Correlates of anaemia in pregnant urban South Indian women: a possible role of dietary intake of nutrients that inhibit iron absorption

Tinu Mary Samuel1,2, Tinku Thomas1, Julia Finkelstein3,4, Ronald Bosch5, Ramya Rajendran1, Suvi M Virtanen2,6, Krishnamachari Srinivasan1, Anura V Kurpad1 and Christopher Duggan3,7,*

1Division of Nutrition, St John’s Research Institute, Bangalore, India: 2Division of Epidemiology, School of Health Sciences, University of Tampere, Tampere, Finland: 3Department of Nutrition, Harvard School of Public Health, Boston, MA, USA: 4Division of Nutritional Sciences, College of Human Ecology, Cornell University, Ithaca, NY, USA: 5Department of Biostatistics, Harvard School of Public Health, Boston, MA, USA: 6The Unit of Nutrition, National Institute for Health and Welfare, Helsinki, Finland: 7Division of Gastroenterology and Nutrition, Children’s Hospital – Boston, 300 Longwood Avenue, Boston, MA 02115, USA

Submitted 26 September 2011: Final revision received 8 March 2012: Accepted 15 March 2012: First published online 11 May 2012

Abstract

Objective: To identify correlates of anaemia during the first trimester of pregnancy among 366 urban South Indian pregnant women.
Design: Cross-sectional study evaluating demographic, socio-economic, anthropometric and dietary intake data on haematological outcomes.
Setting: A government maternity health-care centre catering predominantly to the needs of pregnant women from the lower socio-economic strata of urban Bangalore.
Subjects: Pregnant women (n=366) aged ≥18 and ≤40 years, who registered for antenatal screening at ≤14 weeks of gestation.
Results: Mean age was 22.6 (SD 3.4) years, mean BMI was 20.4 (SD 3.3) kg/m² and 236 (64.5%) of the pregnant women were primiparous. The prevalence of anaemia (Hb <11 g/dl) was 30.3% and of microcytic anaemia (anaemia with mean corpuscular volume <80 fl) 20.2%. Mean dietary intakes of energy, Ca, Fe and folate were well below the Indian RDA. In multivariable log-binomial regression analysis, anaemia was independently associated with high dietary intakes of Ca (relative risk; 95% CI: 1.79; 1.16, 2.76) and P (1.96; 1.31, 2.96) and high intake of meat, fish and poultry (1.94; 1.29, 2.91).

Conclusions: Low dietary intake of multiple micronutrients, but higher intakes of nutrients that inhibit Fe absorption such as Ca and P, may help explain high rates of maternal anaemia in India.

Keywords
Anaemia
Pregnancy
Correlates
South India

Anaemia is a global public health problem that affects nearly 2 billion people in both developed and developing countries(1). Anaemia is highly prevalent among pregnant women in developing countries and is associated with poor pregnancy outcomes(2). Anaemia in early pregnancy is associated with a 50% greater risk of inadequate weight gain for gestation(3). The risk of preterm delivery is increased by 10–40% with mild anaemia(4). The National Family Health Survey reported the prevalence of anaemia among pregnant women in India to be 59%(5). A survey among pregnant women from sixteen districts of eleven states in India showed that 61.0% to 96.8% of pregnant women were anaemic (Hb <11 g/dl)(6). Despite the ongoing national anaemia prophylaxis programme of Fe and folic acid supplementation to pregnant women, two large national surveys(5,7) have indicated that there has been little change in the prevalence of anaemia and the adverse consequences associated with it.

Studies conducted in India suggested that micronutrient deficiencies (Fe, folate and vitamin B12) are the primary cause of anaemia in pregnancy(8). Dietary intake surveys among pregnant women show low intake of several key micronutrients(9) and subclinical deficiencies of riboflavin, pyridoxine and folic acid have been reported(10). The relative contribution of each of these factors to anaemia in pregnancy often varies by geographical location, season and dietary intake(11). Even within India there are wide state-level variations in the
prevalence of moderate and severe anaemia\(^{(7,12)}\), often attributed to differences in the simultaneous presence of several micronutrient deficiencies in addition to Fe deficiency, acute and chronic infections and differences in bioavailability of various micronutrients in the diet\(^{(13)}\). Despite a literacy rate of 68.1% among women in Karnataka\(^{(14)}\) and 85.3% of the women having received antenatal care\(^{(15)}\), the prevalence of anaemia among pregnant women in Karnataka remains 47.6%\(^{(16)}\). We therefore were interested to determine the modifiable risk factors associated with anaemia among pregnant women in urban Karnataka early in their pregnancy.

**Materials and methods**

**Study design**

We performed a cross-sectional study among a cohort of pregnant women enrolled in a randomized controlled trial of vitamin B\(_{12}\) supplementation (NCT00641862). The study was conducted at Hosahalli Referral Hospital, Bangalore, Karnataka, South India. This government maternity healthcare centre caters predominantly to the needs of pregnant women from the lower socio-economic strata of urban Bangalore and has approximately 200 deliveries per month. Pregnant women were enrolled in early pregnancy (≤14 weeks of gestation) from December 2008 to November 2010. The pregnant women are currently being followed through 2 years postpartum as part of the ongoing trial. The institutional review boards at St John’s Medical College Hospital and Harvard School of Public Health approved all study procedures, and written informed consent was obtained from each participant at enrolment.

**Study population**

All pregnant women aged ≥18 and ≤40 years, who were ≤14 weeks of gestation and registered for antenatal screening at the Hosahalli Referral Hospital, were invited to participate in the study. Pregnant women with multiple gestation, those with a clinical diagnosis of chronic illness (diabetes mellitus, hypertension, heart disease or thyroid disease), those who tested positive for HbSAg (surface antigen of the hepatitis B virus), HIV or syphilis, those who anticipated moving out of the city before delivery, those who were already consuming vitamin B\(_{12}\) supplements and those who had been treated for infertility were excluded.

Of the 1376 pregnant women who were contacted at the antenatal clinic during the study period, 958 were excluded for the following reasons: planning to deliver outside Bangalore at maternal home town (n 836); wishing to terminate the pregnancy (n 67); age <18 years (n 4); history of hypertension (n 7); previous Caesarean section (n 4); and pregnancy was not confirmed (n 40). Of the remaining 418 pregnant women who were considered eligible fifty-two declined to participate, leaving 366 who consented.

**Sociodemographic and anthropometric information**

The pregnant women were interviewed by trained research assistants to obtain sociodemographic information. Gestational age (in weeks) was calculated from the reported first day of the last menstrual period. A digital balance (Salter’s 9016, Tonbridge, Kent, UK) was used to record the weights of all mothers to the nearest 100 g. Measurements of height were made using a stadiometer to the nearest 0.1 cm. Mid-upper arm circumference was measured to the nearest 0.1 cm using a plastic measuring tape and triceps skinfold was measured using a Holtain calliper (Crosswell, Crymych, UK). BMI was calculated as weight in kilograms divided by the square of height in metres (kg/m\(^2\)).

**Haematological data**

Blood was drawn from pregnant women after an overnight fast by venepuncture and collected in both EDTA-containing and plain Vacutainer\(^{\text{TM}}\) tubes (BD Diagnostics, Franklin Lakes, NJ, USA). Hb and complete blood count were measured on an automated Coulter counter (ABX Pentra 60C+; Horiba Ltd, Kyoto, Japan). Anaemia was defined as Hb <11.0 g/dl and severe anaemia as Hb <7.0 g/dl\(^{(1)}\). Microcytosis was defined as mean corpuscular volume (MCV) <80 fl\(^{(17)}\), while microcytic anaemia was defined as anaemia with MCV <80 fl. Haematocrit was considered to be low in pregnancy at values <33%\(^{(18)}\) while the reference range for red-cell distribution width was considered to be 11.5% to 14.5%\(^{(17)}\).

**Dietary data**

A pre-tested interviewer-administered FFQ was used to assess the habitual dietary intake for the three months preceding the date of the pregnant women’s enrolment into the study. Standard measures were placed before the respondent to quantify the portion size of each food item when administering the questionnaire. The questionnaire was adapted from a questionnaire developed for the urban population residing in South India\(^{(19)}\) and has a food list of 127 items, derived from a food database developed from studies at St John’s Medical College. Nutrient scores were computed by multiplying the relative frequency of consumption of each food item by the nutrient content of the standard portion size. Nutrient information was obtained on twenty-seven macro- and micronutrients. Energy-adjusted nutrient intakes were calculated by the residual method\(^{(20)}\). Data on the amount of food groups consumed were calculated as the total grams of the food groups consumed daily.

**Statistical analysis**

Continuous data were summarised as means and standard deviations, and categorical data as numbers and percentages.
Women who had missing data on any variable were not considered for the analysis involving that variable. The association of anaemia with maternal sociodemographic characteristics and energy-adjusted nutrient intakes, categorized by tertiles, was examined using the chi-square test. The parameters that were found significant in this analysis were considered in multivariable log-binomial regression analysis to examine the independent effect of certain dietary nutrient intakes and food group intakes while adjusting for possible confounding effects of maternal sociodemographic characteristics. All maternal sociodemographic characteristics with \( P < 0.02 \) in the univariate analyses were considered in the multivariable model. Characteristics contributing at least 95% change in the adjusted estimate after exclusion of the covariate from the full model were retained as confounders in the final model. Separate models were constructed for Ca and P as they were collinear and could not be considered in the same model. Similar analyses were performed with tertiles of nutrient intakes or food groups which were likely to be associated with anaemia. In addition, Fe intake was retained in the model as an exposure of interest. The presence of effect modification by maternal sociodemographic characteristics, dietary intake of nutrients and food groups was examined using stratified analyses. No effect modification was observed (data not shown). Relative risks (RR) with 95% confidence intervals and corresponding \( P \) values for both unadjusted and adjusted models are presented. Statistical analyses were carried out with the SPSS statistical software package version 16 (SPSS Inc., Chicago, IL, USA). Log-binomial regression analysis was carried out using the PROC GENMOD program in the SAS statistical software package version 9.2 (SAS Institute, Cary, NC, USA).

**Results**

The mean age of the pregnant women was 22.6 (SD 3.4) years and the mean gestational age was 11.2 (SD 2.4) weeks (Table 1). High-school graduation was attained by at least 95.8% of the women. A majority of them (83.8%) were unemployed. Primiparous pregnant women made up 64.5% of the cohort. The mean weight and height of the women were 47.8 (SD 8.1) kg and 153.0 (SD 5.6) cm, respectively. BMI was less than 18.5 kg/m\(^2\) in 31.3% of the women. The mean mid-upper arm circumference (an estimate of peripheral muscle and fat mass) and triceps skinfold (an estimate of peripheral fat mass) of the women were 23.6 (SD 3.1) cm and 15.6 (SD 5.7) mm, respectively. None of the women were consuming Fe or folate supplements on study entry.

The mean Hb and haematocrit levels on study entry were 11.5 (SD 1.5) g/dl and 34.6 (SD 5.1) %, respectively (Table 2). The prevalence of anaemia (Hb < 11.0 g/dl) at baseline was 30.3% (111/366). Very few women (0.8%) had severe anaemia (Hb < 7.0 g/dl). Nearly one-third of the women had microcytosis (MCV < 80 fl) and 20.2%

---

**Table 1** Baseline sociodemographic and anthropometric characteristics of the study population: pregnant Indian women aged ≥18 and ≤40 years (n = 366), enrolled in early pregnancy (≤ 14 weeks of gestation), urban Bangalore, December 2008 to November 2010

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) (n = 366)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>102</td>
<td>27.9</td>
</tr>
<tr>
<td>20–24</td>
<td>170</td>
<td>46.4</td>
</tr>
<tr>
<td>25–29</td>
<td>77</td>
<td>21.0</td>
</tr>
<tr>
<td>≥30</td>
<td>17</td>
<td>4.6</td>
</tr>
<tr>
<td>Level of education (n = 364)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No formal education</td>
<td>15</td>
<td>4.1</td>
</tr>
<tr>
<td>Finished high school (10th grade)</td>
<td>257</td>
<td>70.5</td>
</tr>
<tr>
<td>Post high school</td>
<td>71</td>
<td>19.5</td>
</tr>
<tr>
<td>University degree and above</td>
<td>21</td>
<td>5.8</td>
</tr>
<tr>
<td>Occupation (n = 364)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>305</td>
<td>83.8</td>
</tr>
<tr>
<td>Unskilled worker</td>
<td>21</td>
<td>5.8</td>
</tr>
<tr>
<td>Skilled worker</td>
<td>27</td>
<td>7.4</td>
</tr>
<tr>
<td>Others (secretarial jobs, teachers, business, shop owners)</td>
<td>11</td>
<td>3.1</td>
</tr>
<tr>
<td>Parity (n = 366)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>236</td>
<td>64.5</td>
</tr>
<tr>
<td>≥1</td>
<td>130</td>
<td>35.6</td>
</tr>
<tr>
<td>BMI &lt; 18.5 kg/m(^2) (n = 364)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>47.8</td>
<td>8.1</td>
</tr>
<tr>
<td>SD</td>
<td>5.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Mid-upper arm circumference (cm)</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Triceps skinfold (mm)</td>
<td>5.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Total monthly household income (Rs) (n = 365)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>6000</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>4500</td>
<td></td>
</tr>
</tbody>
</table>
| 25th, 75th percentile | 9000 | 18%

LMP, last menstrual period; Rs, rupees.

*US$ 1 = Rs 50.2 as of 21 January 2012.

**Table 2** Haematological characteristics of the study population: pregnant Indian women aged ≥18 and ≤40 years (n = 366), enrolled in early pregnancy (≤ 14 weeks of gestation), urban Bangalore, December 2008 to November 2010

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb (g/dl)</td>
<td>11.5</td>
<td>1.6</td>
</tr>
<tr>
<td>Haematocrit (%)</td>
<td>34.6</td>
<td>5.1</td>
</tr>
<tr>
<td>MCV (fl)</td>
<td>81.1</td>
<td>8.9</td>
</tr>
<tr>
<td>RDW (%)</td>
<td>13.3</td>
<td>2.2</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anaemia (Hb &lt; 11.0 g/dl)</td>
<td>111</td>
<td>30.3</td>
</tr>
<tr>
<td>Hb &lt; 8.5 g/dl</td>
<td>18</td>
<td>4.9</td>
</tr>
<tr>
<td>MCV &lt; 80 fl</td>
<td>117</td>
<td>32.0</td>
</tr>
<tr>
<td>MCV &gt; 80 fl</td>
<td>37</td>
<td>10.1</td>
</tr>
<tr>
<td>RDW &gt; 14.5 %</td>
<td>81</td>
<td>22.1</td>
</tr>
<tr>
<td>Anaemia and MCV &lt; 80 fl</td>
<td>74</td>
<td>20.2</td>
</tr>
<tr>
<td>Anaemia and MCV &gt; 90 fl</td>
<td>2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

MCV, mean corpuscular volume; RDW, red-cell distribution width.
had anaemia with microcytosis. The percentage of women with a red-cell distribution width >14.5%, suggestive of Fe-deficiency anaemia, was 22.1%.

The dietary intakes of the anaemic and non-anaemic pregnant women, as means with standard deviations and as percentage adequacy compared with the Indian RDA, are presented in Table 1. The mean Fe intakes of anaemic (15.6 mg/d) and non-anaemic women (14.9 mg/d) were not significantly different from each other; however, intakes were very low and met only 44.5% and 42.6% of the RDA, respectively, in the two groups. Although the overall mean energy intake was low among both anaemic (7513 kJ/d) and non-anaemic women (7162 kJ/d), it was significantly higher among anaemic pregnant women compared with 797 mg/d, 0.11 (SD 0.07) g/d and 0.25 (SD 0.23) g/d, respectively. The main contributors towards high Mn intake in anaemic pregnant women were cereals and tea, mean Mn intakes from these being 2.7 mg/d and 0.7 mg/d, respectively. The main contributor to high Cu intake was cereals (mean 0.64 mg/d); while milk and meat contributed towards vitamin B_{12} intake, the main producers of vitamin B_{12} were cereals, pulses and milk and milk products; mean P intakes from these were 0.41 (SD 0.13) g/d, 0.11 (SD 0.07) g/d and 0.25 (SD 0.23) g/d, respectively. The main contributors towards high Mn intake in anaemic pregnant women were cereals and tea, mean Mn intakes from these being 2.6 (SD 0.8) mg/d and 4.2 (SD 2.3) mg/d, respectively. The significant difference in intakes of protein, Ca, P, Mn and Zn between anaemic and non-anaemic pregnant women persisted even after energy adjustment of nutrients. The intakes of vitamin C, vitamin B_{12} and Cu were all greater than the RDA and were not significantly different between the two groups. The primary food groups contributing towards higher intake of P in anaemic pregnant women were cereals, pulses and milk and milk products; mean P intakes from these were 0.41 (SD 0.13) g/d, 0.11 (SD 0.07) g/d and 0.25 (SD 0.23) g/d, respectively. The primary food groups contributing towards higher intake of P in anaemic pregnant women were cereals, pulses and milk and milk products; mean P intakes from these were 0.41 (SD 0.13) g/d, 0.11 (SD 0.07) g/d and 0.25 (SD 0.23) g/d, respectively.

Results of log-binomial regression analyses of anaemia among pregnant women aged ≥18 and ≤40 years, enrolled in early pregnancy (14 weeks of gestation), urban Bangalore, December 2008 to November 2010. Mean values were significantly different between anaemic and non-anaemic pregnant women using the independent t test (two-sided): *P < 0.05, **P < 0.01, ***P < 0.001.
Table 3: Sociodemographic and nutritional correlates of anaemia among the study population: pregnant Indian women aged ≥18 and ≤40 years (n 366), enrolled in early pregnancy (≥14 weeks of gestation), urban Bangalore, December 2008 to November 2010

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n/N</th>
<th>RR</th>
<th>95% CI</th>
<th>P value</th>
<th>Adjusted RR</th>
<th>95% CI‡</th>
<th>P value</th>
<th>Adjusted RR</th>
<th>95% CI‡</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working at home</td>
<td>86/305</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-016</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-06</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-05</td>
</tr>
<tr>
<td>Working outside the home</td>
<td>25/58</td>
<td>1-53</td>
<td>1-09, 2-16</td>
<td></td>
<td>1-45</td>
<td>1-01, 2-09</td>
<td></td>
<td>1-40</td>
<td>1-01, 1-94</td>
<td></td>
</tr>
<tr>
<td>Monthly family income</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (&lt;Rs 5000)</td>
<td>43/155</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-15</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-14</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-220</td>
</tr>
<tr>
<td>Tertile 2 (Rs 5000–8000)</td>
<td>26/98</td>
<td>0-74</td>
<td>0-52, 1-05</td>
<td></td>
<td>0-71</td>
<td>0-50, 1-02</td>
<td></td>
<td>0-76</td>
<td>0-55, 1-05</td>
<td></td>
</tr>
<tr>
<td>Tertile 3 (&gt;Rs 8000)</td>
<td>42/112</td>
<td>0-71</td>
<td>0-47, 1-06</td>
<td></td>
<td>0-73</td>
<td>0-49, 1-08</td>
<td></td>
<td>0-79</td>
<td>0-53, 1-17</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>37/95</td>
<td>1-43</td>
<td>0-94, 2-18</td>
<td>0-12</td>
<td>1-36</td>
<td>0-89, 2-09</td>
<td>0-24</td>
<td>1-49</td>
<td>0-98, 2-26</td>
<td>0-11</td>
</tr>
<tr>
<td>High school</td>
<td>49/177</td>
<td>1-02</td>
<td>0-67, 1-54</td>
<td></td>
<td>1-04</td>
<td>0-68, 1-57</td>
<td></td>
<td>1-10</td>
<td>0-73, 1-64</td>
<td></td>
</tr>
<tr>
<td>More than high school</td>
<td>25/92</td>
<td>1-00</td>
<td>Ref.</td>
<td></td>
<td>1-00</td>
<td>Ref.</td>
<td></td>
<td>1-00</td>
<td>Ref.</td>
<td></td>
</tr>
<tr>
<td>Fe intake (mg/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (&lt;13·9)</td>
<td>32/120</td>
<td>0-83</td>
<td>0-56, 1-23</td>
<td>0-55</td>
<td>0-76</td>
<td>0-51, 1-14</td>
<td>0-41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 2 (13·9–15·6)</td>
<td>39/121</td>
<td>1-00</td>
<td>0-69, 1-44</td>
<td></td>
<td>0-89</td>
<td>0-62, 1-28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 3 (15·6–25·0)</td>
<td>39/121</td>
<td>1-00</td>
<td>Ref.</td>
<td></td>
<td>1-00</td>
<td>Ref.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folate intake (µg/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (&lt;260·6)</td>
<td>42/120</td>
<td>1-46</td>
<td>0-98, 2-18</td>
<td>0-15</td>
<td>1-36</td>
<td>0-89, 2-07</td>
<td>0-34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 2 (260·6–293·5)</td>
<td>39/121</td>
<td>1-34</td>
<td>0-89, 2-02</td>
<td></td>
<td>1-25</td>
<td>0-83, 1-89</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 3 (&gt;293·5)</td>
<td>29/121</td>
<td>1-00</td>
<td>Ref.</td>
<td></td>
<td>1-00</td>
<td>Ref.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca intake (mg/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (&lt;738·7)</td>
<td>24/121</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-006</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 2 (738·7–887·7)</td>
<td>41/121</td>
<td>1-71</td>
<td>1-10, 2-64</td>
<td></td>
<td>1-59</td>
<td>1-04, 2-42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 3 (&gt;887·7)</td>
<td>45/120</td>
<td>1-89</td>
<td>1-23, 2-90</td>
<td></td>
<td>1-79</td>
<td>1-16, 2-76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P intake (mg/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (&lt;1147·1)</td>
<td>25/121</td>
<td>1-00</td>
<td>Ref.</td>
<td>&lt;0·001</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 2 (1147·1–1234·3)</td>
<td>34/121</td>
<td>1-36</td>
<td>0-87, 2-13</td>
<td></td>
<td>1-28</td>
<td>0-82, 1-98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 3 (&gt;1234·3)</td>
<td>51/120</td>
<td>2-06</td>
<td>1-37, 3-09</td>
<td></td>
<td>1-96</td>
<td>1-30, 2-96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibre intake (g/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (&lt;4·1)</td>
<td>30/121</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-15</td>
<td></td>
<td></td>
<td></td>
<td>1-00</td>
<td>Ref.</td>
<td>0-11</td>
</tr>
<tr>
<td>Tertile 2 (4·1–6·2)</td>
<td>36/120</td>
<td>1-21</td>
<td>0-80, 1-83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-18</td>
<td>0-80, 1-74</td>
<td></td>
</tr>
<tr>
<td>Tertile 3 (&gt;6·2)</td>
<td>44/121</td>
<td>1-47</td>
<td>0-99, 2-17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-46</td>
<td>1-01, 2-11</td>
<td></td>
</tr>
<tr>
<td>Meat, poultry &amp; fish intake (g/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tertile 1 (&lt;9·2)</td>
<td>24/121</td>
<td>1-00</td>
<td>Ref.</td>
<td>0-002</td>
<td></td>
<td></td>
<td></td>
<td>1-00</td>
<td>Ref.</td>
<td>0·002</td>
</tr>
<tr>
<td>Tertile 2 (9·2–25·6)</td>
<td>37/123</td>
<td>1-52</td>
<td>0-97, 2-37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-35</td>
<td>0-87, 2-10</td>
<td></td>
</tr>
<tr>
<td>Tertile 3 (&gt;25·6)</td>
<td>49/118</td>
<td>2-09</td>
<td>1-38, 3-18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-94</td>
<td>1-29, 2-91</td>
<td></td>
</tr>
</tbody>
</table>

RR, relative risk; Ref, referent category.
P values (two-sided) are reported for the adjusted RR.
*Multivariable log-binomial regression of anaemia v. occupation, monthly family income, education, Fe, Ca, folate and P intakes.
†Multivariable log-binomial regression of anaemia v. occupation, monthly family income, education, fibre and meat, poultry & fish intakes.
‡Adjusted RR from a log-binomial regression model adjusted for the effects of the other variables in the model.
§Due to collinearity of Ca and P intakes (r = 0·8), the adjusted RR for dietary P intakes were obtained from a separate model adjusted for the effects of the other variables in the model.
food groups). In the univariate analyses, the sociodemographic variable that was significantly associated with a higher prevalence of anaemia was working outside the home ($P=0.016$). Maternal age, parity, income and education were not associated with anaemia. Energy-adjusted nutrient intakes associated with higher prevalence of anaemia included higher intake of Ca and P ($P=0.006$ and $P<0.001$, respectively). In multivariable Model 1, working outside the home was no longer associated with anaemia. The significant association of Ca and P intakes with anaemia observed in the univariate analyses persisted in the multivariable Model 1 (Table 3).

In multivariable Model 2 (Table 3), the RR of anaemia was higher for pregnant women with the greatest intakes of meat, fish and poultry ($RR=1.94$; 95% CI 1.29, 2.91), consistent with the univariate analyses. The relationship of milk intake with anaemia did not show a monotonic trend and was not significant in either the univariate or multivariable analyses.

**Discussion**

In a cross-sectional analysis of 366 urban pregnant Indian women, we found a high prevalence of both anaemia (30.3%) and microcytic anaemia (20.2%) during the first trimester of pregnancy. Among these pregnant women, who had low intakes of Fe and several other nutrients, higher intakes of Ca and P (dietary components known to inhibit Fe absorption) were independently associated with a higher prevalence of anaemia.

Our study is unique in that we have identified the prevalence and dietary correlates of anaemia as early as ≤14 weeks of gestation. A study from the urban areas of Udupi, Karnataka found the prevalence of anaemia to be 50.1% (Hb determined by the cyanmethaemoglobin method) among pregnant women at ≤14 weeks of gestation, and identified age, parity, education, socio-economic status, compliance with Fe supplements, history of bleeding and food selection ability as significant determinants of anaemia; however, dietary factors were not studied. Other studies have reported a higher prevalence of anaemia than our reported rate of 30.3% but these have been carried out among pregnant women later in pregnancy and have used different methods of measuring Hb. The present anaemia prevalence is also lower than the published figures of 59% for any anaemia among pregnant Indian women and 32% for moderate to severe anaemia among pregnant women in Karnataka. This may be attributed to the fact that our study was a hospital-based study recruiting urban women in early pregnancy based on strict inclusion and exclusion criteria, and possible differences in the method of Hb analysis. It is also noteworthy that the years of schooling attained by pregnant women in our cohort were generally higher in comparison to the overall level of education attainment by pregnant women from urban Karnataka.

Nevertheless, a prevalence of 30.3% anaemia is in itself an indication that anaemia continues to be a problem of public health significance among pregnant Indian women.

Our results indicate that nearly one-third of the pregnant women had BMI < 18.5 kg/m². This is in accordance with nationally representative data from the National Family Health Survey that has shown more than one-third of women to have a BMI < 18.5 kg/m², reflecting chronic energy and micronutrient deficiencies. The mean intakes of several macro- and micronutrients were well below the RDA for both pregnant anaemic and non-anaemic women. For example, the energy intake was low in comparison to the RDA among all pregnant women in our cohort, although it was higher among the anaemic pregnant women compared with the non-anaemic pregnant women possibly reflecting a diet high in energy but poor in quality. Similar low intake of energy has been reported among pregnant women from urban South India during early pregnancy. The mean dietary intake of Fe was less than 50% of the RDA. It is noteworthy that all of the pregnant women were ≤14 weeks of gestational age and at enrolment none was receiving Fe or folic acid supplements. Perhaps because of the low and narrow range of dietary Fe intake, we did not observe any association of Fe intake with anaemia. These results are consistent with data from the National Nutrition Monitoring Bureau surveys in India that also showed no correlation of Fe intake with anaemia. Vitamin C is known to have an enhancing and dose-dependent effect on Fe absorption in many single-meal radioisotope studies in human volunteers, and can overcome the negative effect of inhibitors on Fe absorption. However prolonged cooking and storage of food can reduce its enhancing effect. Although the mean intake of vitamin C among pregnant women in our cohort exceeded the RDA, it was apparently not sufficient to overcome the inhibitory effect of Fe absorption inhibitors such as P and Ca. This may be due to practices commonly observed among these women, such as prolonged cooking and allowing the meals to stand for longer durations. On the contrary, intakes of Fe absorption inhibitors such as Mn, P and Zn were higher in anaemic pregnant women.

In the setting of low dietary Fe intake, the intakes of several other nutrients and their role in increasing the risk of anaemia through possible interactions with Fe are important to consider. A higher intake of Mn may impose a risk for reduced Fe utilization by affecting Fe absorption, while higher doses of Zn in aqueous solutions are known to impair Fe absorption, although this effect has not been observed when Zn was added to meals. Among pregnant women we observed that higher intake of Ca was associated with a greater risk of anaemia. In single-meal studies conducted in adult men and women, CaCl₂ at doses ranging from 40 to 300 mg had a dose-dependent inhibitory effect on the absorption of 5 mg.
non-haem Fe, and 165 mg of Ca given as milk, cheese or
CaCl₂ diminished absorption of 5 mg haem Fe \(^{(35,34)}\). More
recently, an isolated effect of CaCl₂ on absorption of
both 5 mg non-haem Fe and haem Fe was observed at
Ca doses ≥1000 mg and 800 mg, respectively, among
non-pregnant women \(^{(35)}\). The effect of Ca supplemen-
tation on the uptake of haem Fe is independent of Fe
bioavailability in the meal \(^{(36)}\) and is a direct effect on
haem Fe absorption rather than an indirect counteracting
effect on the enhancing effect of meat \(^{(37)}\). This effect is
not only seen when Ca and Fe are taken together in the
same meal \(^{(38,39)}\). Ca is known to inhibit Fe absorption
by the formation of poorly soluble calcium phytate
complexes \(^{(40)}\) or at the cellular level by its effect on DMT
1 (divalent metal-ion transporter-1) receptors \(^{(41)}\). The
competitive inhibition between Ca and Fe in the final
transport steps from the mucosal cells to the plasma,
common for haem and non-haem Fe, has also been
suggested \(^{(42)}\). This significant association of dietary Ca
intake with anaemia may have a greater relevance among
pregnant women from India because of their inadequate
Fe stores, overall low intakes of both Fe and Ca, a pre-
dominantly cereal/pulse-based diet and the relative low
Fe bioavailability of Indian meals.

Higher intake of P was also observed to be an inde-
pendent risk factor for anaemia among pregnant women in
the present study. P may have a direct inhibitory effect on
Fe absorption \(^{(42)}\). Even relatively small quantities of resi-
dual phytate, which is the storage form of P (<10 mg phytic
acid/meal), are known to strongly inhibit Fe absorption
\(^{(43)}\). Although we did not analyse the phytate content in
the meals of women in this current cohort, results from another
study in a similar group of young women of low socio-
economic status from Bangalore showed that the phytate
content in their diets was as high as 1287 mg/d \(^{(44)}\). We also
observed that a higher intake of meat was associated with a
greater risk of anaemia. It is, however, noteworthy that the
median (25th, 75th percentile) intake of meat even in the
highest group of meat intake was only 39 (32, 50) g/d,
making it difficult to draw any conclusions about the
relationship between meat intake and anaemia.

In addition to the nutritional factors that cause anaemia,
chronic Fe losses due to parasitic infections such as hook-
worm and schistosomiasis may cause anaemia \(^{(44)}\). We did
not evaluate for the presence of parasitic infections among
pregnant women in our cohort; however, a low prevalence
of parasitic infections has been previously reported among
women from urban slums in South India \(^{(44)}\). Our study is
limited in that the dietary data were recorded with an
FFQ and not via alternative methods including prospective
food weighing and other techniques. However, we did
employ a validated FFQ with a trained interviewer and
portion sizes to minimize recall bias. Fluctuations in
appetite and nausea commonly experienced by pregnant
women in the first trimester may have influenced reported
dietary intakes \(^{(45)}\). Further, our assessment of Fe status was
limited to red-blood-cell morphologic indices. The results
of our study are based on cross-sectional data with a
moderate sample size, so caution should be exercised
when drawing conclusions, especially for different popu-
lations. In addition, our study results are based on a sample
of pregnant women enrolled in a clinical trial at a single
hospital and therefore the findings may not be repre-
sentative of all urban Indian pregnant women.

Conclusions

The results of the present study indicate that higher
intakes of Ca and P may be important correlates of
anaemia among women with low Fe intake. Further
research is warranted to elucidate the modulatory effect
of Ca and P on Fe absorption and the levels at which
these effects are pronounced among pregnant women in
the Indian subcontinent, where such effects have not
been previously documented.

Acknowledgements

This research was financially supported by the Indian
Council of Medical Research, India (ICMR: 5/7/192/06-
RHN) and the National Institutes of Health, USA (NICHD
HD052143 and NICHD K24 HD058795). None of the
authors has any personal or financial conflict of interest.
T.M.S. was involved in data collection and wrote the first
draft of the manuscript; T.T. was involved in analysis and
writing of the manuscript; J.F. was involved in data anal-
ysis; R.B. was involved in data analysis and manuscript
writing; R.R. was involved in data collection; S.M.V. was involved
in manuscript writing; K.S. was involved in conception of the
study design, supervision of data collection and manuscript
writing; A.V.K. was involved in conception of the study
design and writing of the manuscript; C.D. was involved
in conception of the study design, supervision of data
collection, data analysis and manuscript writing. The data
were presented in part at Experimental Biology 2011
(Washington, DC, 9–13 April 2011). The authors thank
the pregnant women for their participation in the study. They
are grateful to Dr B Nirmala in obtaining all clearances
to conduct the study at Hosahalli Referral Hospital and
thank the doctors, nurses and technical staff at the hospital
for their support. The authors also acknowledge Dr S
Muthayya for her assistance during the study; and thank
Ms Vijaya, Ms Surekha, Ms Devi, Ms Asha, Ms Shilpa,
Ms Ammu, Ms Asha, Ms Preethi and Ms Poornima for
technical support.

References

1. World Health Organization/Centers for Disease Control
   Populations: Joint Report by World Health Organization/
Correlates of anaemia in pregnancy

34. Gaitan D, Flores S, Saavedra P et al. (2011) Calcium does not inhibit the absorption of 5 milligrams of nonheme or heme iron at doses less than 800 milligrams in non pregnant women. J Nutr 141, 1652–1656.