Review Article

Prevalence of anaemia among adolescent girls (10–19 years) in India: A systematic review and meta-analysis

ROY AROKIAM DANIEL, MANI KALAIVANI, SHASHI KANT, SANJEEV GUPTA

ABSTRACT

Background. Anaemia is a serious public health problem. It is the second-commonest contributing factor to years lost by adolescents to disability and death. Targeting adolescent girls will allow a window of opportunity to correct their nutritional health and improve their obstetric outcomes. Studies in India have reported varying prevalence rates of anaemia among adolescent girls. Hence, we did a systematic review and meta-analysis of community-based studies to obtain a comprehensive pooled estimate of the prevalence of anaemia among adolescent girls in India.

Methods. We did a systematic electronic search in PubMed, Embase, Cochrane Library and Google scholar to retrieve community-based studies that reported the prevalence of anaemia among adolescent girls (10–19 years) in India, without any date or language restriction. To estimate the pooled prevalence and heterogeneity, the random-effects model and I^2 statistical methods were used. We did subgroup analyses based on geographical region, study setting, method used to measure haemoglobin concentration, and year of publication.

Results. We included 35 studies in this meta-analysis comprising 152 640 participants. The pooled prevalence of anaemia among adolescent girls was 65.7% (95% CI 59.3%–71.9%). There was significant heterogeneity between the studies (I^2 99.6%; $p < 0.001$).

Conclusion. There is a high prevalence of anaemia among adolescent girls in India. While all regions of the country have a high prevalence, tribal areas need special attention. Targeted actions need to focus on the identification of determinants of anaemia apart from iron supplementation.

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INTRODUCTION

Anaemia is a state in which the hemoglobin (Hb) level and/or red blood cells are insufficient to cope with the body's physiological needs. Globally, iron deficiency is the most common reason for anaemia.[1] It is a major public health problem that had affected 1.9 billion people globally in 2017. It is also a leading cause of impairment, with 58.2 million years lived with disability.[2] Though present widely across the globe, it is more pronounced in low- and middle-income countries. In India, it mainly affects women of reproductive age group, lactating women, children and adolescent girls.[3]

India is home to 243 million adolescents, comprising 21.4% of the country's population. Adolescence (10–19 years) is a unique phase of life where they experience brisk physical, cognitive and psychosocial growth.[4] In 2016, worldwide, the second leading cause of years lost by adolescents to death and disability was iron deficiency anaemia.[4] The major health consequences of anaemia among adolescents are poor cognition, concentration, memory and scholastic performance, low immunity, recurrent infections, poor motor development outcomes, and irregular menstruation.[5] Adolescent girls are a priority age group since they may be on the verge of motherhood. Also, depletion of body iron reserve in women begins during the adolescent phase with the commencement of menstruation.

In Asia, anaemia is the second leading cause of maternal mortality.[6] Added to this, the leading cause of death among girls aged 15–19 years is complications from pregnancy and childbirth. Girls who become pregnant during adolescence will have a poor obstetric outcome as they are physically immature.[7] Hence, targeting anaemia, especially in adolescent girls, improves not only their health status, but also their pregnancy outcomes.

In India, malnutrition in the form of anaemia is prevalent in over 56% of adolescent girls and 30% of adolescent boys.[8,9] Studies conducted to estimate the prevalence of anaemia among adolescent girls in India have reported a wide range (21% to 96%).[10,11] This wide range could be due to differences in sample size, participants' characteristics, inclusion and exclusion criteria, study setting, tool used to measure haemoglobin concentration, etc. The quality of individual studies also vary considerably. Hence, we conducted a systematic review and meta-analysis to estimate the pooled prevalence of anaemia among adolescent girls in India.

METHODS

Data sources and search strategy

A comprehensive literature search was done to identify relevant studies published between their inception to 1 August 2021. The following electronic databases were searched: Medline via PubMed, Embase, Cochrane library and Google Scholar with no restriction on language using Medical Subject Headings (MeSH) and keywords. The keywords used to build the search strategy were: 'prevalence', 'epidemiology', 'anaemia', 'hemoglobin', 'hematocrit', 'adolescent girls', and 'India'. We used the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) and Meta-analysis of Observational Studies in Epidemiology (MOOSE) statements as a guide for this study.[12,13] We also reviewed cross-references of the published primary studies.

Selection criteria

The following criteria were used for eligibility of studies: (i) population/community-based studies; (ii) conducted among adolescent girls (10–19 years); (iii) should have estimated the prevalence of anaemia; (iv) estimation of hemoglobin should be based on an objective method; (v) data should be sufficient to obtain the prevalence of anaemia among 10–19 years age group; and (vi) studies conducted in India. The exclusion criteria were as follows: (i) studies assessing anaemia among adolescents with specific conditions such as HIV/tuberculosis, chronic kidney disease, etc. because they might show higher than expected prevalence and thus, selection bias and (ii) abstracts, conference proceedings, letters, review articles, editorials, case reports and studies not conducted on humans.

Selection of studies

Two independent reviewers (RAD and SKG) screened all the titles and abstracts of retrieved records from the databases. Only those abstracts that fulfilled the selection criteria were chosen for the full-text review. Disagreements regarding the selection of studies were discussed and resolved. After verifying the most recent and complete version, the duplicates were excluded. Reference lists of the retrieved studies were searched (additional sources). The retrieved full-text studies were judged further to confirm whether they satisfied the inclusion criteria.

Data extraction

We devised a data collection form in Microsoft Excel 2013 to extract and enter the relevant data fields from the selected full-text studies. The following data were extracted from each study: author information, year of publication, place of study, study setting, sampling strategy, sample size, method of estimation of haemoglobin, criteria used to classify anaemia, and the reported prevalence of anaemia. Quality assessment of the selected studies was done based on the CASP (Critical Appraisal Skills Programme) checklist.[14]

Statistical analysis

We provided summary estimates of the prevalence of anaemia among adolescent girls. The standard error (SE) of the prevalence was calculated from the prevalence and the sample size for each of the studies, using the formula 'square root of $p\times(1-p)/n$'. Forest plots were created to display the prevalence with a corresponding 95% CI. The meta-analysis was performed by package metan[15] in STATA 13.0 (Stata Corp LP, College Station, Texas, USA) using random effects model, weighted by the inverse of the variance. I^2 statistic (percentage of residual variation attributed to heterogeneity) was performed to evaluate heterogeneity. Publication bias was assessed by visual inspection of the funnel plot, and the small-study effect was assessed by Egger test. To investigate the observed heterogeneity, subgroup analysis was done based on geographical region, study setting, the method used to estimate haemoglobin concentration and year of publication. Sensitivity analysis was conducted to assess the changes in pooled estimates after removing two large nationally representative surveys. Test of interaction was also done to determine if any significant difference was present in the prevalence of anaemia between subgroups.

RESULTS

Study selection

Overall, 995 studies were retrieved from electronic databases. After removing 103 duplicates, 892 studies were screened based on titles and abstracts using the selection criteria, and 839 were excluded. Of the remaining 53 studies, 18 were excluded, and finally, 35 studies satisfied the inclusion criteria, and were included in the meta-analysis (Fig. 1).

Characteristics of studies included in the meta-analysis

The studies included in this review yielded a combined total of 152 640 adolescents (aged 10–19 years) with a mean age of 14.6 years. The majority of studies included in this review were rural-based and from southern India. There were three multicentre studies,[16] of which two were nationally representative surveys.[17,18] Of 35 studies included in this review, all were cross-sectional studies except three conducted by Deshmukh *et al.*,[19] Patil *et al.*[20] and Shah *et al.*,[21] which were interventional studies. All except four studies included in this review had adopted the WHO criteria for the classification of anaemia (Hb <12 g/dl).[22] Four studies, conducted by Rajaratnam *et al.*,[23] Gupta *et al.*,[24] Sulakshana *et al.*,[25] Shinde *et al.*,[26] had not mentioned the cut-off used to classify anaemia. The majority of studies used simple random sampling to recruit the participants (Table I).

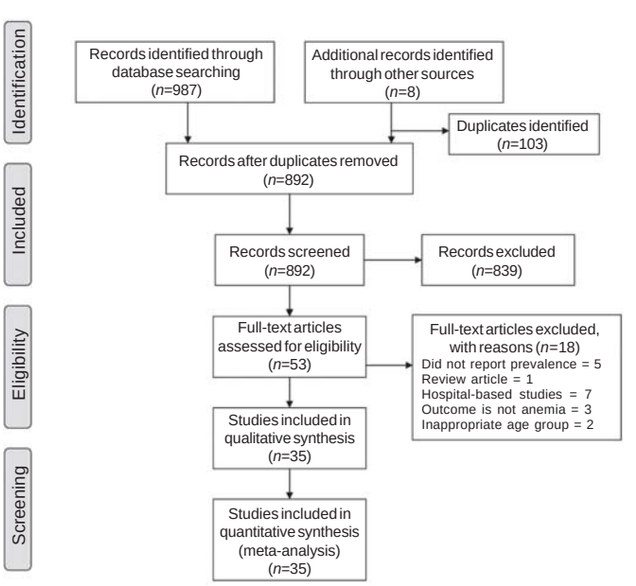

FIG 1. Flow of selection of studies for meta-analysis

TABLE I. Characteristics of studies included in the meta-analysis

Author	Year of publication	Place	Study setting	Age group	Sample size	Prevalence (%)
Rajaratnam *et al.*[23]	2000	Vellore, Tamil Nadu	Rural	13–19	288	44.8
Rawat *et al.*[27]	2001	Meerut, Uttar Pradesh	Rural	10–18	504	34.5
Rao *et al.*[28]	2003	Jabalpur, Madhya Pradesh	Tribal	11–19	377	86.5
Choudhary *et al.*[29]	2006	Vellore, Tamil Nadu	Urban	11–18	100	29.0
Kaur *et al.*[30]	2006	Sewagram, Maharashtra	Rural	13–19	630	59.8
Singh *et al.*[31]	2006	Lucknow, Uttar Pradesh	Urban	10–19	400	56.0
Toteja *et al.*[16]	2006	Multicentric study	Mixed	11–18	4337	90.1
Bulliyya *et al.*[11]	2007	Khurda, Jajpur, Bargarh, Odisha	Rural	11–19	1937	96.5
Chaudhary and Dhage[32]	2008	Nagpur, Maharashtra	Urban	10–19	296	35.1
Deshmukh *et al.*[19]	2008	Nashik, Maharashtra	Mixed	14–18	360	65.3
Patil *et al.*[33]	2009	Ratnagiri, Maharashtra	Rural	10–19	620	41.9
Dongre *et al.*[34]	2011	Wardha, Maharashtra	Rural	12–19	260	73.8
Shivaramakrishna *et al.*[35]	2011	Kolar, Karnataka	Rural	10–19	230	34.8
Kulkarni *et al.*[36]	2012	Jaitala, Maharashtra	Urban	13–19	208	88.5
Amarnath and Lakshmanrao[37]	2013	Visakhapatnam, Andhra Pradesh	Tribal	10–19	270	88.9
Pattnaik *et al.*[38]	2013	Bhubaneswar, Odisha	Rural	10–19	151	79.0
Gupta *et al.*[24]	2014	Meerut, Uttar Pradesh	Urban	10–19	216	52.8
Patil *et al.*[20]	2014	Satara, Maharashtra	Urban	11–18	103	85.4
Sulakshana *et al.*[25]	2014	Belgaum, Karnataka	Rural	10–19	410	75.0
Kappala *et al.*[39]	2014	Bellary, Karnataka	Urban	10–19	400	82.5
Kumar *et al.*[40]	2015	Rajahmundry, Andhra Pradesh	Rural	11–18	215	63.7
Phuljhele *et al.*[41]	2015	Raipur, Chhattisgarh	Urban	10–19	385	61.0
Shinde *et al.*[26]	2015	Bhopal, Madhya Pradesh	Urban	10–19	267	52.1
NFHS-4[17]	2016	Multicentric study	Mixed	15–19	117 711	54.1
Shah *et al.*[21]	2016	Jhagadia, Gujarat	Tribal	10–19	117	79.5
Siva *et al.*[10]	2016	Kottayam, Kerala	Rural	10–19	257	21.0
Ahankari *et al.*[42]	2017	Marathwada, Maharashtra	Rural	13–17	1010	87.0
Raj and Chopra[43]	2017	Belkhera, Madhya Pradesh	Rural	10–19	200	52.5
Srivastava *et al.*[44]	2017	Amroha, Uttar Pradesh	Rural	13–19	604	69.2
Arya *et al.*[45]	2017	Kanpur, Uttar Pradesh	Rural	10–19	400	78.5
CNNS[18]	2018	Multicentric study	Mixed	10–19	17 965	39.6
Pareek and Ojha[46]	2018	Jaipur, Rajasthan	Rural	12–15	472	73.7
Kulkarni *et al.*[47]	2019	Palghar, Maharashtra	Tribal	12–18	240	92.7
Gayakwad and Shankar[48]	2019	Bagalkot, Karnataka	Urban	10–19	400	63.3
Reshmi and Takalkar[49]	2020	Narketpally, Telangana	Rural	10–19	300	59.0

NFHS National Family Health Survey CNNS Comprehensive National Nutrition Survey

Pooled estimate of prevalence of anaemia among adolescent girls in India

The prevalence of anaemia among adolescents from the 35 included studies ranged from 21% in a cross-sectional study done by Siva *et al.*[10] in southern India to 96.5% by Bulliyya *et al.*[11] conducted in eastern India. The random effects pooled estimate for the prevalence of anaemia among adolescent girls was 65.7% (95% CI 59.3%–71.9%; Fig. 2). There was significant heterogeneity between the studies. Heterogeneity test showed I^2 value of 99.6% and $p<0.001$.

Subgroup analysis

Prevalence of anaemia based on geographical region. Of the 35 included studies, 10 each were conducted in the South and West, nine studies in Central, two studies in the East, and one study in the North region of India. Since there were only two studies from the East, we combined them with North for the subgroup analysis. The prevalence of anaemia in South, West, Central and North with East regions was 57.0%, 72.4%, 61.0% and 84.8%, respectively. There was no significant difference in the heterogeneity between the studies based on geographical region (Fig. 3; p=0.121). We did not include three multicentric studies (Toteja *et al.*, NFHS-4 and CNNS) in this subgroup analysis.

Prevalence of anaemia based on study setting. Among the 35 included studies, 17 were conducted in rural areas, 10 in urban

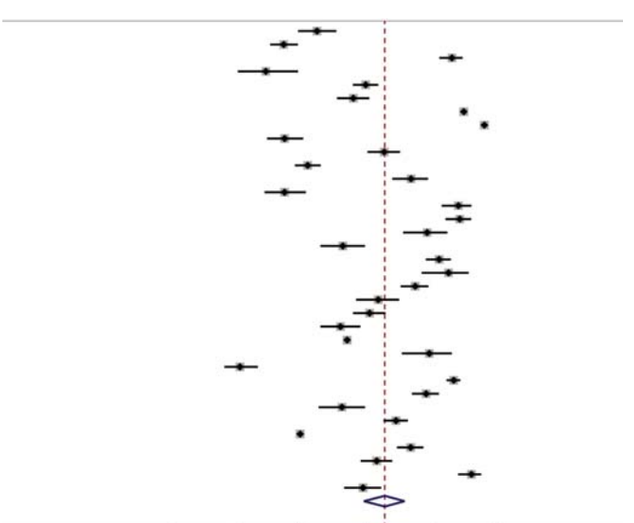

FIG 2. Forest plot of the meta-analysis for prevalence of anaemia

areas, and 4 in tribal areas. The study by Deshmukh *et al.*[19] was conducted in rural, tribal and urban slums, whereas other studies by Toteja *et al.*, NFHS-4 and CNNS[16–18] obtained samples from urban and rural populations. These four studies have been categorized under a 'mixed' group. The prevalence of anaemia in rural, urban, tribal and mixed areas were 62.7%, 61.6%, 87.5% and 63.8%, respectively. We observed a small decrease in heterogeneity among studies from the tribal area of India. There was a significant difference in the heterogeneity between the studies based on setting (Fig. 4; p<0.001).

Prevalence of anaemia based on year of publication. Of the 35 studies, 11 were published between 2000 and 2010, and 24 studies were published between 2011 and 2020. The prevalence of anaemia in these two time periods was 60.3% and 68.0%, respectively. We did not observe any decrease in heterogeneity in this subgroup. There was no significant difference in the heterogeneity between the studies based on these two time periods (Fig. 5; p=0.398).

Prevalence of anaemia based on method of haemoglobin estimation. Of the 35 included studies, 14 used the cyanmethae-moglobin method, 11 used Sahli haemoglobinometer, 3 used Hemocue, 3 an autoanalyser and 2 a haemoglobin colour scale (HCS). Two studies by Choudhary *et al.*[29] and Raj and Chopra,[43] had not mentioned the method used to estimate haemoglobin. For the subgroup analysis, apart from Sahli and cyanmethaemoglobin methods, we combined the remaining methods under the heading 'others'. The prevalence of anaemia among Sahli, cyanmethaemoglobin, and others was 69.2%, 67.6%, 58.4%, respectively. We did not observe any decrease in heterogeneity in this sub-group. There was no significant difference in the heterogeneity between the studies based on the method used for haemoglobin estimation (Fig. 6; p=0.388).

Quality assessment

Across the nine quality domains evaluated, most of the studies met six or more of the quality criteria (Table II). Only one study mentioned confidence intervals in their main results. The response rate was satisfactory for all the included studies. Of the 35 studies, 23 studies had calculated the required minimum sample size *a priori*. Two studies did not clearly explain the methods of participant selection. Two studies had included participants that could not be representative of the population to which the findings were referred.

Publication bias

The funnel plot showed a mild asymmetry (Fig. 7). However, the p value for Egger test was 0.226, implying no or undetected publication bias.

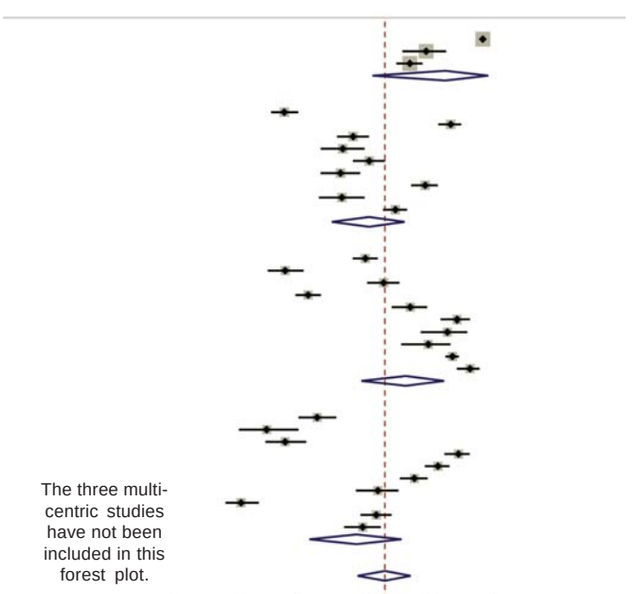

FIG 3. Forest plot of the meta-analysis for prevalence of anaemia based on geographical region

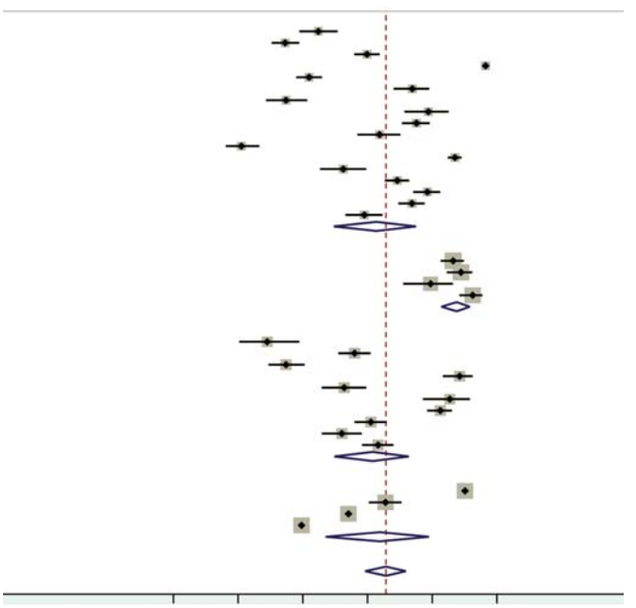

FIG 4. Forest plot of the meta-analysis for prevalence of anaemia based on study setting

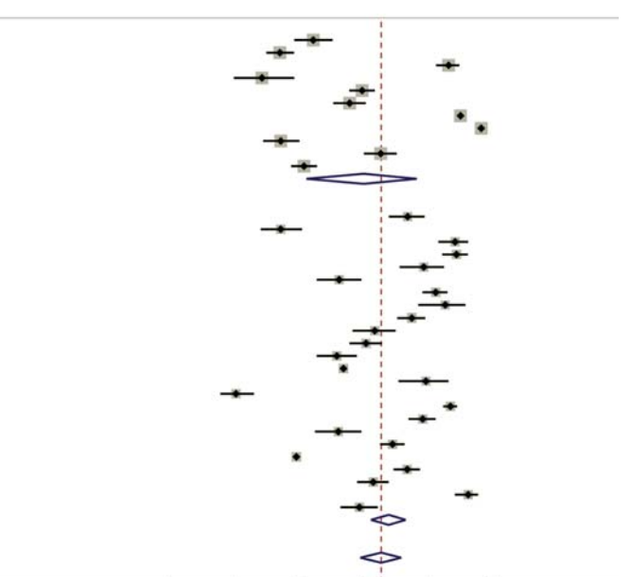

FIG 5. Forest plot of the meta-analysis for prevalence of anaemia based on year of publication

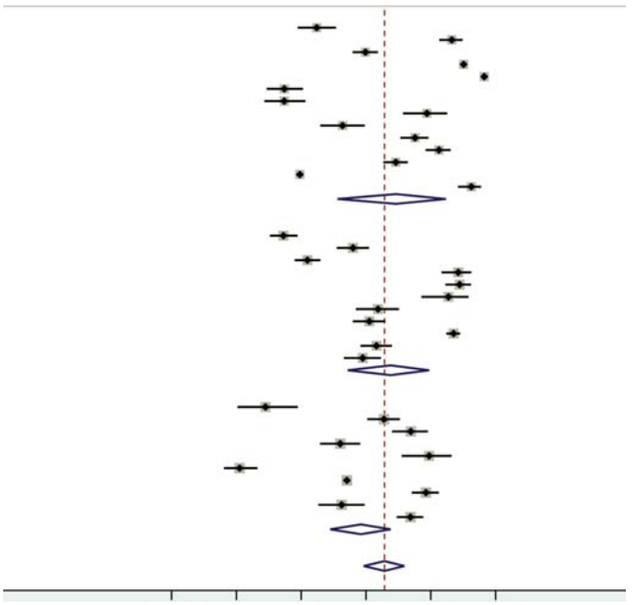

FIG 6. Forest plot of the meta-analysis for prevalence of anaemia based on method of haemoglobin estimation

Sensitivity analysis

We performed sensitivity analysis by removing two large nationally representative multicentric surveys (NFHS and CNNS). The pooled estimate of the prevalence of anaemia among the remaining 33 studies was 66.8% (95% CI 58.6%–

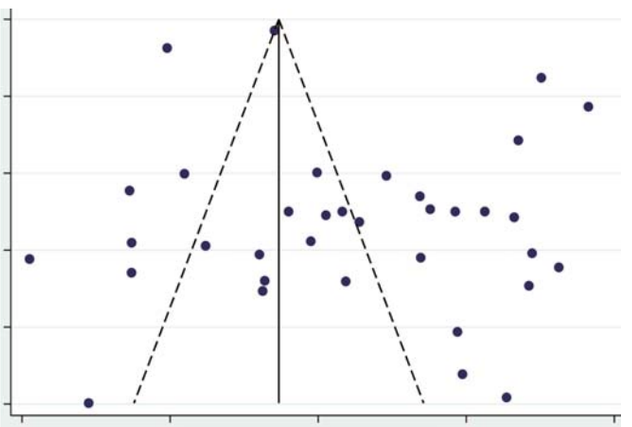

FIG 7. Funnel plot for assessing publication bias

TABLE II: Risk of bias assessment of studies included in the meta-analysis

Question	Rajaratnam *et al.*[23]	Rawat *et al.*[27]	Rao *et al.*[28]	Choudhary *et al.*[29]	Kaur *et al.*[30]	Singh *et al.*[31]	Toteja *et al.*[16]	Bulliyya *et al.*[11]	Chaudhary and Dhage[32]
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Could the way the sample was obtained introduce (selection) bias?	No	No	No	No	No	Can't say	No	No	No
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Yes	Yes	Can't say	Yes	Yes	Yes
Was the sample size based on pre-study considerations of statistical power?	No	No	No	Yes	Yes	No	Yes	Yes	Yes
Was a satisfactory response rate achieved?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Yes	Yes	Can't say	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	No	No	No	No	No	No	No	No

Question	Deshmukh *et al.*[19]	Patil *et al.*[33]	Dongre *et al.*[34]	Shivaramakrishna *et al.*[35]	Kulkarni *et al.*[36]	Amarnath and Lakshmanrao[37]	Pattnaik *et al.*[38]	Gupta *et al.*[24]	Patil *et al.*[20]
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Could the way the sample was obtained introduce (selection) bias?	No	No	No	No	No	No	No	No	No
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

contd.

Question	Deshmukh *et al.*[19]	Patil *et al.*[33]	Dongre *et al.*[34]	Shivaramakrishna *et al.*[35]	Kulkarni *et al.*[36]	Amarnath and Lakshmanrao[37]	Pattnaik *et al.*[38]	Gupta *et al.*[24]	Patil *et al.*[20]
Was the sample size based on pre-study considerations of statistical power?	Yes	No	No	Yes	Yes	Yes	No	Yes	No
Was a satisfactory response rate achieved?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	No	No	No	No	No	No	No	No

Question	Sulakshana *et al.*[25]	Kappala *et al.*[39]	Kumar *et al.*[40]	Phuljhele *et al.*[41]	Shinde *et al.*[26]	NFHS-4[17]	Shah *et al.*[21]	Siva *et al.*[10]	Ahankari *et al.*[42]	Raj and Chopra[43]
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Could the way the sample was obtained introduce (selection) bias?	No	No	No	No	No	No	No	No	No	No
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the sample size based on pre-study considerations of statistical power?	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
Was a satisfactory response rate achieved?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	Yes	No	No	No	No	No	No	No	No

Question	Srivastava *et al.*[44]	Arya *et al.*[45]	CNNS[18]	Pareek and Ojha[46]	Kulkarni *et al.*[47]	Gayakwad and Shankar[48]	Reshmi and Takalkar[49]
Did the study address a clearly focused question/issue?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the research method (study design) appropriate for answering the research question?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the method of selection of the participants (employees, teams, divisions, organizations) clearly described?	Yes	Yes	Yes	No	Yes	Yes	Yes
Could the way the sample was obtained introduce (selection) bias?	No	No	No	Can't say	No	No	No
Was the sample of participants representative with regard to the population to which the findings will be referred?	Yes	Yes	Yes	Can't say	Yes	Yes	Yes
Was the sample size based on pre-study considerations of statistical power?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was a satisfactory response rate achieved?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were the measurements (questionnaires) likely to be valid and reliable?	Yes	Yes	Yes	Can't say	Yes	Yes	Yes
Were confidence intervals given for the main results?	No	No	No	No	No	No	No

NFHS-4 National Family Health Survey–4 CNNS Comprehensive National Nutritional Survey

74.6%), compared to 65.7% (95% CI 59.3%–71.9%) of the 35 studies. The prevalence of anaemia showed no significant change.

DISCUSSION

We did a systematic review and meta-analysis of data from 35 community-based studies involving 152 640 participants, and the estimated pooled prevalence of anaemia was 65.7% (95% CI 59.3%–71.9%) among adolescent girls in India.

A systematic review and meta-analysis conducted in 2017 by Akbari *et al.*,[50] among Iranian children and adolescents (<18 years), estimated the prevalence of anaemia to be 13.9% (95% CI 10.8%–17.1%); among men and women these were 7.9% (95% CI 4.1%–11.7%) and 8.5% (95% CI 6.1%–10.8%), respectively. Their findings are much lower than our study's pooled estimate. The reason for the low prevalence of anaemia in their study might be the difference in race and ethnicity.[51] Anaemia is multifactorial in origin, diet being an important variable. The reason(s) for the observed difference is not clear and needs further investigation.

There could be various sources for the heterogeneity observed among the studies. Hence, to explore the heterogeneity,

we conducted subgroup analysis based on the method used for haemoglobin estimation, geographical region, year of publication, and study setting.

In this review, cyanmethaemoglobin (14/35) and Sahli method (11/35) were the two most commonly used methods to estimate the haemoglobin concentration. Subgroup analysis based on the methods used to estimate the haemoglobin concentration revealed no decrease in heterogeneity, and no significant difference in heterogeneity across the subgroups. The validity of the methods used for measurement of haemoglobin has been tested in various conditions. Studies conducted among school children and adults to estimate the sensitivity and specificity of Sahli method to detect anaemia (capillary and venous blood) was 83%–92% and 39%–63%, respectively.[52,53] The sensitivity and specificity of the Hemocue method to detect anaemia (capillary and venous blood) was 82%–93% and 63%–94%, respectively.[54–56] Few studies included in this review had used the HCS to assess the concentration of haemoglobin. The sensitivity and specificity of HCS has been reported to be 50%–88% and 49%–84%, respectively.[53,57,58] Though the sensitivity and specificity of tools used to measure haemoglobin concentration vary, they did not contribute to the heterogeneity observed between the subgroups. Digital haemoglobinometers (e.g. HemoCue®) have emerged as a new point-of-care diagnostic tool with acceptable sensitivity and specificity. For a community-based survey for the prevalence of anaemia, it is an easy, simple and portable instrument.

There was no significant decrease in heterogeneity based on geographical region. Based on the study setting, subgroup analysis revealed a modest decrease in heterogeneity among the studies conducted in the tribal area. The prevalence of anaemia among the tribal population was higher than India's rural and urban areas (87.5%, 62.7% and 61.6%). India has the second-largest tribal population in the world, representing 8.6% of India's population.[59] Apart from other causes of anaemia, the tribal population in India has the additional burden of haemoglobinopathies, e.g. sickle cell anaemia. Hence, it is important from the public health perspective to study the underlying determinants of anaemia in this population.

The prevalence of anaemia estimated from the studies published between 2011 and 2020 is a little higher than that of studies published earlier (68.0% and 60.3%). Despite launching appropriate interventional programmes such as the Weekly Iron and Folic Acid Supplementation (WIFS) and National Iron Plus Initiative (NIPI), the prevalence of anaemia has not declined. The Comprehensive National Nutritional Survey (CNNS) (2016–2018) estimated that among adolescents (10–19 years), only 12% of those who had anaemia had iron deficiency.[18] Another meta-analysis from the national surveys of various countries estimated that only 37% of anaemia was associated with iron deficiency among non-pregnant women of reproductive age group.[60] Hence, it appears that only supplementing iron and folic acid will not reduce the burden of anaemia. More research is needed to estimate the proportion of anaemia caused by each determinant apart from iron deficiency. We also did a sensitivity analysis to see whether the inclusion of two large nationally representative studies affected our study's estimate. There was no difference in the summary estimate after the removal of these two studies.

We systematically searched various electronic databases to identify community-based studies that had estimated the prevalence of anaemia among adolescent girls in India. In total, we identified 35 studies, which allowed us to pool results from 152 640 participants. We used a standard search strategy, risk of bias assessment for individual studies, explored heterogeneity using subgroup analysis and performed sensitivity analysis. The findings of this systematic review and meta-analysis should be interpreted with the following limitations. Even though we followed a comprehensive search strategy, we might have missed some studies in the grey literature, which could have affected the pooled estimate. The estimated pooled prevalence from this study should be interpreted with caution as there was high heterogeneity among the studies.

Conclusion

Our findings suggest a high prevalence of anaemia among adolescent girls in India. Studies are needed to establish the causative factors so that appropriate public health strategies to control anaemia could be developed.

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