ST, scheduled tribes.

supported by an analysis of seven states of India,¹⁸ and an analysis of the burden of anaemia in the state of Andhra Pradesh.¹⁵ Recent analysis of the five Eastern states of India using NFHS-3 survey corroborated the socioeconomic gradient of anaemia, and highlighted the vulnerability of the urban poor.¹⁶

We found that wealth is consistently the strongest marker of anaemia status, more so than education and caste. This finding is consistent with a previous study of social inequalities in child survival in India, which, in a decomposition analysis, identified poor household wealth as the greatest factor contributing to social inequalities (46%), followed by mother's illiteracy and rural residence.³⁸

From regression models testing for interactions between wealth, education, caste and survey year, we found that the change in relative inequalities in anaemia for each of these predictors was significant. Our finding of narrowing inequalities in anaemia over time was unexpected. While considerable attention has been paid to understanding socioeconomic inequalities in health in developing countries,³⁹ fewer studies have examined

trends in inequalities and these have mostly focused on child health. The existing literature from developing countries suggests that the socioeconomic inequalities in health appear to be widening, or remaining the same.^{34 40–45} An exception is trends in inequalities in under five mortality in Brazil, where inequalities by household wealth narrowed, but widened by mother's education.⁴⁵ In the Indian context, a previous study which examined trends in social inequalities in child undernutrition found that inequalities either widened or remained the same between 1992/1993 and 2005/2006.³⁴ Our findings are driven by the fact that, among the more advantaged, trends in anaemia have been increasing at a faster rate than among the more disadvantaged.

Interpretation of findings

Anaemia is determined by several factors, but inadequate dietary intake of bioavailable iron is by far the most important cause of anaemia² and therefore likely to be the key factor behind these changing patterns. As data from the National Nutrition Monitoring Board

(NNMB) Surveys demonstrate, Indian women have a sustained low intake of iron.⁴⁶ The 2004–2005 NNMB survey conducted among rural populations residing in nine states indicate that women's iron intake is around half of the recommended daily allowance.⁴⁷ Factors related to the Indian diet, such as its reliance on less bioavailable non-haem iron, higher phytate and polyphenols levels and low ascorbic/iron ratios which constrain iron absorption,⁴⁸ and possibly lower basal acidity of gastric fluid found in the Indian population,⁴⁹ may account for the high prevalence of anaemia in this population. However, there is limited evidence from such surveys as to how dietary intake of iron has changed due to changes in the estimation methods used over time.

Other aetiological factors such as recurrent infections with intestinal parasites, primarily hookworm and schistosoma, as well as malaria, tuberculosis and HIV/AIDS may be important. However, the limited monitoring systems and population-based studies make it difficult to assess whether changing exposure to these risk factors may be contributing to rising anaemia prevalence. Although hereditary haemoglobinopathies may help explain some of the geographical variation in high anaemia prevalence, especially in specific tribal populations,^{50 51} this is unlikely to have changed over this time frame. Future work which explores state differences in anaemia trends, especially in the four states where significant improvements occurred, may help further understand which factors drive changes in anaemia prevalence. Given the importance of nutrition in determining anaemia status, it is quite likely that the low iron bioavailability in the Indian diet and the changes in dietary intake are the key drivers of the change and variation seen in this analysis.

India's nutrition transition with its rapid changes to diet and lifestyles is likely to be affecting social groups differentially. For example, with increasing purchasing power for food, there may be shifts in food preferences with increased consumption of convenience and processed foods.⁵² There is evidence that when poorer households gain more money to spend on food, they prefer to buy more expensive, yet not necessarily more nutritious, food such as sugar, salt and processed food.⁵³ Also, richer households are twice more likely to eat out (although eating out is not uncommon among low-income households (monthly per capita expenditure less than 500 rupees), where 17% eat out).⁵² These preferences may shift diets towards less iron bioavailable food sources, with less consumption of green leafy vegetables and fruits, offering some explanation of why the anaemia trend has been more marked in the socially advantaged.

Over this time period, the prevalence of overweight and obesity among women of reproductive age has increased significantly.⁵⁴ The fact that the prevalence of anaemia exceeds 40% even among overweight and obese women with caloric excess indicates that food quality and diversity are critical, as well as food availability and supply. Interestingly urbanisation, which is a

strong determinant of overweight and obesity,⁵⁴ does not appear to be as significant for anaemia, which may reflect anaemia's different aetiology.

Future work that explores the primary determinants of anaemia may help understand which factors are driving changes in anaemia prevalence. Also, understanding why significant improvements occurred in select states may help further understand which factors drive changes in anaemia prevalence at the population level.

Limitations of the study

There are limitations to this study. First, we explicitly chose to measure inequalities by groups (wealth, education and caste) as we deem the social, political and historical significance of such groupings important.³³ Yet an extensive literature discusses issues relating to measurement of inequalities in health,^{55–57} which necessitates technical and normative judgements in the choice of metrics.³⁹ An alternative measure of anaemia distribution among individuals within the population, such as concentrations curves and indices, may have given rise to different, albeit complementary, results.

Second, we note that the strong association between socioeconomic status and anaemia detected here fails to determine the direction of causality which may be bidirectional. A consequence of morbidity associated with chronic anaemia is loss of productivity as a result of impaired work capacity, cognitive impairment and increased susceptibility to infection.⁵⁸ Thus, anaemia itself may contribute to and perpetuate poverty. The aggregate effect of these individual losses has a large impact on human capital; for example, iron deficiency anaemia leads to an estimated \$4.2 billion annual loss in the South Asia region.⁵⁹

Third, it is not possible to distinguish between the different types and causes of anaemia. Consequently, we are limited in our ability to understand the reasons for these trends and the different nutritional and infectious disease factors that may drive these trends, as this analysis focused on examining the differences between geographical and socioeconomic groups.

Fourth, this analysis used repeated cross-sectional surveys to assess trends, and it was not possible to follow Hb levels in individual women over time. However, given that these surveys are nationally representative and use consistent methodologies in the assessment of anaemia and classification of anaemia across time, this is likely to yield representative population-based estimates of anaemia prevalence. Furthermore, we attempted to make comparisons over time as robust as possible by restricting to ever-married women, using previous state boundaries and constructing a new-wealth index. It is unlikely that restricting to ever-married women led to significance bias in the findings, given that most women (>98%) above age 20 are married in this context. We also controlled for time-invariant state effects in examining the inequalities over time.

Fifth, despite the use of consistent sampling and methodology in the NFHS surveys over time, the HemoCue

analyser used to measure Hb changed between the two surveys as an upgraded model came out. It is unlikely though this was responsible for the increase in trends, as both systems are calibrated against a standard.

Implications of this study

The severe and worsening trends in anaemia among women of reproductive age over time have a number of implications for both policy makers and health professionals, as anaemia continues to be a major public health problem in the country. These increasing trends have occurred in the context of a well-established anaemia policy framework. Indeed, India was the first country in the developing world to establish a national anaemia programme, which has continued to evolve over time⁵⁷ (see online supplementary table S6). In the 1970s, the Nutritional Anaemia Prophylaxis Programme was constituted by the Ministry of Health and Family Welfare to target specific populations at high risk of anaemia, namely pregnant and lactating women and preschool children between 1 and 5 years of age.⁶⁰ Over time, anaemia policies have expanded to cover more population groups: initially, pregnant and lactating women and preschool children between 1 and 5 years of age deemed at 'high-risk', as defined by severe anaemia status, were targeted, but now both anaemic and non-anaemic adolescents, pregnant and lactating women and children above 6 months are covered. There has also been further integration of anaemia prevention and control into existing health strategies and programmes. India's latest 11th Five Year Plan sets out an ambitious time-bound goal of reducing anaemia among women and girls by 50% by 2012.⁶¹ However, this goal is unlikely to be reached without improved capacity to translate policy commitments into practice. Variation in state capacity to implement policies relating to health and nutrition may in part explain the variable performance in responding to anaemia in this population.

Improving the implementation of the current policy response to anaemia prevention and control, together with addressing knowledge gaps behind these increasing trends, will improve our ability to address the multifactorial aetiology of anaemia within this population and alleviate India's anaemia burden. The finding of a narrowing of socioeconomic relative and absolute inequalities in anaemia warrants further research to understand why this is occurring in this population.

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Contributors The authors' responsibilities were as follows: YB, WWF and SVS designed and conceptualised the study; planned the data analysis; interpreted the results; drafted the manuscript; reviewed and approved the final manuscript. YB performed the data analysis and had access to the data and has primary responsibility for the final content.

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