Prevalence of iron deficiency anaemia and risk factors in 1,010 adolescent girls from rural Maharashtra, India: a cross-sectional survey

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Keywords
Adolescent, Anaemia, Haemoglobin, India, Iron Deficiency, Maharashtra

Abstract

Objective: Iron deficiency anaemia (IDA) is the most common nutritional disorder observed in adolescent girls in India. Our aim was to investigate the prevalence and risk factors associated with IDA in rural Maharashtra, India to address current evidence gaps.

Study Design: Cross sectional survey

Methods: The study recruited 13 to 17 year old adolescent girls living in 34 villages of Osmanabad district. Data were collected on individual health, dietary, sociodemographic factors, and anthropometric measurements were taken. Haemoglobin (Hb) levels were measured using Sahli's hemometer. Logistic and linear regressions were used to identify risk factors associated with IDA and Hb level respectively.

Results: Among 1,010 adolescent girls (response rate 97.5%), the mean Hb was 10.1 g/dl (standard deviation=1.3), and 87% had anaemia (Hb<12 g/dl). The prevalence of mild (11.0-11.9 g/dl), moderate (8.0-10.9 g/dl) and severe (Hb≤ 7.9 g/dl) anaemia was 17%, 65% and 5% respectively. Anaemia likelihood increased significantly with age (odds ratio (OR): 1.41 per year, 95% confidence interval (CI): 1.17 to 1.70). Factors associated with decreased anaemia risk were mid upper arm circumference (MUAC) ≥22 cm (OR: 0.51, 95% CI: 0.31 to 0.82), ≥3 days/week consumption of fruit (OR: 0.35, 95% CI: 0.23 to 0.54) or rice (OR: 0.39, 95% CI: 0.17 to 0.91), and incomplete schooling (OR: 0.47, 95% CI: 0.24 to 0.91). In the final model lower age, MUAC and fruit consumption were significantly associated with Hb level.

Conclusion: Anaemia prevalence was extremely high among adolescent girls in rural areas of Maharashtra. Whilst we identified risk factors that could be used for targeting interventions, there is urgent need of comprehensive preventative interventions for the whole adolescent girl population.

Introduction

Iron deficiency anaemia (IDA) is the most common nutritional disorder observed in India particularly in under-five year old children, adolescent girls and pregnant women[1]. About 56% of adolescent girls in India are affected by IDA[1,2]. During adolescence, IDA may lead to growth retardation, impaired physical and mental development and poorer reproductive outcomes continuing through childbearing years; thus, it is a serious public health issue in the country [3,4]. The government has emphasised the need for education programmes and national iron supplementation initiatives for adolescent girls. However practical implementation has revealed important health services and infrastructural issues as well as inadequate iron tablet supplies for young girls; as a result, IDA prevalence remains much higher than predicted targets [3,4].

One of the largest surveys of adolescent girls reported an overall anaemia prevalence of 89% with substantial regional variation [5]. This survey was described to be nationally representative, and reported higher prevalence in older girls (15 to 19 years). Studies published in the past ten years from Maharashtra state of India reported 40% to 65% anaemia prevalence in western Maharashtra [6,7] and 35% to 40% in eastern Maharashtra [8] with a higher prevalence in deprived areas (up to 90%)[9]. However, evidence from central Maharashtra (the Marathwada region) is limited to a 2012 study of 385 adolescent girls, which reported 68% anaemia and assessed dietary preference, parents' education and menarche in addition to factors studied in the national survey [2].

There are no published studies from rural areas particularly in the Marathwada region on anaemia prevalence in adolescent girls, and there is limited evidence on their sociodemographic, dietary and medical risk factors. Therefore, we conducted a cross-sectional study of 1,010 adolescent girls; the first conducted in the Osmanabad district and largest from rural areas of Maharashtra state, India.

Methods

Study context

The Maharashtra Anaemia Study (MAS) was a joint collaboration between the Halo Medical Foundation (HMF), India and the University of Nottingham, UK. The cross sectional study was conducted to investigate anaemia prevalence in adolescent girls and associated risk factors in villages of Marathwada region of Maharashtra state. The target population was all unmarried girls aged 13 to 17 years from 34 villages (total population: 60,921) in the Tuljapur and Lohara blocks of Osmanabad district. We decided on this age-group following consultation with our local partner (HMF). Upper age limit (17 years) was suggested because of early marriages (typically at 18 years), and also due to migration of girls for higher secondary education in our study region. While lower age limit (13 years) was agreed following ethical requirements (where independent decision processing) was necessary to provide written consent to participate in the study. Between April 24, 2014 and June 30, 2015, villages were visited with the aim of recruiting 1000 participants [10]. No formal sample size calculation was performed as the project was designed as an initial feasibility study. The study was approved by the Institutional Ethics Committee of the Government Medical College Aurangabad (Pharma/IEC/GMA/196/2014), and the Medical School Ethics Committee of the University of Nottingham, UK (E10102013).

Field area

Osmanabad district is one of the most marginalised areas of India; 83% of its 1.6 million population lives in rural areas [11]. The 2013 state report showed that the annual per capita income of the district was only half of the state average [12]. Overall literacy was 76% (53% in underprivileged communities), and the district ranked 28th in the state out of 35 based on the human development index [12]. HMF’s head office is in Andur, on the Mumbai-Hyderabad national highway. The project villages were accessible with semi-permanent paved roads connecting to the highway, and had limited electricity and transport facilities. The nearest and farthest project villages were 5 and 57 kilometres from the head office respectively.

Participant recruitment and data collection

The primary investigator (PI) and a trained project assistant worked with the network of village health workers developed by HMF across the field area to identify, contact and recruit eligible participants. Each eligible adolescent girl present on the village’s assigned data collection day was approached in the presence of a local guardian. Those who agreed to participate were recruited after obtaining a written consent. The data collection form was used to obtain information on sociodemographic, medical history, iron folic acid (IFA) and other supplements, 7-day dietary food frequency recall, family assets and menstrual history data as self-reported by participants, in accordance with the Standard Operating Procedures Guidelines [10]. The main occupation in our field area is farming therefore, following consultation with HMF, land size was judged to be an appropriate proxy marker for socioeconomic status.

Diseases such as malaria or other conditions that could influence haemoglobin (Hb) levels were assessed based on past one year medical history, and clinical examination conducted at the time of data collection by the PI. Height and Mid Upper Arm Circumference (MUAC) of the dominant hand were recorded using standard measuring tapes, and weight was recorded using a digital machine (OMRON healthcare). MUAC was recorded using the circumference measured at the mid point between tip of elbow and the tip of shoulder. MUAC of <22 cm was used as a recommended cut-off for the identification of malnutrition [13]. Capillary Hb investigation was performed using the third finger of the non-dominant hand by a qualified laboratory personnel using Sahli's hemometer method. The device is an economical and portable tool commonly used for Hb assessment in India [14]. Sahli's method is a well-established technique in the country, and recommended by the Government of India mainly for use in the rural setting [14]. The technician involved in the MAS study had four years of laboratory experience, and received necessary training to ensure quality of the investigation.

Anaemia was defined as an Hb level below 12.0 g/dl [15]. The study protocol and operational procedures were piloted between January and March 2014, which resulted in minor changes to the data collection form. Field equipment and tools were checked on the 1st working day of every month by ensuring standardised performance against equipment stored permanently at HMF research office.

Statistical analysis

Data were analysed using Stata 13.1 (Stata 13, StataCorp, College Station, Texas, USA). Logistic regression was used to estimate odds ratios (OR) and 95% confidence intervals (CI) for the association of each risk factor with anaemia status. Linear regression was used to assess the association between each risk factor with Hb level. A systematic multivariable data analysis plan was developed whereby risk factor variables were assigned to one of three groups according to their theoretical relationship with anaemia: individual health factors, dietary factors and socioeconomic factors (Figure 1). The first three models only included within-group factors, with the fourth model allowing for full adjustment for all risk factors. We assessed multicollinearity using a covariate correlation matrix and the variance inflation factor (VIF). Multicollinearity was only found between height, weight, calculated body mass index, and MUAC; therefore, MUAC was the only anthropocentric measurement included in the model (VIF <4). Statistical significance was defined as $p<0.05$. The study is presented according to the STROBE guidelines.

Results

We approached 1,035 adolescent girls from 34 villages, of which only 25 (2%) did not participate in full data collection (Figure 2). Villages from the project had similar social and health infrastructure; all villages had government nurses, however most of them were visiting only once a month (N= 29), few had government health centres (N=9), and only one had an established primary health centre (PHC). None had a centralised water purification facility and all had limited private transport services. A very high prevalence of any anaemia was observed (87%) with severe anaemia (Hb ≤7.9 g/dl) in 5%, moderate anaemia (Hb 8.0 to 10.9 g/dl) in 65% and mild anaemia (Hb 11.0 to 11.9 g/dl) in 17% of the study participants. No participants reported systemic diseases that could influence Hb levels. None were admitted to hospital or received blood transfusions in the 12 months prior to the recruitment. Hb levels were normally distributed for the 1,010 participants (supplementary 1), and ranged from 5.0 to 14.0 g/dl with a mean of 10.1 g/dl (standard deviation (SD): 1.3).

Table 1 shows anaemia prevalence according to studied risk factors. Anaemia prevalence did not vary substantially by year of age. Almost all participants were either underweight (67% with BMI < 18.5 kg/m^2) or normal weight (32% with BMI 18.5 to 24.9 kg/m^2). Anaemia was more prevalent (90%) among girls with MUAC < 22 cm. We observed an overall low consumption (≤2 times per week) of milk, eggs, green leafy vegetables, bean sprouts and fruits/fruit juices, whereas pulses/lentils and rice were more frequently included in the diet (Table 1). Of the factors outlined in the table 1, current education, religion category and farmland possession were associated with anaemia in the unadjusted analyses.

The only factors that remained statistically significant in the fully adjusted logistic regression model (Table 2), which included all individual health, dietary and socioeconomic factors, were age, MUAC, current IFA supplementation, fruit/fruit juice, rice intake, current education and land ownership. In the fully adjusted model, factors associated with an increased odds of anaemia were increasing year of age (OR 1.41 per year, 95% CI: 1.17 to 1.70, linear increase, p<0.001), IFA supplementation (OR 5.68, 95% CI: 1.35 to 23.79, p=0.01), and parental land ownership (OR 1.74, 95%CI: 0.98 to 3.08, p=0.05). Larger MUAC (OR 0.51, 95%CI: 0.31 to 0.82 for ≥22cm compared with <22cm, p=0.006), consumption of fruit/fruit juice or rice ≥3 times per week compared with less often (OR 0.35, 95%CI: 0.23 to 0.54, p<0.001, and OR 0.39, 95%CI: 0.17 to 0.91, p<0.001), and having dropped out of school

(OR 0.47, 95%CI: 0.24 to 0.91, p=0.02) were all associated with reduced odds of anaemia. The effect estimates of the studied risk factors were roughly similar across all three models (unadjusted analysis, with group adjustment and a fully adjusted model, Table 2).

The fully adjusted linear regression model (Table 3) showed that only larger MUAC (p<0.001) and higher fruit/fruit juice consumption (p<0.001) were significantly associated with increased Hb levels, whereas current IFA supplementation was associated with decreased Hb levels (p=0.002), however the sizes of these associations were small.

Discussion

To our knowledge, this is the largest study from Marathwada region of the state where findings from a large representative rural adolescent population are presented. The prevalence of anaemia in adolescent girls in our study area of rural Maharashtra was extremely high (87%) with the majority of participants having moderate anaemia (65%).

Strengths and limitations

The response rate of 97.6% was high, thus minimising bias in the data collected. We also conducted regular quality controls to ensure optimal data quality. Our study had one key limitation, mainly the inability to perform venous blood withdrawal to use automated Hb analyser, mainly due to limited electricity, poor road infrastructure, and the logistic challenges of venous withdrawal and post-withdrawal transport of >1,000 samples from field sites to the laboratory [16].

Synthesis

Our analysis showed that risk of anaemia was higher with increasing age, which is consistent with prior studies from Maharashtra [2,17], and some of this increase in risks could be due to menarche [18]. Studies showed that low haemoglobin levels are associated with delayed menarche, while high menstrual flow is a direct cause of low haemoglobin[19]. However, we did not find any difference between pre and post-puberty participants (p=0.27).

Low fruit consumption was associated with a higher risk of anaemia. Common iron rich fruits consumed in our study population were apples, grapes, watermelon and pomegranate, which have high iron content. A recent clinical trial showed an increase in iron levels as a result of high fruit consumption, particularly due to vitamin C, which improved iron absorption [20]; it is therefore, likely that those who consumed more fruits were more likely to have increased iron absorption resulting in lower risk of IDA. Low MUAC (an indicator of poor nutrition) was associated with an increased risk of anaemia, and it is recognised that an overall compromised nutritional status is likely to affect haemoglobin levels [21,22]. Our findings showed an association between rice consumption and anaemia, which may be due to the type of rice, and the way it was consumed in our study population; for example, combination of rice with other food items such as traditional Indian curries (generally made up of range of vegetables) may influence haemoglobin levels [23]. Secondly, unpolished rice (brown rice) was commonly consumed in our study area, which has higher iron content than the polished rice (brown rice: 5.8 mg of iron/100 gram) [24]. The high prevalences of both anaemia (87%) and low BMI (67%) may be the consequences of chronic malnutrition influenced by food availability, costs and preferences [22, 25].

We observed higher anaemia in those who were on IFA supplements; 99% of those attended school, of whom 75% had undertaken a Hb investigation in the preceding 6 weeks at school, following which they were included in the school-based supplementation programme. In total 93 girls (of 1,010 participants) were consuming IFA supplements at the time of data collection. Majority of these individuals (73 girls of 93) started receiving weekly supplements in the same month when data were collected, which could explain the association with anaemia (supplementation initiative started by the school with not enough time elapsed for the supplements to have had an observable impact on Hb levels). National anaemia guidelines suggest that a minimum of 3 months of iron supplementation may be required to reverse anaemia in the absence of any major underlying pathology [15].

Less anaemia was observed in school dropouts in our study population, 42% of whom were engaged in agricultural employment. This may be explained by the fact that employment in our field area typically provides remuneration on a weekly basis (on an average 7-8 GBP per week for 6 days of work for adolescence), which may have provided opportunities to purchase additional food resources. Based on our understanding of the field area, we hypothesise that this small earning by young girls were likely to support the purchase of supplementary food items. As a result, the improved access to supplementary nutritional foods may have improved Hb levels. It is important to note that our analysis showed no association with menarche, socioeconomic status and family size in our study population.

Conclusion

Anaemia prevalence was extremely high among adolescent girls in rural areas of Maharashtra. Older age, low mid upper arm circumference (typically less than 22 cm), and low consumption of fruits were major risk factors of acquiring anaemia among adolescent girls. Future research is required to identify reversible causes of anaemia in both females and males living in this region of India, and test the hypotheses generated.

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Ethical approvals: The study was approved by the Institutional Ethics Committee of the Government Medical College Aurangabad, Maharashtra, India (Reference number: Pharma/IEC/GMA/196/2014), and the Medical School Ethics Committee of the University of Nottingham, UK (Reference number: E10102013). All participants and their guardians provided signed informed consent for the survey and blood withdrawal separately. Other than those who declined to participate, all adolescent girls received a standardised health report including information on their haemoglobin level and anaemia status along with facilitated access to educational materials on anaemia through the health NGO, Halo Medical Foundation's (HMF) village based services. Participant health reports were also provided to the village health worker/government nurse with arrangements for free consultation and assistance if any significant health problems requiring further assessment or treatment were identified during the study. HMF's hospital was also made available for free consultation as a primary referral centre if more specialist assessment or treatment was needed. On completion of data collection, an additional reminder letter was issued to village health workers indicating details of each severe anaemic case in their village to ensure that necessary medical advice and treatment was available.

Funding Source: This study was conducted as a part of Dr Anand Ahankari's PhD programme of with the University of Nottingham, UK which was sponsored by the University's Vice Chancellor Scholarship for Research Excellence International 2013 (Tuition fee support, Reference 12031). The anaemia project conducted in Maharashtra, India was a joint collaboration between the University and the Halo Medical Foundation (HMF), with the latter providing laboratory testing and data storage facilities. Project management and data collection were funded by Dr Hardikar through the Maharashtra Foundation, USA. Professor (Mr) and Mrs Chawathe, Mumbai, India provided generous support for Dr Ahankari's study. Dr Ahankari also received a bursary from Durgadevi Charitable Trust, India during PhD programme.

Financial disclosure: The donors/organisations/individuals listed above have had no role in defining the study hypothesis, data collection, analysis, interpretation or manuscript preparation.

Conflicts of interest: Authors have no conflicts of interest to disclose that are relevant to this study.

Author contributions: The study was designed by AF, PM, LT and AA. AA obtained the data and AA and LT conducted the analysis. All authors (AA, PM, AF, JD and LT) participated in manuscript preparation and approved the final manuscript for submission.

Acknowledgments: We acknowledge the support of Ms Sandhya Rankhamb in data collection, data entry, verification, and recognise her contribution in the project. We thank HMF village health workers for providing field level support for this study. We dedicate our research to Dr Sulbha Hardikar and Professor (Mr) and Mrs Chawathe who supported the project and the PhD studies respectively.

Table 1 Distribution of potential anaemia risk factors in the study population (N=1,010)

Characteristics	All study participants N (%)	Anaemic participants N (% with anaemia for each level of risk factor)	p value
Age in years			
13	207 (20.5)	182 (87.9)	0.20
14	229 (22.6)	190 (82.9)	
15	199 (19.7)	173 (86.9)	
16	173 (17.1)	152 (87.8)	
17	202 (20.0)	183 (90.5)	
Mid-upper arm circumference of dominant hand (MUAC)			
< 22 cm	507 (50.2)	456 (89.9)	0.007
≥ 22 cm	503 (49.8)	424 (84.2)	
Currently consuming Iron Folic Acid supplements			
No	917 (90.7)	789 (86.0)	0.001
Yes	93 (9.2)	91 (97.8)	
Attained menarche			
No	360 (35.6)	321 (89.1)	0.27
Yes	635 (62.8)	547 (86.1)	
Declined	15 (1.4)	12 (80)	
Diet recall (last seven days history)			
Pure milk (not in the form of tea/coffee)			
≤ 2 times a week	792 (78.4)	699 (86.7)	0.04
≥ 3 times a week	218 (21.5)	181 (79.6)	
Green leafy vegetables			
≤ 2 times a week	723 (71.5)	640 (87.1)	0.03
≥ 3 times a week	287 (28.4)	240 (80.5)	
Bean sprouts			
≤ 2 times a week	967 (95.7)	841 (85.1)	0.47
≥ 3 times a week	43 (4.2)	39 (89.8)	
Pulses-lentils			
≤ 2 times a week	307 (30.4)	266 (84.6)	0.76
≥ 3 times a week	703 (69.6)	614 (85.6)	
Fruits/Fruit juices			
≤ 2 times a week	774 (76.6)	700 (89.5)	<0.001
≥ 3 times a week	236 (23.3)	180 (68.9)	
Rice			
≤ 2 times a week	103 (10.2)	96 (92.8)	
≥ 3 times a week	907 (89.8)	784 (84.4)	0.05
Eggs			
≤ 2 times a week	980 (97.0)	855 (85.4)	0.52
≥ 3 times a week	30 (2.9)	25 (80)	
Chicken			
≤ 2 times a week	1001 (99.1)	873 (85.7)	0.40
≥ 3 times a week	9 (0.89)	7 (71.5)	
Goat meat			
≤ 2 times a week	1005 (99.5)	878 (85.6)	0.002
≥ 3 times a week	5 (0.5)	2 (40)	
Current education status			
School going	921 (91.1)	811 (88.0)	0.005
School dropout	89 (8.8)	69 (77.5)	
At least one elder sibling (immediate brother/sister)			
No	276 (27.3)	239 (86.5)	0.75
Yes	734 (72.6)	641 (87.3)	
At least one younger sibling (immediate brother/sister)			
No	337 (33.3)	295 (87.5)	0.78
Yes	673 (66.6)	585 (86.9)	
Religion and category			

Hindu open category	623 (61.6)	557 (89.4)	<0.001
Hindu reserved category	321 (31.7)	261 (81.3)	
Muslim	66 (6.5)	62 (7.0)	
Parents possess farming land			
No land	222 (21.9)	183 (82.4)	0.01
Less than 5 acres	420 (41.5)	364 (86.6)	
More than 5 acres	368 (36.4)	333 (90.4)	

Table 2 Logistic regression results: risk factors associated with anaemia in adolescent girls (N= 1,010)

Characteristics	Unadjusted OR (95% CI)	Models adjusted for within-group factors only[1] OR (95% CI)	Fully adjusted model[1] OR (95% CI)
Individual health factor group			
Age in years	1.09 (0.96 to 1.25)	1.34 (1.13 to 1.58) **	1.41 (1.17 to 1.70) **
Mid-upper arm circumference of dominant hand (MUAC)			
≥ 22	0.60 (0.41 to 0.87) *	0.52 (0.33 to 0.81) **	0.51 (0.31 to 0.82) **
Currently consuming Iron Folic Acid supplements			
Yes	7.38 (1.79 to 30.33) *	7.52 (1.82 to 31.05) *	5.68 (1.35 to 23.79) *
Attained menarche			
Yes	0.75 (0.50 to 1.12)	0.65 (0.39 to 1.10)	0.78 (0.45 to 1.34)
Declined	0.48 (0.13 to 1.79)	0.45 (0.11 to 1.74)	0.43 (0.10 to 1.83)
Dietary factor group (Ref ≤ 2 times a week)			
Pure milk (not in the form of tea/coffee)			
≥ 3 times a week	0.65 (0.42 to 0.98) *	0.71 (0.46 to 1.10)	0.65 (0.41 to 1.02)
Green leafy vegetables			
≥ 3 times a week	0.66 (0.44 to 0.97) *	0.73 (0.48 to 1.11)	0.69 (0.44 to 1.06)
Bean sprouts			
≥ 3 times a week	1.46 (0.51 to 4.15)	2.42 (0.80 to 7.28)	2.59 (0.82 to 8.18)
Pulses-lentils			
≥ 3 times a week	1.06 (0.71 to 1.58)	1.26 (0.83 to 1.92)	1.22 (0.79 to 1.88)
Fruits/Fruit juices			
≥ 3 times a week	0.33 (0.23 to 0.49) **	0.35 (0.23 to 0.52) **	0.35 (0.23 to 0.54) **
Rice			
≥ 3 times a week	0.46 (0.21 to 1.02)	0.45 (0.20 to 1.02)	0.39 (0.17 to 0.91) *
Eggs			
≥ 3 times a week	0.73 (0.27 to 1.94)	0.96 (0.31 to 2.94)	0.93 (0.30 to 2.89)
Chicken			
≥ 3 times a week	0.51 (0.10 to 2.49)	0.75 (0.09 to 6.26)	1.02 (0.13 to 7.82)
Goat meat			
≥ 3 times a week	0.09 (0.01 to 0.58) *	0.11 (0.01 to 0.88)	0.23 (0.02 to 2.15)
Socioeconomic factor group			
Current education status			
School dropout	0.46 (0.27 to 0.79) *	0.56 (0.32 to 0.99) *	0.47 (0.24 to 0.91) *
At least one elder sibling (immediate brother/sister)			
Yes	1.06 (0.70 to 1.60)	1.19 (0.76 to 1.86)	0.96 (0.60 to 1.56)
At least one younger sibling (immediate brother/sister)			
Yes	0.94 (0.63 to 1.40)	1.03 (0.67 to 1.58)	0.90 (0.57 to 1.43)
Religion and category (Hindu open category as a reference)			
Hindu reserved category	0.51 (0.35 to 0.75) *	0.61 (0.40 to 0.94) *	0.75 (0.48 to 1.17)
Muslim	1.83 (0.64 to 5.21)	2.12 (0.73 to 6.11)	2.34 (0.78 to 6.99)
Parents possess farming land (No land as a reference)			
Less than 5 acres	2.02 (1.24 to 3.31) *	1.56 (0.90 to 2.70)	1.74 (0.98 to 3.08) *
More than 5 acres	1.38 (0.88 to 2.16) *	1.10 (0.67 to 1.79)	1.12 (0.67 to 1.86)

*p<0.05 **p<0.001

[1]Models with within-group adjustments include only risk factors within that group, i.e. there are 3 models: the first with mutual adjustment only for individual health factors, the second with mutual adjustment only for dietary factors and the third with mutual adjustment only for socioeconomic factors, as described in figure 1. The fully-adjusted model includes all risk factors in the table.

OR=odds ratio; CI= confidence interval

Table 3 Linear regression results: risk factors associated with haemoglobin level in adolescent girls (N= 1,010)

Characteristics	Unadjusted β (95% CI)	Models adjusted for within-group factors[1] only β (95% CI)	Fully adjusted model[1] β (95% CI)
<u>Individual health factor group</u>			
Age in years	0.00 (-0.06 to 0.04)	-0.06 (-0.13 to -0.00)	-0.07 (-0.14 to 0.00)
Mid-upper arm circumference of dominant hand (MUAC)			
≥ 22 cm	0.36 (0.19 to 0.52) **	0.49 (0.30 to 0 .68) **	0.46 (0.27 to 0.66) **
Currently consuming Iron Folic Acid supplements			
Yes	-0.55 (-0.83 to -0.26) **	-0.53 (-0.82 to -0.25) *	-0.44 (-0.72 to -0.15) **
Attained menarche			
Yes	0.00 (-0.16 to 0.18)	-0.14 (-0.37 to 0.08)	-0.17 (-0.40 to 0.5)
Declined	0.41 (-0.28 to 1.10)	0.26 (-0.42 to 0.95)	0.29 (-0.39 to 0.99)
<u>Dietary factor group</u> (Ref ≤ 2 times a week)			
Pure milk (not in the form of tea/coffee)			
≥ 3 times a week	0.13 (-0.06 to 0.33)	0.10 (-0.10 to 0.30)	0.08 (-0.11 to 0.28)
Green leafy vegetables			
≥ 3 times a week	0.03 (-0.14 to 0.22)	0.00 (-0.19 to 0.18)	0.00 (-0.17 to 0.19)
Bean sprouts			
≥ 3 times a week	-0.14 (-0.55 to 0.26)	-0.27 (-0.69 to 0.13)	-0.25 (-0.66 to 0.15)
Pulses-lentils			
≥ 3 times a week	0.02 (-0.15 to 0.20)	-0.03 (-0.21 to 0.15)	-0.01 (-0.19 to 0.16)
Fruits/Fruit juices			
≥ 3 times a week	0.48 (0.28 to 0.67) **	0.47 (0.28 to 0.67) **	0.45 (0.25 to 0.64) **
Rice			
≥ 3 times a week	0.11 (-0.16 to 0.38)	0.09 (-0.17 to 0.37)	0.14 (-0.13 to 0.41)
Eggs			
≥ 3 times a week	0.00 (-0.49 to 0.48)	-0.11 (-0.63 to 0.40)	-0.09 (-0.61 to 0.42)
Chicken			
≥ 3 times a week	0.30 (-0.58 to 1.18)	0.24 (-0.73 to 1.22)	0.21 (-0.75 to 1.18)
Goat meat			
≥ 3 times a week	1.27 (0.09 to 2.45) *	1.08 (-0.14 to 2.32)	0.76 (-0.45 to 1.99)
<u>Socioeconomic factor group</u>			
Current education status			
School dropout	0.24 (-0.04 to 0.53)	0.22 (-0.07 to 0.52)	0.18 (-0.12 to 0.49)
At least one elder sibling (immediate brother/sister)			
Yes	-0.12 (-0.30 to 0.06)	-0.11 (-0.31 to 0.09)	-0.06 (-0.26 to 0.13)
At least one younger sibling (immediate brother/sister)			
Yes	0.12 (-0.04 to 0.30)	0.07 (-0.11 to 0.26)	0.10 (-0.08 to 0.29)
Religion and category (Ref Hindu open category)			
Hindu reserved category	0.18 (0.00 to 0.36) *	0.20 (0.00 to 0.40) *	0.13 (-0.06 to 0.33)
Muslim	-0.00 (-0.34 to 0.34)	0.02 (-0.32 to 0.37)	0.02 (-0.32 to 0.36)
Parents possess farming land (Ref No land)			

Less than 5 acres	0.00 (-0.21 to 0.23)	0.12 (-0.12 to 0.37)	0.09 (-0.14 to 0.34)
More than 5 acres	-0.06 (-0.28 to 0.15)	0.02 (-0.20 to 0.26)	0.06 (-0.16 to 0.29)

*p<0.05 **p<0.001

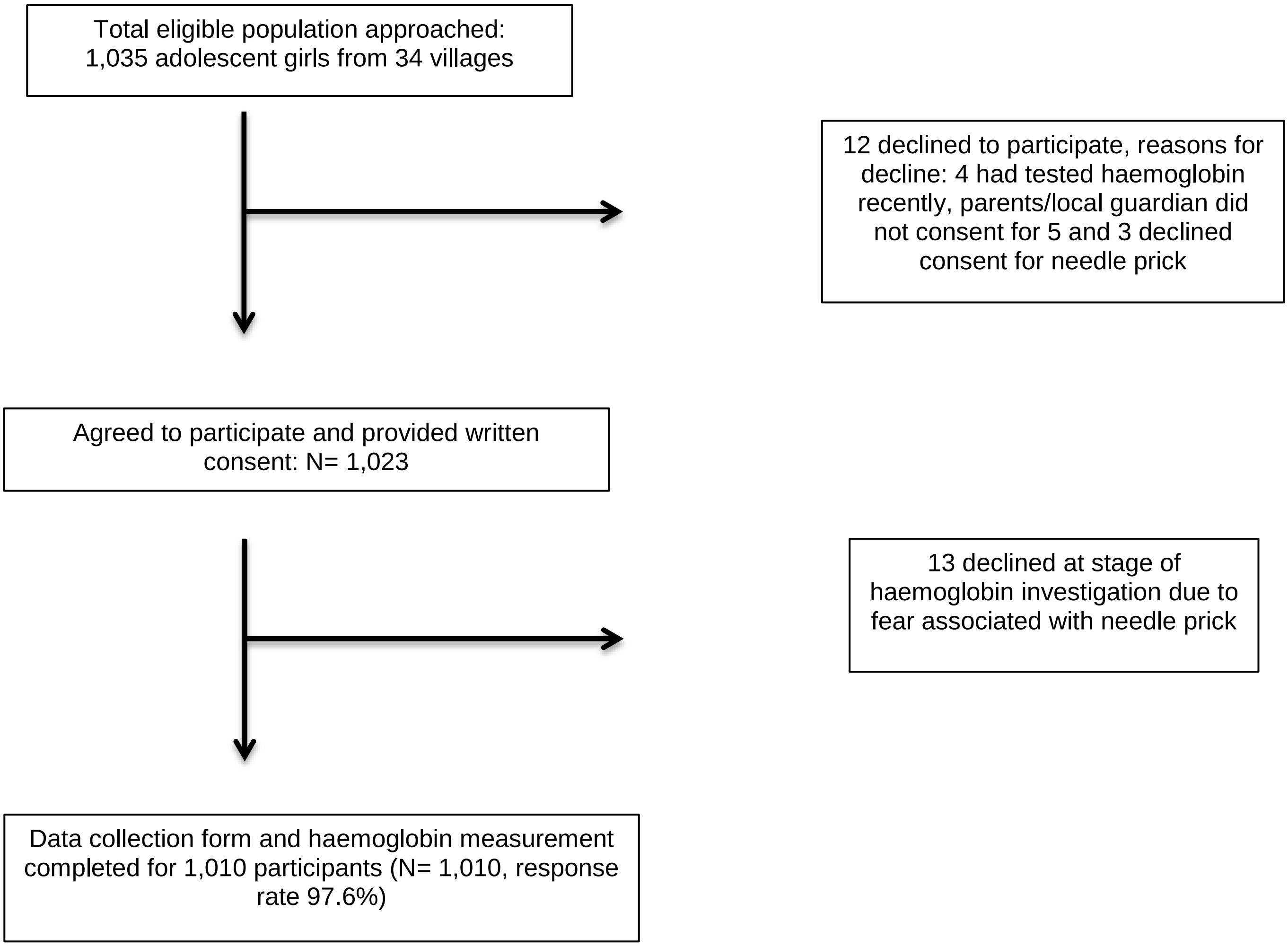
[1]Models with within-group adjustments include only risk factors within that group, i.e. there are 3 models: the first with mutual adjustment only for individual health factors, the second with mutual adjustment only for dietary factors and the third with mutual adjustment only for socioeconomic factors, as described in figure 1. The fully-adjusted model includes all risk factors in the table.

β=linear regression correlation coefficient; CI= confidence interval

Figure 1: Risk factor groupings for multivariable modelling

Individual health factors Age, Mid upper-arm circumference (MUAC), Currently consuming iron folic acid supplements, Attained menarche
Dietary factors 7-day diet recall of daily intake (milk, green leafy vegetables, sprouts, pulses-lentils, fruits/fruit juices, eggs, chicken and goat meat)
Socioeconomic factors Current education status, Siblings (elder/younger), Religion and broad caste category, Farming land

Figure 2: Flow chart of recruitment process and final study population



Supplementary 1: Histogram of haemoglobin distribution in 1010 adolescent girls