Factors Influencing Receipt of Iron Supplementation by Young Children and their Mothers in Rural India: Local and National Cross-Sectional Studies

Sant-Rayn Pasricha1, Beverley-Ann Biggs2, NS Prashanth3, H Sudarshan3, Rob Moodie4, Jim Black4 and Arun Shet5*

Abstract

Background: In India, 55% of women and 69.5% of preschool children are anaemic despite national policies recommending routine iron supplementation. Understanding factors associated with receipt of iron in the field could help optimise implementation of anaemia control policies. Thus, we undertook 1) a cross-sectional study to evaluate iron supplementation to children (and mothers) in rural Karnataka, India, and 2) an analysis of all-India rural data from the National Family Health Study 2005-6 (NFHS-3).

Methods: All children aged 12-23 months and their mothers served by 6 of 8 randomly selected sub-centres managed by 2 rural Primary Health Centres of rural Karnataka were eligible for the Karnataka Study, conducted between August and October 2008. Socioeconomic and demographic data, access to health services and iron receipt were recorded. Secondly, NFHS-3 rural data were analysed. For both studies, logistic regression was used to evaluate factors associated with receipt of iron.

Results: The Karnataka Study recruited 405 children and 377 of their mothers. 41.5% of children had received iron, and 11.5% received iron through the public system. By multiple logistic regression, factors associated with children’s receipt of iron included: wealth (Odds Ratio (OR) 2.63 [95% CI 1.11, 6.24] for top vs bottom wealth quintile), male sex (OR 2.45 [1.47, 4.10]), mother receiving postnatal iron (OR 2.31 [1.25, 4.28]), mother having undergone antenatal blood test (OR 2.10 [1.09, 4.03]); Muslim religion (OR 0.02 [0.00, 0.27]), attendance at Anganwadi centre (OR 0.23 [0.11, 0.49]), fully vaccinated (OR 0.33 [0.15, 0.75]), or children of mothers with more antenatal health visits (8-9 visits OR 0.25 [0.11, 0.55]) were less likely to receive iron. Nationally, 3.7% of rural children were receiving iron; this was associated with wealth (OR 1.12 [1.02, 1.23] per quintile), maternal education (compared with no education: completed secondary education OR 2.15 [1.17, 3.97], maternal antenatal iron (2.24 [1.56, 3.22]), and child attending an Anganwadi (OR 1.47 [1.20, 1.80]).

Conclusion: In rural India, public distribution of iron to children is inadequate and disparities exist. Measures to optimize receipt of government supplied iron to all children regardless of wealth and ethnic background could help alleviate anaemia in this population.

Keywords: Anaemia, Iron Deficiency, India, Children, Public Health

* Correspondence: arunshet@sjri.res.in
5Division of Global Health, Department of Public Health Sciences, Karolinska Institutet, Nobelsv 9, 171 77, Stockholm, Sweden
Full list of author information is available at the end of the article

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Background
In India, approximately 55% of women of reproductive age and 69.5% of under-5 children are anaemic [1], and in children, over 70% of anaemia is attributable to iron deficiency [2]. Iron deficiency anaemia in mothers may be associated with an increased risk of maternal mortality, preterm delivery, and low birth weight [3]; and in children with reduced cognitive development [4]. Thus, anaemia is a major public health concern in India.

The Indian National Nutritional Anaemia Prophylaxis Programme recommends that all children aged 6 to 59 months, and all pregnant and lactating women, receive Iron Folic-Acid (IFA) [5]. Despite this policy, the prevalence of anaemia among toddlers aged 6-36 months has risen from 74.3% in 1998-9 to 78.9% in 2005-6 [1]. The third National Family Health Study (NFHS-3) examined receipt of iron and found that only 4.7% of children in India aged 6-59 months were receiving supplementation [1]. Several previous, local studies have also suggested that distribution of iron in India is poor [6,7].

An improved understanding of the coverage of and factors associated with receipt of iron supplements by mothers and children in India could inform efforts to strengthen and better direct iron delivery programmes, especially in rural India. We hypothesised that receipt of iron supplementation to children in India is poor, and is associated with socioeconomic conditions and access to health care. To test this hypothesis and better understand factors associated with the receipt of iron supplementation among children in rural India, we conducted two analyses. 1) In two districts of rural Karnataka (the ‘Karnataka Study’), we undertook a cross-sectional study to evaluate the receipt of iron to young children and their mothers, and identify factors at the socioeconomic, demographic and health-care delivery levels that may contribute to disparities in receipt of supplementation. 2) We analysed data obtained from the third National Family Health Study (NFHS-3) performed across India, to evaluate factors associated with delivery of iron to children and their mothers throughout rural India.

Methods
The Karnataka Study
The study was performed between August and October 2008. A detailed description of the methodology of this study has been previously published [8].

Study site and participants
The study was based in two rural Primary Health Centres (PHCs) in southern Karnataka. The Gumballi PHC, in Chamarajnagar district, the southernmost district of Karnataka, is 180 km south of Bangalore, and provides care for about 21,700 people in 13 villages. The Suggannahalli PHC is 90 km west of Bangalore in the Ramnagara district, and provides care for 14,400 people in approximately 80 villages [9]. Agriculture comprises the major economic activity in both regions. The average rural income in Chamarajnagar in 2006 was (Indian rupees) Rs 22,006 per capita, in Ramnagara was Rs 26,009 [10], as compared with Karnataka overall Rs 26,123 [11]. In the 2011 Indian census, the Ramanagara district had a population of 1,082,739 and a literacy rate of 69.2%; Chamarajnagar had a population of 1,020,962 with a literacy rate of 61.1% [12].

The sampling design was developed to be acceptable to the local population and the Non-Government Organisation managing the PHCs. Three of four sub-centres managed by each PHC were randomly selected for involvement in the study [13]. All children aged 12 to 23 months living in the villages served by the selected sub-centres (enumerated by a compilation of local lists and a house to house survey), and their mothers, were eligible for inclusion in the study, unless children were unwell or febrile, or had ever received a previous blood transfusion (as this was part of a larger study investigating the determinants of anaemia in this population). Field workers visited each eligible village on a pre-publicised day and administered the questionnaire to and collected blood samples from all mothers of children living in the site who were eligible for recruitment. If the child presented with a guardian who was not their mother (for example, a grandmother, sibling or aunt), maternal blood samples and details of pregnancy were not obtained.

Study Procedures
The questionnaire evaluated demographics (religion and caste, age of mother and child, sex of child, education level and literacy of mother). A wealth index adapted from the NFHS-3 was also used, in which household assets are assigned a weighted score [14]. Subjects were allocated to wealth quintiles based on this score. Delivery of important maternal (antenatal and postnatal health worker visits) and child (vaccinations, vitamin A supplementation) primary health services were recorded, as was use of available resources including whether the child had ever visited an Anganwadi (Integrated Child Development Scheme) centre. Receipt of antenatal and postnatal iron supplementation by the mother was evaluated: mothers were shown bottles (liquid formulations) and strips (tablets) of iron supplements and asked to recall if they had received these. Mothers were also asked to recall whether their child had ever received iron, and if so, the source. The questionnaire is available online [8]. The field team was trained in administration of the questionnaire; all completed questionnaires were reviewed for errors, and cross-checked between interviewers.
Venous blood was collected from children for evaluation of haemoglobin (Sysmex XT-2000i, Sysmex Inc., Kobe, Japan) and capillary blood haemoglobin was estimated in their mothers by HemoCue (HemoCue 201+, Angelholm, Sweden). Anaemia in children was defined as haemoglobin < 11 g/dL, and in women as < 12 g/dL (11 g/dL if pregnant) [15].

**Third National Family Health Study**

The NFHS-3 (performed in 2005-6 by the International Institute for Population Sciences (Mumbai, India) and ICF Macro (Washington DC, USA)) surveyed women aged 15-49 years and their children aged 0-59 months across all 29 Indian states. Respondents were selected through a multistage cluster-based survey stratified by urban and rural populations. Only rural families were included in our analysis. The rural sample was obtained through a selection of villages based on the probability proportional to size principle, followed by random selection of households [16]. The questionnaire recorded whether children were currently receiving iron and whether their mothers had received iron during their most recent pregnancy [17]. It also recorded child’s age, sex, birth order, maternal education, family caste and religion, household wealth index, and health care practices.

**Statistical Considerations**

Data from the Karnataka Study were entered into an EpilInfo database (EpilInfo 3.4.3, Centers for Disease Control and Prevention, Atlanta, USA) and exported to statistical software for analysis (Stata 11, StataCorp, College Station, Texas, USA). We calculated a sample size of 390 to ensure that the 95% confidence interval for an estimate of prevalence of 50% would have precision +/- 5%. Significance for statistical tests was defined as p < 0.05. Associations with receipt of iron supplementation (a binary variable) were estimated using univariate and then multiple logistic regression. Wealth index and number of antenatal health worker visits were analysed as quintiles using dummy variables. The multiple regression models were fitted after forward stepwise logistic regression including all variables with retention of variables with p < 0.05. Each model was evaluated using likelihood ratio tests and confirmed using the Hosmer-Lemeshow goodness-of-fit test. T-tests were used to identify differences in continuous variables between groups.

NFHS-3 data was analysed with Stata 11 using the children’s recode data (IAKR) file. Independent variables from the NFHS-3 questionnaire that reflected variables found to be associated with receipt of iron by mothers or children in the Karnataka Study were included in the analysis. Simple and multiple logistic regression models accounting for sample weights and the multistage cluster survey sampling design of the survey were used to identify associations with receipt of iron during pregnancy by the mother, or current receipt of iron by the child.

**Ethics**

The Karnataka study was approved by ethics committees of St John’s National Academy of Health Sciences, Bangalore, India, and the Faculty of Medicine, Dentistry and Health Sciences, the University of Melbourne, Australia. Written informed consent was obtained from mothers or guardians of all participating children. The NFHS-3 had received approval from institutional review boards of the International Institute of Population Sciences, Mumbai, India and the ORC Macro, Calverton, Maryland, USA. Verbal informed consent was obtained from participating mothers by the interviewers [17].

**Results**

**The Karnataka Study**

**Demographics and delivery of health services**

We estimated that 470 children were living in the selected villages and thus potentially eligible for the study; 415 (88.3%) presented for screening [8], of which 10 were excluded: 7 due to fever and 3 due to previous transfusion. Thus, 405 children were recruited. The sample included two pairs of twins; mother and child data was adjusted to avoid duplication. Of 403 included children, 203 (50.3%) were male. The profile of the sampled population of mothers and children is presented in Table 1. We found that 63.1% of mothers and 75.3% of the children were anaemic [2].

**Receipt of iron supplements**

Delivery of health services to and receipt of iron by mothers and children is presented in Table 2. Less than half of the children, 167/402 (41.5% [36.7-46.4]) had ever received iron supplements. Only 45/393 (11.5% [8.3-14.6]) had ever received iron from a government source (PHC, sub-centre or Anganwadi centre). The majority - 113/158 (71.5% [64.4-78.6]) - of children who had received iron received it from a private rather than a government source. The wealth index of families of those children who received iron from private sources was higher than those who received it from a government source (21.1 points [19.1-23.1] versus 17.0 points [14.0-20.7] p = 0.034). Most of the mothers (92.0% [89.2-94.8]) reported receipt of iron supplements during pregnancy, although the majority (80.8%) received 40 or fewer tablets.

**Factors associated with receipt of iron supplements**

Results of simple logistic regression analyses for factors associated with receipt of antenatal iron supplements by mothers are presented in Table 3 and results of multiple
logistic regression analyses of these associations are shown in Table 4. Results of simple logistic regression analyses for factors associated with receipt of iron by children are presented in Table 5 and results of multiple logistic regression analyses of these associations are shown in Table 6.

No association was identified between anaemia in children and receipt of iron by either the child or their mother (for receipt of iron ever by children odds ratio (OR) 0.80 [0.51-1.27]; for receipt of any antenatal iron by mothers OR 1.97 [0.89, 4.34]). Similarly, there was no association between anaemia in mothers and receipt of either antenatal or postnatal iron (receipt of any antenatal iron OR 1.10 [0.51-2.44], receipt of any postnatal iron OR 0.95 [0.57-1.60]).

Third National Family Health Study
The dataset included 51,555 children and 36,850 of their mothers, of which 29,706 children and 20,631 mothers were coded as living in rural areas. Nationally, 4.6% [4.3-5.0] of all children were receiving iron at the time of interview: urban children were more likely to be receiving iron (7.0% [6.1-7.8]) than rural children (3.7% [3.3-4.1]) (OR for rural 0.55 [0.47-0.64], P < 0.001). Of mothers, 65.4% [64.0, 66.8] had received iron during their most recent pregnancy; women living in urban areas (73.9% [72.2-75.5]) were more likely to receive iron than rural mothers (61.1% [59.4-62.9]) (OR for rural 0.52 [0.50-0.55], P < 0.001). Because of differences between urban and rural India, further analysis was restricted to subjects living in rural India. Simple and multiple logistic regression analyses for factors associated with receipt of iron supplements by children and by mothers antenatally are presented in Table 7. The prevalence of each independent factor evaluated is presented in the NFHS-3 report [1].

Discussion
The Indian Government has endorsed a policy, in line with World Health Organization recommendations [15],...
| Factor                           | Total Population | Iron supplements received (345/375) | Iron supplements not received (30/375) | p     |
|---------------------------------|------------------|-------------------------------------|--------------------------------------|-------|
|                                 | N                | Prevalence n (% [95% CI], Mean [95% CI], or Median [Range]) | N | Prevalence n (% [95% CI], Mean [95% CI], or Median [Range]) |
| Wealth quintile1, 4             |                  |                                     |                                      |
| Quintile 1                      | 375              | 69 (18.4 [14.4, 22.4])             | 69 56 (81.2 [71.7, 90.6])            | 1.00 (Reference) |
| Quintile 2                      | 375              | 66 (17.6 [13.7, 21.4])             | 66 61 (92.4 [85.9, 99.0])            | 2.83 [0.95, 8.45] 0.062 |
| Quintile 3                      | 375              | 86 (22.9 [18.7, 27.2])             | 86 80 (93.0 [87.5, 98.5])            | 2.65 [1.0, 7.07] 0.051 |
| Quintile 4                      | 375              | 75 (20.0 [15.9, 24.1])             | 75 75 (93.3 [87.6, 99.1])            | 3.25 [1.09, 6.66] 0.034 |
| Quintile 5                      | 375              | 79 (21.1 [16.9, 25.2])             | 79 78 (98.7 [96.2, 100.0])           | 18.57 [2.36, 146.06] 0.005 |
| Mother’s age (years)2          |                  |                                     |                                      |
| 1-6 years                       | 374              | 23.2 [22.8, 23.6]                  | 342 23.2 [22.8, 23.5]                | 0.95 per year [0.87, 1.04] 0.275 |
| Child’s age (months)3          |                  |                                     |                                      |
| 0-5 months                      | 401              | 17.2 [16.8, 17.5]                  | 343 17.0 [16.7, 17.4]                | 0.94 per month [0.84, 1.04] 0.251 |
| Maternal Education1            |                  |                                     |                                      |
| 0-6 years                       | 373              | 259 (69.4 [64.7, 74.1])            | 259 241 (93.1 [89.9, 96.2])          | 0.90 [0.58, 1.41] 0.634 |
| Religion/Caste1                 |                  |                                     |                                      |
| Hindu, non SC/ST5               | 374              | 198 (52.9 [47.9, 58.0])            | 198 198 [96.0 [93.2, 98.7]]          | 1.00 [0.80, 1.29] 0.001 |
| Scheduled Caste                 | 374              | 97 (26.0 [21.5, 30.4])             | 97 85 [87.6 [81.6, 94.3]]            | 0.30 [0.12, 0.76] 0.011 |
| Scheduled Tribe                 | 374              | 58 (15.6 [11.8, 19.2])             | 58 52 [89.7 [81.6, 97.7]]            | 0.7 [0.12, 1.09] 0.073 |
| Muslim                          | 374              | 21 (5.6 [3.3, 8.0])                | 21 17 [81.0 [62.6, 99.3]]            | 0.18 [0.05, 0.66] 0.009 |
| Number of antenatal health worker visits1,6 |                  |                                     |                                      |
| Quintile 1                      | 374              | 69 (18.5 [14.5, 22.4])             | 69 57 [82.6 [73.4, 91.8]]            | 1.38 [0.50, 3.80] 0.529 |
| Quintile 2                      | 374              | 53 (14.2 [10.6, 17.7])             | 53 46 [86.8 [77.4, 96.2]]            | 8.21 [1.02, 65.74] 0.047 |
| Quintile 3                      | 374              | 40 (10.7 [7.6, 13.8])              | 40 39 [97.5 [92.4, 100.0]]           | 2.55 [1.01, 6.41] 0.047 |
| Quintile 4                      | 374              | 118 (31.6 [26.8, 36.3])            | 118 109 [92.3 [87.5, 97.2]]          | 19.59 [2.48, 154.61] 0.005 |
| Quintile 5                      | 374              | 94 (25.1 [20.7, 29.6])             | 94 93 [98.9 [96.8, 100.0]]           | 8.43 [2.51, 28.33] 0.001 |
| Postnatal health worker visit1  | 369              | 167 (45.3 [40.2, 50.4])            | 167 164 [98.2 [96.2, 100.0]]         | 4.61 [1.08, 19.78] 0.040 |
| Iron supplementation given post pregnancy1 | 369 | 86 (23.3 [19.0, 27.6]) | 86 84 [97.7 [94.4, 100.0]] | 4.12 [1.92, 8.84] < 0.001 |
| Blood test during pregnancy1    | 373              | 291 (78.0 [73.8, 82.2])            | 291 291 [94.9 [92.3, 97.4]]          | 4.12 [1.92, 8.84] < 0.001 |

1 Prevalence: n (% [95% CI])
2 Mean [95% CI]
3 Median [range]
4 Wealth index: Quintile 1: 2-8 Quintile 2: 9-12; Quintile 3: 13-18; Quintile 4: 19-26; Quintile 27-62.
5 SC = Scheduled Caste, ST = Scheduled Tribe
6 Number of antenatal health worker visits: Quintile 1: 1-3; Quintile 2: 4; Quintile 3: 5; Quintile 4: 6-7; Quintile 8-9.
of providing routine iron supplementation to all children aged 6-60 months, and all pregnant and lactating women [5]. By conducting both a targeted study in two districts of rural Karnataka and also using data from a nationally representative survey, we have found a marked difference between anaemia control policy and iron supplementation receipt in the field. We have also identified considerable disparities that are partly mediated by socio-economic and health care factors.

Private providers, rather than government health care workers, are the major source of supplements for children. Possible reasons for this may include, firstly, a lack of availability of appropriate supplements within the government system: inadequate supply of supplements in rural Indian PHCs has been previously observed [18], and government supplied liquid preparations suitable for children may be particularly difficult to access [19]. Iron preparations appropriate for young children are more expensive than iron tablets in retail pharmacies in India [20]. Secondly, government health workers and managers may be insufficiently educated about the importance of iron supplementation for prevention of anaemia in young children, and hence may not routinely provide this therapy [21]. Thirdly, wealthier families may be more likely to seek optimal health outcomes through private providers [22]. The unexpected finding in the Karnataka Study of an inverse association between children’s receipt of iron supplementation and indicators of apparently good primary health care (receiving a full course of vaccinations and visits to the Anganwadi centre), together with the very low rate of distribution from government sources, raises the possibility that families who exclusively use government services are unable to receive iron supplements for their child through that system.

Data from both our field study and the NFHS-3 identify clear links between maternal anaemia control measures and delivery of iron to children. This may be due to improved awareness of anaemia and the value of iron in mothers, or to superior knowledge, attitudes and practices regarding anaemia prophylaxis in health workers caring for both mothers and their children. We have previously reported that children’s haemoglobin concentrations in this population are chiefly associated with their iron status and their mother’s haemoglobin [2]. Thus, controlling maternal anaemia may prevent anaemia in children as well as improve the health of the mother. Iron supplementation programmes for pregnant [23] and non-pregnant women [24] have been successfully implemented in several settings worldwide, including in India [25], and these programmes could be expanded with potential benefits for children as well as their mothers.

There are important differences between the methodology of the Karnataka Study and the NFHS-3. The two studies evaluated different outcomes: NFHS-3 asked whether children were currently receiving iron; the Karnataka Study asked whether children had ever received iron supplements. This may partly explain the lower national prevalence of receipt of iron identified on the NFHS-3: assuming all children received the nationally recommended 100 days of supplementation annually, and supplementation was evenly distributed across a year, 27% of children should have been receiving iron in the NFHS-3. However, the NFHS-3 data also indicated overall performance of services was poorer nationally than in the Karnataka Study. For example, whereas the Karnataka Study showed that 85.7% of children had ever visited an Anganwadi centre, NFHS-3 data shows that only 20.2% of children had visited a centre in the previous 3 months; this difference suggests heterogeneous access to ICDS services nationally that may explain the disparate findings in association between attendance at Anganwadi centres and receipt of iron between the two studies. Unlike the NFHS-3 data, the Karnataka study identified the source of iron received by children and thus was able to specifically evaluate government distribution. Although lower receipt of iron by children of

### Table 4 Factors associated with mother receiving iron supplementation during pregnancy (multiple logistic regression)

| Factor                                      | Odds Ratio [95% CI] | P     |
|---------------------------------------------|---------------------|-------|
| Postnatal health worker visit              | 9.57 [2.50, 36.58]  | 0.001 |
| Wealth quintile¹                           |                     |       |
| Quintile 1                                 | 1.00 (Reference)    |       |
| Quintile 2                                 | 2.28 [0.61, 8.53]   | 0.223 |
| Quintile 3                                 | 2.83 [0.84, 9.50]   | 0.093 |
| Quintile 4                                 | 2.63 [0.71, 9.67]   | 0.146 |
| Quintile 5                                 | 11.20 [1.17, 106.82]| 0.036 |
| Religion/Caste                             |                     |       |
| Hindu, Non SC/ST²                          | 1.00 (Reference)    |       |
| Scheduled Caste                            | 0.32 [0.11, 0.96]   | 0.041 |
| Scheduled Tribe                            | 0.63 [0.18, 2.19]   | 0.468 |
| Muslim                                     | 0.11 [0.02, 0.56]   | 0.008 |
| Number of antenatal health worker visits³  |                     |       |
| Quintile 1                                 | 1.00 (Reference)    |       |
| Quintile 2                                 | 1.69 [0.51, 5.64]   | 0.394 |
| Quintile 3                                 | 8.66 [0.93, 80.87]  | 0.058 |
| Quintile 4                                 | 1.07 [0.35, 3.29]   | 0.908 |
| Quintile 5                                 | 16.02 [1.83, 140.06]| 0.012 |
| Blood test during pregnancy                | 3.00 [1.19, 7.57]   | 0.020 |

¹Wealth index: Quintile 1: 2-8 Quintile 2: 9-12; Quintile 3: 13-18; Quintile 4: 19-26; Quintile 5: 27-62.  
²SC = Scheduled Caste, ST = Scheduled Tribe  
³Number of antenatal health worker visits: Quintile 1: 1-3; Quintile 2: 4; Quintile 3: 5; Quintile 4: 6-7; Quintile 8-9.
Table 5 Factors associated with child ever receiving iron supplementation (univariate logistic regression)

| Factor                        | Total Population | Iron supplements received (345/375) | Iron supplements not received (30/375) | Odds Ratio [95% CI] for receipt of iron |
|-------------------------------|------------------|--------------------------------------|----------------------------------------|----------------------------------------|
|                               | N                | Prevalence n (% [95% CI], Mean [95% CI], or Median [Range]) | N                                      | Prevalence n (% [95% CI], Mean [95% CI], or Median [Range]) | p           |
| Wealth quintile1, 4           |                  |                                      |                                        |                                        |             |
| Quintile 1                    | 402              | 77 (19.2 [15.3, 23.0])               | 77                                      | 24 (31.2 [20.6, 41.8])               |             |
| Quintile 2                    | 402              | 71 (17.7 [13.9, 21.4])               | 71                                      | 25 (35.2 [23.8, 46.6])               |             |
| Quintile 3                    | 402              | 91 (22.6 [18.5, 26.7])               | 91                                      | 35 (38.5 [28.3, 48.6])               |             |
| Quintile 4                    | 402              | 79 (19.7 [15.8, 23.6])               | 79                                      | 37 (46.8 [35.6, 58.1])               |             |
| Quintile 5                    | 402              | 84 (20.9 [16.9, 24.9])               | 84                                      | 46 (54.8 [43.9, 65.6])               |             |
| Mother’s age (years)2         | 374              | 23.2 (22.8, 23.6)                    | 161                                    | 21.3 (22.6, 23.6)                    |             |
| Child’s age (months)3         | 401              | 17.2 (16.8, 17.5)                    | 165                                    | 17.0 (16.5, 17.5)                    |             |
| Maternal Education1           |                  |                                      |                                        |                                        |             |
| 0                             | 374              | 89 (23.8 [19.5, 28.1])               | 89                                      | 31.5 (21.6, 41.3)                    |             |
| 1-6 years                     | 374              | 45 (12.0 [8.7, 15.3])                | 45                                      | 53.3 (38.2, 68.5)                    |             |
| 7-9 years                     | 374              | 117 (31.3 [26.6, 36.0])              | 117                                     | 40.2 (31.2, 49.2)                    |             |
| 10 years                      | 374              | 98 (26.2 [21.7, 30.7])               | 98                                      | 48.0 (37.9, 58.0)                    |             |
| 11+ years                     | 374              | 25 (6.7 [4.1, 9.2])                  | 25                                      | 60.0 (39.4, 80.6)                    |             |
| Literate mother3              | 373              | 259 (69.4 [64.7, 74.1])              | 259                                     | 48.3 (42.1, 54.4)                    |             |
| Birth order3                  | 377              | 2 (1.5)                              | 215                                    | 2 (1.5)                              |             |
| Religion/Caste1               |                  |                                      |                                        |                                        |             |
| Hindu, non SC/ST2             | 389              | 209 (53.7 [48.8, 58.7])              | 209                                     | 101 (48.3 [41.5, 55.2])              |             |
| Scheduled Caste               | 389              | 99 (25.4 [21.1, 29.8])               | 99                                      | 34 (34.3 [24.8, 43.9])               |             |
| Scheduled Tribe               | 389              | 61 (15.7 [12.1, 19.3])               | 61                                      | 25 (41.0 [28.3, 53.6])               |             |
| Muslim                        | 389              | 20 (5.1 [2.9, 7.4])                  | 20                                      | 1 (5.0 [0.0, 15.5])                  |             |
| Number of antenatal health worker visits1, 6 |            |                                      |                                        |                                        |             |
| Quintile 1                    | 374              | 68 (18.2 [14.3, 22.1])               | 68                                      | 38 (55.9 [43.8, 68.0])               |             |
| Quintile 2                    | 374              | 53 (14.2 [10.6, 17.7])               | 53                                      | 15 (28.3 [15.8, 40.8])               |             |
| Quintile 3                    | 374              | 50 (10.7 [7.6, 13.8])                | 50                                      | 18 (45.0 [28.9, 61.1])               |             |
| Quintile 4                    | 374              | 53 (11.6 [8.6, 16.3])                | 53                                      | 63 (53.4 [44.3, 62.5])               |             |
| Quintile 5                    | 374              | 55 (25.4 [21.0, 29.8])               | 55                                      | 26 (27.4 [18.2, 36.3])               |             |
| Postnatal health worker visit | 369              | 166 (45.0 [39.9, 50.1])              | 166                                     | 74 (44.6 [36.9, 52.2])               |             |
| Iron supplementation given post pregnancy1 | 369 | 86 (23.3 [19.0, 27.6])               | 86                                      | 84 (97.7 [94.4, 100.0])              |             |
| Antenatal maternal iron supplementation1 | 374 | 344 (92.0 [89.2, 94.7])              | 344                                     | 153 (44.5 [39.2, 49.8])              |             |
| Postnatal maternal iron supplementation1 | 369 | 85 (23.0 [18.7, 27.4])              | 85                                      | 54 (63.5 [53.1, 73.9])               |             |
| Blood test during pregnancy1  | 374              | 291 (78.0 [73.8, 82.2])              | 291                                     | 137 (47.1 [41.3, 52.8])              |             |
| Child’s sex (male = 1)1       | 402              | 203 (50.5 [45.6, 55.4])              | 203                                     | 103 (50.7 [43.8, 57.7])              |             |

Note: p values are based on univariate logistic regression analysis.
Very few other published studies have reported receipt of iron in the field by children in India. A study of 487 pregnant women in Andhra Pradesh identified receipt of iron by only 19%, and only 1% among children [7]. The Micronutrient Taskforce reviewed national nutritional anaemia control programmes in 1996 and identified limitations, including "poor compliance, irregular supplies, (and) low education/counseling" [26]. Thus, our study provides one of few comprehensive evaluations of iron supplementation both nationally, and in detail in a representative rural population.

The results of our study should be interpreted within the context of its strengths and limitations. This study analysed cross-sectional rather than longitudinal data, thus we are able to report only associations between variables, rather than definite cause and effect. Since the Karnataka Study sample size was relatively small, we sought to improve the external generalisability by also evaluating national (NFHS-3) data and making comparisons. Beyond variables measured in this study, there are likely to be multiple other factors that interact to affect the efficacy of anaemia control policies, concerning distribution and supply chains of iron supplements, performance of the health system as a whole, affordability of supplements, and acceptability of iron formulations to families.

Further research, including qualitative studies, are required to understand the gap between national anaemia control policy and practice in the field, and for disparities in receipt of iron supplements. Specifically, additional research is required to understand why receipt of iron was suboptimal in a setting where other vertical programmes (such as vaccination and Vitamin A distribution) function relatively well, as noted in the Karnataka Study. Such information may help to either specifically improve the iron supplementation programme or offer potential opportunities for synergy with these other programmes. Secondly, a study of the supply chain required for the provision of iron

Table 5 Factors associated with child ever receiving iron supplementation (univariate logistic regression) (Continued)

Table 6 Factors associated with child ever receiving iron supplementation (multiple logistic regression)
Table 7 Factors associated with receipt of iron across rural India: National Family Health Study-3 data

| Factor | Antenatal iron supplements received by mother | Iron supplements currently received by children |
|--------|---------------------------------------------|-----------------------------------------------|
|        | Odds Ratio [95% CI] | P | Odds Ratio [95% CI] | P |
|        | Univariate logistic regression |        | Multiple logistic regression |
|        | Wealth quintile | 1.51 [1.44, 1.57] | < 0.001 | 1.35 [1.26, 1.45] | < 0.001 |
| Maternal education | 0 years Reference |        | 0 years Reference |        |
| Primary | 2.58 [2.30, 2.89] | < 0.001 | 1.76 [1.36, 2.28] | < 0.001 |
| Secondary | 4.11 [3.66, 4.61] | < 0.001 | 2.41 [1.96, 2.96] | < 0.001 |
| Higher | 14.00 [8.87, 22.08] | < 0.001 | 3.80 [2.61, 5.52] | < 0.001 |
| Child’s sex (male = 1) | 0.98 [0.91, 1.05] | 0.516 | 1.10 [0.95, 1.26] | 0.191 |
| Literate mother1 | 1.94 [1.84, 2.05] | < 0.001 | 1.47 [1.34, 1.61] | < 0.001 |
| Birth order | 0.78 [-0.77, 0.80] | < 0.001 | 0.85 [0.81, 0.89] | < 0.001 |
| Religion/Caste2 | Hindu, non SC/ST | 1.21 [1.08, 1.34] | 0.001 | 1.10 [1.09, 1.34] | 0.001 |
| Scheduled Caste | 0.95 [0.85, 1.07] | 0.418 | 0.71 [0.55, 0.92] | 0.008 |
| Scheduled Tribe | 1.04 [0.88, 1.23] | 0.657 | 1.06 [0.82, 1.38] | 0.651 |
| Muslim | 0.74 [0.62, 0.87] | < 0.001 | 0.82 [0.61, 1.09] | 0.167 |
| Antenatal health worker visits (OR per visit) | 1.77 [1.70, 1.85] | < 0.001 | 1.02 [1.01, 1.02] | < 0.001 |
| Antenatal iron received by mother | N/A | N/A | 3.02 [2.32, 3.93] | < 0.001 |
| Postnatal iron received by mother | Not measured | Not measured | Not measured | Not measured |
| Blood test during pregnancy | 2.36 [2.10, 2.64] | < 0.001 | 2.50 [2.02, 3.10] | < 0.001 |
| Services accessed: | Anganwadi Centre3 | 2.03 [1.79, 2.30] | < 0.001 | 1.79 [1.47, 2.19] | < 0.001 |
| Child vaccinated4 | 2.03 [1.73, 2.38] | < 0.001 | 1.28 [1.04, 1.54] | < 0.001 |

1Literacy defined as 0 = cannot read, 1 = can read part of a sentence, 2 = can read complete sentence; visually impaired mothers excluded.
2SC = Scheduled Caste; ST = Scheduled Tribe. Logistic regression performed for each category.
3Mother’s use of Anganwadi in the last 3 months.
4Child ever had a vaccination.
5Multiple regression coefficients only displayed for variables found to be significantly associated; variables not associated indicated with ‘-’.
supplementation: from raw materials, manufacture, and distribution to the PHC, may help understand reasons for inadequate receipt of supplements that we did not address in this study. This could help programme managers plan for and procure sufficient stock of iron supplements for distribution through public systems. Thirdly, understanding the knowledge, attitudes and practices of government health workers and managers would help clarify how these factors affect implementation of anaemia control measures [27]. This information would help policymakers direct their management and training messages to improve iron supplementation through the government health system. Finally, research directed at understanding the likely acceptability of liquid iron formulations by children and their mothers in the field could be undertaken to address adherence to supplements, if or when they are made available.

Our finding, both locally and nationally, that children belonging to poorer families are less likely to receive iron (despite a higher burden of anaemia in poorer children [2]), is an example of the ‘inverse care law’: the poorest with greatest need have least access to valuable interventions [28]. Based on our results, improving the receipt of iron supplementation among all, but especially the poorest families, could potentially be achieved through education of health workers responsible for providing iron during pregnancy, in the post partum, and to children. Additionally, other primary health services offer an opportunity to introduce iron supplementation, for example, integrated delivery with 9 and 18 month vaccinations or with Vitamin A supplements [29]. Once women have experienced health benefits from iron, they may be more committed to continuing iron supplementation themselves [30] and may also be more likely to seek iron supplementation for their children, as suggested by our data. However, beyond these strategies, emphasis must also be given to further developing longer-term strategies to eliminate anaemia including: development of effective alternatives to iron supplementation, such as home fortification by micronutrient capsules [31], iron fortification of staple foods, condiments and complementary foods [32], and dietary diversification.

Conclusions

Despite an enormous and deteriorating problem of anaemia in India, iron supplementation policies for rural children and mothers are inadequately implemented. Key factors associated with access to iron supplements are wealth and maternal access to health services; ethnic disparities seem to be important, and improved maternal access to anaemia control measures also benefits access for children. Ensuring optimal delivery of iron supplements to all children and pregnant women, regardless of their socioeconomic background, could help address the enormous burden of anaemia in this population.

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Author details

1. The Nossal Institute for Global Health, Faculty of Medicine, Dentistry and Health Sciences, The University of Melbourne, Carlton, Victoria, Australia.
2. Department of Medicine, The Royal Melbourne Hospital, The University of Melbourne, Parkville, Victoria, Australia.
3. Hematology Research Unit, Division of Molecular Medicine, St. John’s National Academy of Health Sciences, Sarjapur Road, Bangalore 560034, India.
4. The Karuna Trust, B.R.Hills, Chamarajanagar, Karnataka, India.
5. Division of Global Health, Department of Public Health Sciences, Karolinska Institutet, Nobelbs 9, 171 77, Stockholm, Sweden.

Authors’ contributions

SP, BA-B, JB, and AS planned the study and prepared the manuscript. SP and AS led the fieldwork. SP, BA-B and JB analysed the data. All authors conceived the study, read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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