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Original Research Article

Effectiveness of an integrated 4T intervention test, treat, talk and track in mitigating anemia among tribal communities in Telangana, India

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ABSTRACT

Background: Anaemia affects over 1.6 billion people worldwide, with India bearing a disproportionate burden despite five decades of national programming. Telangana's 70% prevalence exceeds the 67.1% national average, with tribal districts like Bhadradri Kothagudem suffering from poor dietary diversity, limited healthcare access, and socioeconomic disadvantages. This study evaluated whether an integrated "4T" intervention- Test, Treat, Talk, and Track - could reduce Anaemia in this vulnerable population.
Methods: A community-based longitudinal study was conducted in Laxmidevipally Mandal, Bhadradri Kothagudem, covering 1,228 households across 16 villages with a baseline population of 5,291. Haemoglobin levels were screened using the non-invasive EzeCheck device. Anaemic participants received targeted medical treatment, Behaviour Change Communication (BCC), and Nutri-kits for home kitchen gardens.
Results: Following quarterly follow-ups and matched endline analysis, overall anaemia prevalence dropped significantly from 64.59% to 53.75% ($p<0.001$), representing a 10.84 percentage point reduction, with the largest reduction occurring among adolescent girls. Severe anaemia fell by 63% (from 9.8% to 3.6%), and mean haemoglobin levels rose from 11.0 to 11.6 g/dl. Among baseline severe cases, 24.4% recovered to normal or mild status, though 51.7% of the total cohort remained persistently anaemic. Furthermore, a notable knowledge-practice gap remained, while 96% of participants recognized green leafy vegetables as essential, only 56% had consumed them in the past 24 hours.
Conclusions: The 4T model successfully yielded measurable health gains. However, high residual Anaemia and behavioural gaps underscore the need for extended, region-specific interventions, consistent Iron Folic Acid (IFA) supply chains, and sustained community communication.

Keywords: Anaemia, Behaviour change communication, Dietary diversity, Non-invasive screening, Targeted intervention, Telangana tribal community

INTRODUCTION

Anaemia remains one of the most persistent public health challenges worldwide, affecting over 1.6 billion people and severely affecting rural, low-income communities. The condition develops when red blood cell counts or haemoglobin concentrations drop below normal, impairing systemic oxygen delivery and undermining physical growth, cognitive development, and adult productivity over time.[1] According to the World Health

Organization (WHO), anaemia affects 40% of children aged 6–59 months, 37% of pregnant women, and 30% of women of reproductive age globally.[2] The broader consequences are considerable, leading to chronic fatigue among adults, diminished academic performance in children, and reduced earning capacity in vulnerable households.[3]

India's experience with Anaemia is long-standing and, in many respects, challenging. Nearly fifty years of state-sponsored programming have not shifted the trajectory as expected. Instead, recent trends demonstrate an upward trajectory. The Comprehensive National Nutrition Survey and NFHS-4 established baseline Anaemia rates at approximately 40% among children under five and 53% among women of reproductive age.[4,5] However, NFHS-5 recorded a sharp increase: prevalence among children aged 6-59 months rose from 59% to 67%, and among women aged 15-49 years from 53.1% to 57.1%. Adolescent girls saw an increase from 54.1% to 59.1%, while rates among boys climbed from 29.2 to 31.1 percentage points.[6] This upward trend has persisted despite the launch of the Anaemia Mukt Bharat (AMB) strategy in 2018, which integrated previous initiatives into the National Iron Plus Initiative (NIPI) to deliver life-cycle-based nutritional support across all age groups.[7]

Part of the problem stems from a design reliance on universal distribution of Iron and Folic Acid (IFA) tablets rather than a targeted test-and-treat strategy. Consequently, most anaemic individuals remain undiagnosed and receive inadequate preventive doses. Transitioning to direct point-of-care screening and tailored treatment achieves significantly better outcomes.[8] This logic underpins the AMB guidelines, which mandate a "test and treat" approach across six beneficiary groups, emphasizing pregnant women and adolescents aged 10-19 years.[9]

Telangana exemplifies this public health crisis. NFHS-5 puts state-level anaemia at 70% among children aged 6-59 months, well above the national average of 67.1%, and at 57.6% among women aged 15-49 years.[10] Conditions are even more severe in Bhadradri Kothagudem, the state's largest and predominantly tribal district, where roughly 68.7% of women aged 15-49 years and 69.3% of children aged 6–59 months are anaemic.[11] Poor access to nutrient-rich foods, limited dietary diversity, and deep-rooted socioeconomic disadvantage all contribute to these figures.[12] Tribal communities here effectively carry a double burden: geographic isolation that restricts service delivery, and cultural food practices that often steer everyday diets away from iron-rich options.[13]

Given this context, this study determined if a coordinated, community-based intervention could reduce anaemia burden. Specifically, it evaluated the 4T intervention (Test, Treat, Talk, Track) among tribal communities in Bhadradri Kothagudem. The study pursued three primary objectives. First, it assessed the feasibility and coverage of community-wide anaemia screening using a non-invasive point-of-care device (EzeCheck) among the tribal population of Laxmidevipally Mandal. Second, it evaluated the efficacy of an integrated 4T intervention comprising targeted IFA supplementation, dietary diversification through Nutri-kits, and primary healthcare referrals in reducing anaemia prevalence and improving haemoglobin levels over the intervention period. Third, it documented shifts in community-level knowledge, attitudes, and practices (KAP) regarding anaemia, nutrition, and iron-rich diets, while identifying critical points of divergence between knowledge and practice.

METHODS

Study design and setting

This study used a single-arm, community-based longitudinal design in Laxmidevipally Mandal, Bhadradri Kothagudem District, Telangana, following participants from baseline to endline to capture changes in haemoglobin status. Bhadradri Kothagudem, Telangana's largest and predominantly tribal district, is marked by remote settlements, limited healthcare infrastructure, and high rates of undernutrition. The study was conducted from January 2024 to November 2025, comprising baseline screening from January to August 2024, intervention delivery in the subsequent months, and endline assessment from August to November 2025.

Sample size and sampling technique

The study population comprised all residents across 16 selected villages in Laxmidevipally Mandal. The study targeted approximately 5,000 beneficiaries to ensure a substantial sample size across age groups, account for anticipated attrition over the 15-month follow-up period, and achieve near-complete coverage of the eligible tribal population rather than meeting a statistical minimum alone. While ten villages were selected initially, their combined population fell short of this target; consequently, six socio-demographically similar neighboring villages were added, yielding a final sample of 1,228 households with a total population of 5,291. Sampling was census-based, inviting all eligible residents across the 16 villages to participate instead of drawing a subset. Of the 4,804 individuals screened at baseline, 3,866 were retained at endline with matched records, forming the final longitudinal analytic cohort.

Intervention: The 4T model

The intervention built on the Anaemia Mukt Bharat programme's “Test, Treat, and Talk” (3T) framework, adding a fourth component[14], “Track,” to ensure longitudinal follow-up. Under Test, community-wide screening was conducted using EzeCheck, a non-invasive, IoT-enabled haemoglobin device validated against standard laboratory methods with approximately 93% diagnostic accuracy[15]. Under Treat, anaemic

individuals were referred to village Accredited Social Health Activist (ASHA) and Auxiliary Nurse Midwife (ANM) workers for iron and folic acid (IFA) tablets and counselling. Meanwhile, those with severe anaemia, based on World Health Organization (WHO) cut-offs[16], were referred to the Primary Health Centre (PHC) for confirmation and government-funded injectable iron sucrose therapy.

The Talk component covered Behaviour Change Communication (BCC), delivered through home visits by trained Community Health Workers (CHWs), Nutrition Week activities, handwashing sessions, and menstrual health education for adolescent girls. Additionally, every household received a "Nutri-kit" containing seven seed varieties (cluster bean, spinach, bottle gourd, ridge gourd, fenugreek, amaranthus, and brinjal) and Moringa saplings to support kitchen gardens and dietary diversification. Finally, Track involved quarterly haemoglobin re-testing and CHW home visits to monitor adherence, manage side effects, and reinforce positive behaviours throughout the intervention period (Figure 1).

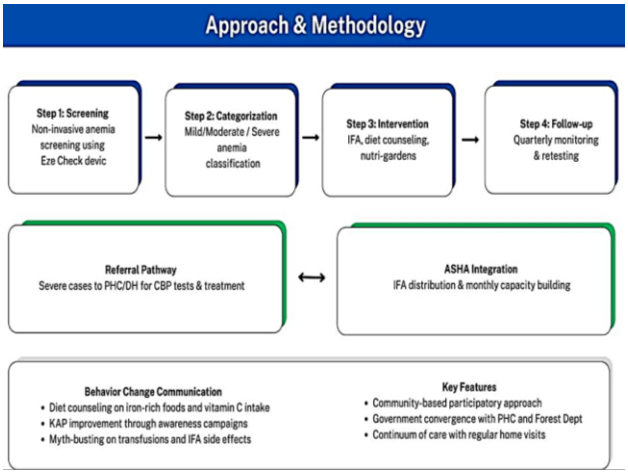

Figure 1: Schematic representation of the 4t methodology adopted in the study.

Data collection tools

Baseline and endline haemoglobin readings were obtained using the EzeCheck non-invasive device and logged through its native software. Prior to screening, written informed consent was secured from all participants, along with guardian consent and minor assent for participants under 18 years. A structured case record form captured sociodemographic details. At endline, trained enumerators administered a Knowledge, Attitudes, and Practices (KAP) questionnaire covering a 24-hour dietary recall, IFA adherence, and awareness of iron-rich foods, enhancers, and inhibitors.

Statistical analysis

Data were cleaned and analysed using IBM SPSS and Microsoft Excel 2019. To preserve the paired structure of the cohort, each participant's baseline and endline records were linked through a unique identifier. Categorical prevalence figures at baseline and endline were compared using the chi-square test, with statistical significance set at $p<0.05$. Changes in mean haemoglobin levels were summarised descriptively using the mean, median, and interquartile range. Additionally, logistic regression was used to estimate odds ratios (ORs) by age group for the likelihood of being non-anaemic at endline relative to baseline. Finally, a transition matrix was constructed to trace individual-level movement across anaemia severity categories from baseline to endline.

RESULTS

Table 1 presents screening coverage against the pre-defined target of 5,000 unique individuals. Baseline screening reached 4,804 individuals, a coverage rate of 96.08%. By endline, 3,866 of them had been rescreened and matched back to their baseline records, resulting in an endline coverage of 77.32% and a fully paired longitudinal cohort of 3,866. Sustaining this level of retention in a remote tribal setting for over 15 months is, on its own, a notable operational achievement.

Table 1: Screening outreach and coverage rates at baseline and endline.

Study phase	Pre-defined target	Unique individuals screened	Coverage rate (%)	Longitudinal matched sub-cohort
Baseline	5,000	4,804	96.08	3,866
Endline	5,000	3,866	77.32	3,866

At baseline, 64.59% of the sample was anaemic, and 35.41% fell within the normal haemoglobin range. By endline, anaemia prevalence had dropped to 53.75%, with the normal range proportion climbing to 46.25%, a 10.84 percentage point swing (Figure 2). This shift also showed up in the underlying haemoglobin distribution: the median moved from 11.0 to 11.7 g/dl, the mean from 11.0 to 11.6 g/dl, and the interquartile range shifted upward from 9.4-12.7 g/dl to 10.0-13.2 g/dl (Figure 3).

Both genders improved, though the gap between them held steady. Anaemia prevalence among females fell from 85.30% to 77.87%, while males saw a sharper drop, from 44.61% to 30.49% (Figure 4). Median haemoglobin rose from 10.2 to 10.6 g/dl among females and from 12.2 to 12.8 g/dl among males (Figure 5), with males retaining the higher absolute concentration consistent with expected physiological differences between the sexes.

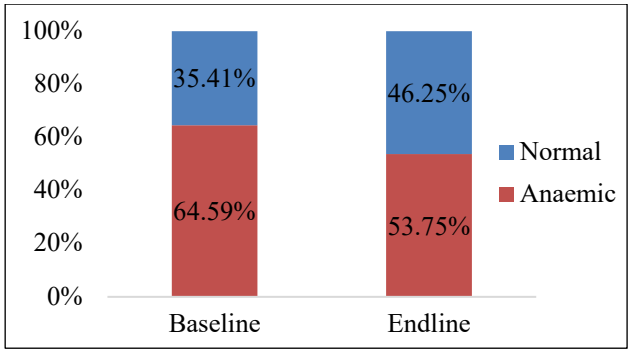

Figure 2: Prevalence of anemia at baseline and endline in study population.

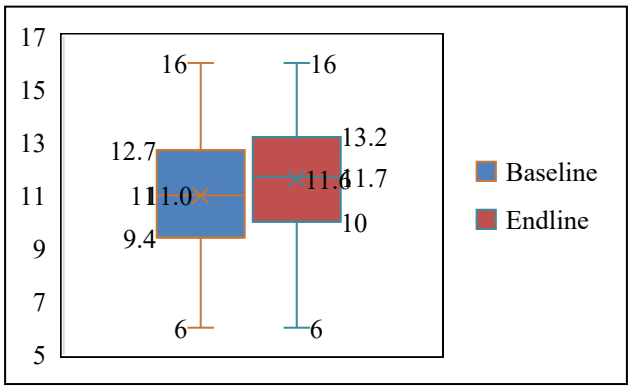

Figure 3: Distribution of hemoglobin (g/dl) levels in the study population at baseline and endline.

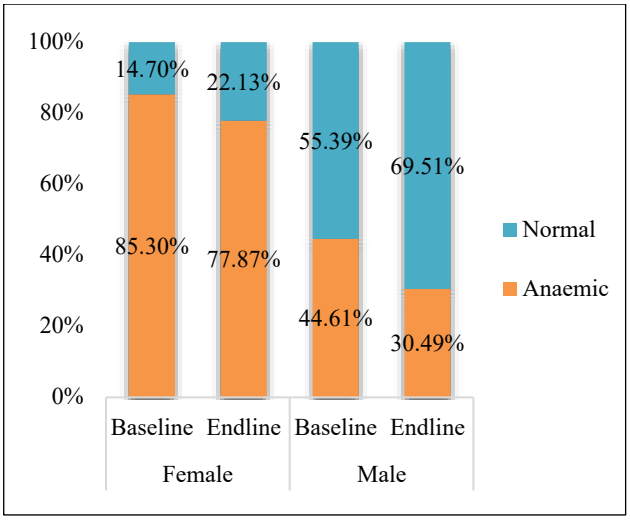

Figure 4: Prevalence of anemia by gender at baseline and endline.

Classifying results by WHO severity cut-offs revealed the intervention's most striking effect (Table 2). The proportion of individuals with haemoglobin below 8 g/dl fell from 9.8% to 3.6%, representing a 63% relative reduction ($p<0.001$). Concurrently, the normal range proportion rose from 35.4% to 46.2% ($p<0.001$), while moderate anaemia declined more modestly, from 39.2% to 36.0% ($p=0.004$). Taken together, the shift in overall severity distribution was highly significant ($x2=172.48$, $p<0.001$).

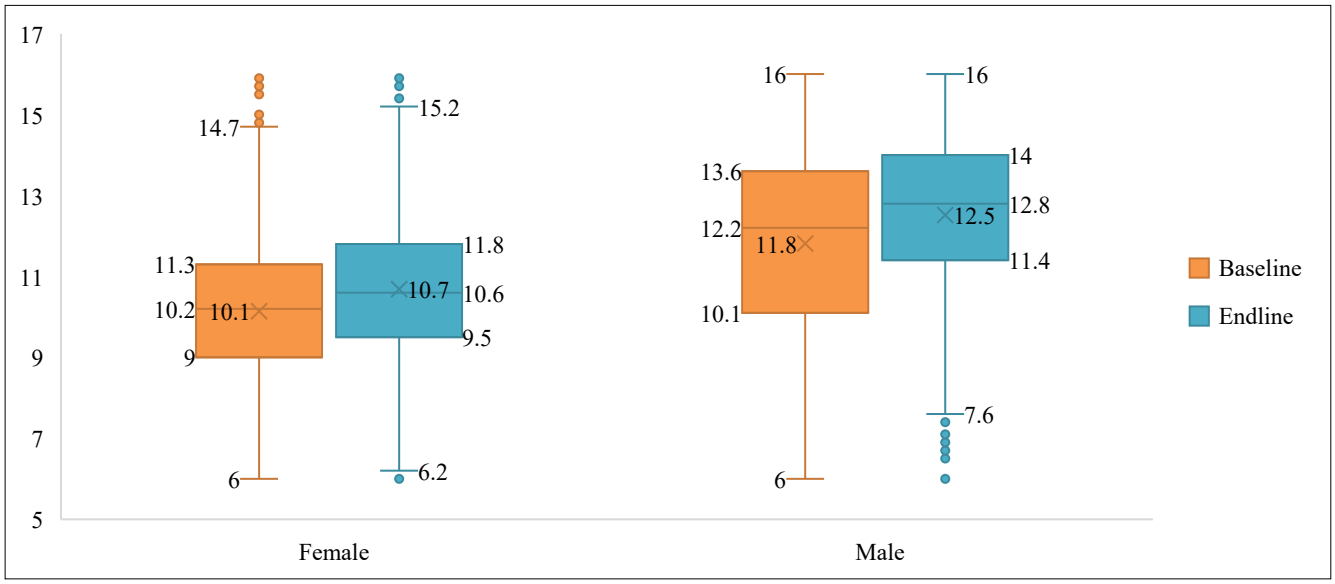

Figure 5: Hemoglobin (g/dl) distribution by gender at baseline and endline.

Baseline prevalence of anaemia varied by age: children aged 6-12 years had the highest prevalence at 85.6%, followed by children under five (80.5%) and seniors over 60 (70.3%). Every age group improved by endline, showing prevalence reductions of 9.1 to 11.3 percentage points and mean haemoglobin gains of 0.6-0.7 g/dl. The 6-12-year-olds responded best (OR=2.04; $p<0.001$), followed by adolescents (OR=1.62), adults aged 20-45 (OR=1.56), and those aged 46-60 (OR}=1.53). Seniors improved directionally as well, but the result fell just short of statistical significance ($p=0.050$), most likely due to a smaller sample size in that group rather than a weaker treatment effect (Table 3).

Three groups emerged as nutritionally vulnerable: children under five, adolescent girls, and pregnant or reproductive-age women, with a baseline prevalence of 80.5-89.1%. Adolescent girls showed the largest improvement (12.95 percentage points), followed by pregnant and reproductive-age women (10.37 points) and children under five (10.20 points) (Table 4).

Table 2: Severity of anaemia among the study population at baseline and endline.

Category	Baseline, N	Baseline, %	Endline, N	Endline, %	P value
Normal (≥12 g/dl)	1,369	35.4	1,788	46.2	< 0.001
Mild (11.0-11.9 g/dl)	605	15.6	546	14.1	0.059 (NS)
Moderate (8.0-10.9 g/dl)	1,515	39.2	1,392	36.0	< 0.004
Severe (<8 g/dl)	377	9.8	140	3.6	< 0.001

Table 3: Prevalence of anaemia by age category at baseline and endline.

Age group in years	Baseline		Endline		Change		Odds Ratio	P value
	Population, %	Avg. Hb	Population, %	Avg. Hb	Population, %	Avg. Hb		
<5	80.50	10.3	70.30	11.0	10.3	0.7	1.75	0.022
6-12	85.60	10.2	74.40	10.8	11.2	0.6	2.04	<0.001
13-19	67.80	11.1	56.50	11.7	11.3	0.6	1.62	<0.001
20-45	57.50	11.3	46.40	12.0	11.0	0.7	1.56	<0.001
46-60	62.50	10.9	52.10	11.6	10.4	0.7	1.53	<0.001
60+	70.30	10.2	61.20	10.8	9.1	0.6	1.5	0.050 (NS)

Table 4: Prevalence of anaemia at baseline and endline among vulnerable groups.

Vulnerable group in years	Baseline, %	Baseline Avg. Hb	Endline, %	Endline Avg. Hb	Change, %	Change in Hb	P value
<5	80.50	10.3	70.30	11.0	-10.20	+0.7	0.022
Adolescent girls (10-19)	87.95	10.5	75.00	11.0	-12.95	+0.5	< 0.001
Pregnant & reproductive-age women (15-49)	89.12	10.2	78.75	10.7	-10.37	+0.5	< 0.001

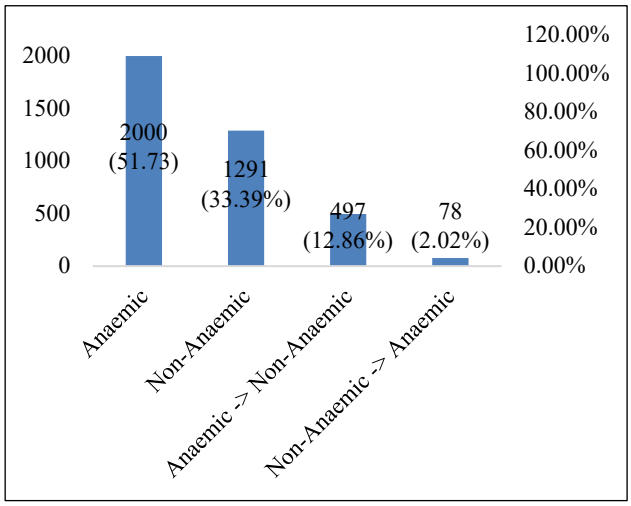

Figure 6: Shift in anaemia status from baseline to endline (n=3,866).

Individual-level transitions reveal a more nuanced picture than the headline prevalence figures. Among the 3,866 paired individuals, 2,000 (51.73%) were anaemic at both time points and 1,291 (33.39%) stayed non-anaemic throughout; 497 (12.86%) moved from anaemic to non-anaemic, against just 78 (2.02%) who moved the other way (Figure 6). Among the 377 individuals severely anaemic at baseline, the transition matrix (Table 5) shows 24.4% recovering to normal or mild status by endline, though 94 (24.9%) remained severe - a subgroup warranting further, targeted clinical attention.

The endline KAP survey revealed a striking gap between knowledge and practice. 96% of respondents correctly named green leafy vegetables as essential iron sources and preferred home-grown produce over store-bought alternatives, yet only 56% had eaten any in the preceding 24 hours. Awareness of factors affecting iron absorption was reasonably strong. 56-70% recognized Vitamin C sources such as lemon, papaya, and guava, and 76% understood that tea and coffee interfere with absorption. Household food security also improved, with 90% of Nutri-kit recipients consuming produce from their own kitchen gardens. On IFA adherence, 68% reported high compliance; among those who defaulted, 28% stopped because they "felt better" and 22% ran out of tablets.

Table 5: Transition matrix of changes in anaemia severity from baseline to endline.

Severity		Endline severity				Total
		Normal	Mild	Moderate	Severe	
Baseline severity	Normal, Number and Percent	1,291	58	20	0	1,369
		94.30	4.24	1.46	0.00	100
	Mild, Number and Percent	178	251	176	0	605
		29.42	41.49	29.09	0.00	100
	Moderate, Number and Percent	255	209	1,005	46	1,515
		16.83	13.80	66.34	3.04	100
	Severe, Number and Percent	64	28	191	94	377
		16.98	7.43	50.66	24.93	100
Total		1,788	546	1,392	140	3,866
		46.25	14.12	36.01	3.62	100

DISCUSSION

The study set out to test whether an integrated 4T intervention -Test, Treat, Talk, and Track- could produce a quantifiable impact in anaemia among tribal communities in Bhadradri Kothagudem, Telangana. Over 15 months, the cohort's anaemia prevalence fell by 10.84 percentage points, and severe anaemia dropped by 63%. These gains were achieved in a setting that has long been difficult to reach. These results highlight the value of bundling non-invasive screening, targeted treatment, Behaviour Change Communication, and active follow-up into a single operational package.

One defining feature of the study's design was its reliance on the EzeCheck non-invasive haemoglobin device, which made rapid, low-cost screening possible at the village level.[15] This offered a real advantage, given that conventional invasive methods are logistically demanding and poorly suited to mass deployment in remote tribal areas.[17] The relatively high retention rate (3,866 of 4,804 individuals matched at endline) likely reflects the ease and acceptability of the non-invasive device, which sidestepped the discomfort and infection risks associated with blood draws.[18] This tracks with earlier validation work showing EzeCheck performing at roughly 93% diagnostic accuracy, with sensitivity and specificity above 95%, thereby supporting its use at scale in community settings.[19]

Both genders showed improvement, but the underlying gender gap persisted. Female anaemia prevalence declined from 85.30% to 77.87%, whereas male prevalence experienced a more pronounced reduction from 44.61% to 30.49%. This trajectory aligns with established empirical evidence indicating that women of reproductive age experience a disproportionately higher anaemia burden due to menstrual blood loss, pregnancy-related iron demands, and compounding socio-cultural disadvantages.[20-21] While the 4T model narrowed this disparity, it did not eliminate it. Consequently, future interventions must integrate additional demand and supply-side components including menstrual health support, access to fortified foods, and gender sensitive counselling anchored within the foundational 4T framework.

Breaking results down by age, children aged 6-12 years emerged as the most responsive group (OR=2.04), followed by adolescents and younger adults. These cohorts align closely with the priority categories of the Anaemia Mukt Bharat strategy, thereby reinforcing the policy relevance of these findings.[22] Although individuals in the senior cohort (60+ years) demonstrated a positive trend, the result did not achieve statistical significance (p=0.050. The limited sample size within this stratum offers a more plausible explanation than a genuine absence of effect.

The transition matrix provides the most direct policy insights from this evaluation. Although the overall prevalence decreased by 10.84 percentage points, an in-depth analysis reveals that 2,000 individuals (51.7%) remained anaemic across both time points, and 78 participants (2.0%) transitioned from non-anaemic to anaemic. Notably, within the severe stratum, 94 individuals persisted in the most critical category despite receiving the full intervention protocol. Collectively, these cohorts delineate the therapeutic limits of a single intervention cycle, underscoring a critical imperative for prolonged, high-intensity follow-up protocols, particularly for individuals exhibiting persistent severe anaemia post-treatment.

The endline KAP survey revealed a critical knowledge-practice gap that explains the observed haemoglobin trends. Participants showed strong foundational knowledge and trusted homegrown garden produce over store-bought alternatives. Awareness of dietary enhancers and inhibitors was also high. Most respondents recognized Vitamin C sources such as lemon, papaya, and guava as absorption boosters, and 75% understood that tea and coffee impede absorption. Household food security improved as well, with 90% of Nutri-kit recipients consuming produce from their own gardens. These findings echo an evaluation of a kitchen-garden

nutrition programme in Pakistan, where participating women showed greater awareness of garden components, improved knowledge of related illnesses (iron deficiency anaemia, pregnancy complications, and fetal health risks), and more positive health-behaviour intentions.[23] However, near-universal awareness of green leafy vegetables rarely translated into daily consumption. Furthermore, IFA adherence was undercut by both behavioural and structural barriers, such as patients stopping once they "felt better" or running out of tablets when supply chains broke down.[24-25] This aligns with the broader literature on IFA programmes in India, where coverage under Anaemia Mukt Bharat has stayed below 50% for most beneficiary groups other than pregnant women.[26] The implication is clear: knowledge alone is insufficient. Future interventions must shift emphasis from "why nutrition matters" toward "how to diversify crops and sustain the habit," while securing buffer IFA stocks with ASHAs so patients are not left without supplies.[27] Counselling also needs to continuously reinforce that achieving a normal haemoglobin level -not just feeling better- is the ultimate goal.

This study has few limitations. The EzeCheck device carries a documented accuracy of around 93%, leaving some room for measurement error, and 938 participants were lost to follow-up through migration or withdrawal. The study was also confined to a single tribal district, which may limit generalizability. The KAP survey, finally, relied on self-reported 24-hour recall, which leaves it open to recall and social-desirability bias. None of this undermines the core finding, though: focused, community-based interventions of this kind can meaningfully reduce anaemia prevalence in tribal populations.

CONCLUSION

Ultimately, the integrated 4T intervention -Test, Treat, Talk, and Track- produced a meaningful reduction in anaemia among tribal communities in Bhadradri Kothagudem, Telangana. The sharpest gains occurred among children aged 6-12 years, alongside a marked decline in severe anaemia. These results validate the life-cycle approach of the Anaemia Mukt Bharat initiative, even as they expose critical behavioural and supply-side gaps, most notably the discrepancy between nutritional knowledge and practice, and the fragility of local IFA supply chains. Moving forward, the priority must shift from generalized rollouts toward data driven, region-specific interventions anchored in robust Behaviour Change Communication and dependable last mile IFA logistics to successfully translate awareness into lasting haematological improvement.

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Ethical approval: Not required

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