

Original Research Article

Diet and WASH practices in the double burden of stunting and thinness among tribal adolescents in Madhya Pradesh, India

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ABSTRACT

Background: Undernutrition is a major public health concern among adolescents, disrupting normal growth and development with long-term health consequences. However, evidence on the nutritional status of tribal adolescents remains limited. This study aimed to assess the prevalence of undernutrition (stunting and thinness) and its associated risk factors among Gond tribal adolescents in Madhya Pradesh, India.

Methods: A community-based cross-sectional study was conducted among 500 Gond tribal adolescents. Data on sociodemographic characteristics, water, sanitation, and hygiene (WASH) practices, and dietary diversity were collected using a structured questionnaire. Height and weight measurements were obtained to assess stunting (height-for-age) and thinness (BMI-for-age) according to WHO standards. Binary and multivariable logistic regression analyses were performed to identify factors associated with undernutrition.

Results: The prevalence of stunting, thinness, and their coexistence was 32.6%, 31.8%, and 13.2%, respectively. In bivariate analyses, age, sex, family type, personal hygiene index, and dietary diversity were significantly associated with undernutrition. After adjustment, females had higher odds of stunting, whereas males had higher odds of thinness. Early adolescents were more likely to experience thinness and the coexistence of stunting and thinness than late adolescents. Poor personal hygiene was independently associated with all three outcomes, while low dietary diversity remained a significant predictor of stunting.

Conclusions: Undernutrition is highly prevalent among Gond tribal adolescents. Poor personal hygiene and low dietary diversity, together with sociodemographic factors, contribute significantly to undernutrition. Community-based interventions focusing on nutrition education, dietary diversification, improved hygiene practices, and regular nutritional screening are essential to improve the nutritional health of tribal adolescents.

Keywords: Dietary diversity, Sanitation and hygiene, Tribal adolescents, Water

INTRODUCTION

Adolescence (10-19 years) is a critical period of rapid physical growth and development accounting for approximately 15-25% of adult height and nearly half of adult skeletal mass.¹ This period represents a second window of opportunity for catch-up growth and the establishment of lifelong health, making adequate nutrition particularly important for preventing adverse health outcomes. These physiological changes

substantially increase nutritional requirements, making adequate nutrition essential for healthy growth and development.²

Nutritional deficiencies and frequent infections can lead to malnutrition, a major public health problem worldwide, especially in Southeast Asia and Sub-Saharan Africa.³ Malnutrition includes both undernutrition and overnutrition; in South Asia, undernutrition among children and adolescents is more prevalent compared to other regions. It can be assessed using indicators such as

stunting and thinness, which are recommended by the World Health Organization (WHO) for anthropometric assessment of nutritional status among adolescents.⁴ The former indicates chronic undernutrition, and the latter indicates acute undernutrition.⁵

Globally, undernutrition remains a major public health concern among adolescents, particularly in low- and middle-income countries, where food insecurity, poverty, and recurrent infections continue to compromise healthy growth and development. According to the NFHS-4, the burden of stunting among adolescent girls and boys was 34.4% and 32.2%, respectively, in India.⁶ Recently, data from the CNNS reported 27.4% stunting and 24.4% thinness in India, with Madhya Pradesh reporting the highest prevalence of thinness.⁷ Adolescent undernutrition adversely affects physical growth, cognitive development, educational attainment, future productivity, and reproductive health and increases the risk of chronic diseases later in life.⁸ However, the Lancet series on adolescent health has also concluded that "failure to invest in the health of the largest generation of adolescents in the world's history jeopardizes earlier investments in maternal and child health, erodes future quality and length of life, and escalates suffering, inequality, and social instability".⁹

Evidence of undernutrition among adolescents acknowledges the multiplicity of factors, including sociodemographic factors (age, sex, socioeconomic status, family size, and education), dietary intake, and water, sanitation, and hygiene (WASH) practices, that affect undernutrition.¹⁰ Although several Indian studies have identified socio-demographic determinants of adolescent undernutrition, evidence simultaneously examining dietary diversity and WASH practices remains limited, particularly in community-based settings.

Most available evidence is derived from school-based surveys, which may exclude out-of-school adolescents and therefore underestimate the burden of undernutrition among socioeconomically disadvantaged tribal populations. Community-based studies are therefore essential to provide more representative estimates and identify context-specific determinants. Poor WASH conditions increase the risk of recurrent enteric infections and environmental enteric dysfunction, reducing nutrient absorption and increasing the risk of growth faltering.¹¹ Similarly, inadequate dietary diversity contributes to deficiencies in essential macro- and micronutrients required for optimal growth during adolescence.¹²

Some studies, such as those by Chattopadhyay et al, among adolescents in Bihar, Chhattisgarh, and Odisha, find a positive association between WASH, diet, and nutritional outcomes. The literature supports the joint implementation of WASH and diet to improve nutritional outcomes, but to do so, India needs more community-based studies. Regarding regional disparity, a higher prevalence of undernutrition is observed in rural and

tribal areas.¹⁴ Tribal adolescents are particularly vulnerable to undernutrition because of persistent socioeconomic disadvantage, food insecurity, limited access to healthcare and education, poor sanitation, and geographical isolation.¹⁵ Despite their increased vulnerability, tribal adolescents remain under-represented in community-based nutrition research, particularly in studies examining the combined influence of dietary diversity and WASH practices on undernutrition.

The Gond tribe is one of India's largest Scheduled Tribes and continues to experience considerable socioeconomic disadvantage, making adolescents from this community particularly vulnerable to poor nutritional outcomes.^{16,17} Addressing this evidence gap is essential for designing culturally appropriate and context-specific nutrition interventions for tribal adolescents. Because stunting reflects chronic nutritional deprivation while thinness reflects acute nutritional deficiency, examining both indicators provides a more comprehensive assessment of adolescent undernutrition. Therefore, this community-based study among Gond tribal adolescents in Madhya Pradesh aimed to estimate the prevalence of stunting and thinness and examine the independent associations of dietary diversity, WASH practices, and sociodemographic characteristics with these nutritional outcomes.

METHODS

Study participants

The present study was a community-based, cross-sectional study. The data was collected from 500 participants selected from 20 villages in Sagar District, Madhya Pradesh, using the convenience sampling method. The sample size was calculated using Krejcie and Morgan's formula¹⁸

$$s = X^2NP(1-P) / [d^2(N-1) + X^2P(1-P)]$$

Where; s=required sample size, X^2 =chi-square for the confidence level at 1 degree of freedom and confidence 95%=3.841, N=population size, P=population proportion (for maximum sample size, assumed to be 0.5), d=the degree of accuracy expressed as a proportion (0.05).

The study was carried out in two phases. The first pilot study was conducted in October 2023, and the second phase was carried out for six months (April to September 2024). The present study was conducted among the Gond adolescents of Sagar District (Madhya Pradesh). The inclusion criteria for participants for the present study were: 1) The participants belonged to the age group of 10-19 years; 2) they should belong to the Gond tribe of Madhya Pradesh; and 3) parents and participants both provided written informed consent. Exclusion criteria were any adolescents who had any physical or psychological problems.

Data collection

In the present study, data on sociodemographic variables, including age, sex, family type, educational attainment, and socioeconomic status, were measured using the Udai Pareek Scale¹⁹, and collected through a household survey.

Water, Sanitation, and Hygiene (WASH)

The questionnaire used to assess WASH practices was adapted from Angeline and Ghugre's study, which measured adolescent hygiene practices.²⁰ Three domains were included to assess WASH practices: drinking water index (DWI), personal hygiene index (PHI), and domestic household hygiene index (DHI). DWI comprises six observations: the source of water, water facilities, water storage vessels, drinking water method, boiling water, and safe drinking water. DHI includes five items: sanitation facility, drainage facility, garbage disposal, stagnant water, and open defecation. The observations forming PHI were washing hands before food, with soap or water, washing hands after defecation (with soap or with water/ash), and wearing footwear in the neighbourhood. This tool consisted of 15 observations. Each observation was scored as 0 or 1; a score of 1 was given to a positive observation. The final category of poor and good WASH was created using the mean score. This scale has a Cronbach's alpha value of 0.76.

Diet diversity: Data about individual diet diversity were collected using the standardised diet diversity questionnaire from the Food and Nutrition Technical Assistance²¹ It was based on the 24-hour recall method. It is composed of 10 food items: 1) grains (white roots and tubers and plantains), 2) pulses, 3) nuts and seeds, 4) dairy, 5) meat, 6) fish and poultry, 7) eggs, 8) dark green leafy vegetables, 9) other vitamin A-rich fruits and vegetables, and 10) other vegetables and fruits. The Total Diet Diversity Score (DDS) was divided into low and high diet diversity categories.

Malnutrition: The definition encompasses both undernutrition and overnutrition. In developing countries, undernutrition is the most prevalent form of malnutrition. The present study used the World Health Organization (WHO) growth reference standards for adolescents aged 10-19 years (22). **Stunting:** Stunting is defined as low height-for-age when the z-score is below -2 standard deviations (SD) from the WHO growth reference, where height was measured to the nearest 0.1 cm using an anthropometer rod with participants standing barefoot in the standard arm-hanging position.²² **Thinness:** Thinness is defined as a low BMI for age when the Z-score is below -2 SD relative to the WHO growth reference (2007), where weight was measured to the nearest 0.1 kg using a calibrated digital weighing scale with participants wearing light clothing and no footwear. BMI was calculated as weight (kg)/height² (m²). The study defines co-existence of thinness and stunting as the presence of both forms of undernutrition. Notably, the WHO has not

defined underweight in adolescents because their bodies undergo rapid physical growth during puberty.

Ethical consideration

The ethical approval for the present study was obtained from the Department of Anthropology, University of Delhi Ethical Committee (Ref. No: Anthro/2022-23/6).

Statistical analysis

The World Health Organization (WHO) Anthro Plus software calculated the height-for-age Z-score and BMI-for-age Z-score. SPSS version 22 (IBM SPSS for Windows) was used for the analysis. The frequency distribution was reported for categorical variables. The chi-square test was used to assess the association between the outcome variables and the predictors. The study outcome variables were binary, so binary logistic regression was used to assess the association between the predictor and the outcome variables. First, separate binary regression models were fitted for each category of the predictor and outcome; later, a multivariable model was fitted to identify individual predictors. The independent variables that were statistically significant at the 5% level in binary regression were retained in the multivariate regression model. The odds ratio was reported with a 95% confidence interval (CI) and was statistically significant ($p < 0.05$) in a two-tailed test.

RESULTS

The sociodemographic characteristics of this study revealed that the sample population comprises almost equal proportions of males and females (50.6% and 49.4%, respectively). The distribution of early and late adolescents (10-14 years) was 55.4% and 44.6%, respectively. By family type, 59.6% of participants belong to nuclear families, and 40.1% to joint families. Almost three-fourths of the participants (73%) were of low socioeconomic status (SES), and one-fourth were of middle socioeconomic status. It was found that 62.6% of participants had poor DWI, 40.6% of participants had poor PHI, and 45.6% of participants had poor DHI. Based on the diet diversity score, 63% of participants had poor diet quality, and 37% had good diet diversity (Table 1).

The practices related to Water, Sanitation, and Hygiene (WASH) are described in Table 2. It was found that almost all participants had improved water sources, but only 18.8% had water facilities on the premises. Most participants (98%) use steel and plastic vessels to store water. It was found that 85.2% of participants used a ladle for the drinking method, three-fourths did not boil their drinking water, and all covered their drinking water. It was reported that 97.8% of participants washed their hands before eating, but only 46.4% did so with soap. After visiting the toilet, 25.2% of participants washed their hands with only water or ash. It was found that three-fourths of the participants had unimproved

sanitation facilities and practised open defecation; 89% of participants had fully open drainage facilities in their households; 79.6% reported daily garbage removal; and

37.2% reported the presence of stagnant water near their households (Table 2).

Table 1: Socio-demographic, Water Sanitation and Hygiene (WASH) and dietary characteristics among the studied population.

Variables	Description	Number (%)
Sociodemographic characteristics		
Sex	Males	253 (50.6)
	Females	247 (49.4)
Age (years)	10-14	277 (55.4)
	15-19	223 (44.6)
Family type	Nuclear	298(59.6)
	Joint	201 (40.1)
Socioeconomic status	Low SES	365 (73)
	Middle SES	130 (26)
	High SES	5 (1)
WaSH practices		
Drinking Water Index (DWI)	Poor	313 (62.6)
	Good	186 (37.2)
Personal Hygiene Index (PHI)	Poor	203 (40.6)
	Good	297 (59.4)
Domestic Household Hygiene Index (DHI)	Poor	228 (45.6)
	Good	272 (54.2)
Diet diversity		
Diet diversity score	Low diversity	315 (63)
	High diversity	185 (37)

Table 2: Water, Sanitation, and Hygiene practices (WASH) among the Gond tribe adolescents of Madhya Pradesh.

Variables		Number (%)
Drinking Water Index (DWI)		
Source of water	Improved	491 (98.2)
	Unimproved	9 (1.8)
Water facilities	Within premises	94 (18.8)
	Outside premises	406 (81.2)
Storage vessels	Steel vessel	3(0.6)
	Plastic vessel	5 (1)
	Both	490 (98)
Drinking methods	Ladle	426 (85.2)
	Tap	72 (14.4)
Boiling water	Yes	139 (27.8)
	No	359 (71.8)
	Sometimes	
Safe drinking water	Cover container	498 (99.6)
	Not covered	2 (0.4)
Personal Hygiene Index (PHI)		
Washing hands before food	Yes	489 (97.8)
	No	9 (1.8)
Washing hands with	Soap	232 (46.4)
	Water	266 (53.2)
After visiting toilet	With water/with ash	126 (25.2)
	With soap	373 (74.6)
Footwear in the neighbourhood	Yes	206 (41.2)
	No	293 (58.6)

Continued.

Variables		Number (%)
Domestic Household Hygiene Index (DHI)		
Sanitation facility	Improved	107 (21.4)
	Unimproved	393 (78.6)
Drainage facility	Fully open	446 (89.2)
	Fully closed	51 (10.2)
	Partially closed	
Garbage disposal	Presence of a garbage bin	102 (20.4)
	Daily removal of garbage	398 (79.6)
Presence of stagnant water	Yes	186 (37.2)
	No	311 (62.2)
Open defecation	Yes	399 (79.8)
	No	98 (19.6)

The associations between socio-demographic variables, WASH practices, and diet and undernutrition (stunting, thinness, and both) were depicted in Table 3. It was revealed that females had a significantly higher prevalence of stunting (36.6%) compared to males (29.2%). In the case of thinness, males had a significantly higher proportion of thinness (38.7% vs. 24.8%). Similarly, both stunting and thinness were more prevalent among females. The prevalence of undernutrition (stunting, thinness, and both) was statistically significantly higher among early adolescents. In family type, participants belonging to the joint family type reported a higher prevalence of stunting (33.5% vs 65.9%), thinness (18.5% vs 51.8%), and both (4% vs 27.4%). The prevalence of

undernutrition was higher among participants belonging to low socioeconomic status, but the difference was not significant. In terms of water, sanitation, and hygiene, the participants with a poor personal hygiene index had a higher proportion of stunting, thinness, and both (stunting and thinness). Participants with a poor domestic household hygiene index (DHI) had a significantly higher proportion of thinness (32.6%). For the Drinking Water Index (DWI), participants with poor DWI were higher in number. Diet, an integral part of better nutrition, was found in the present study to be associated with a higher prevalence of stunting (37.7%), thinness (35.2%), and both stunting and thinness (14.9%) among participants with low diet diversity (Table 3).

Table 3: Association of socio-demographic, WASH practices, and diet with stunting and thinness.

Variables	Description	Stunting, N (%)	P value	Thinness, N (%)	P value	Coexistence of both, N (%)	P value
Sex	Females	90 (36.6)	0.05	61 (24.8)	0.001	34 (13.8)	0.792
	Males	74 (29.2)		98 (38.7)		32 (12.6)	
Age (years)	10-14	103 (37.2)	0.02	117 (23.4)	0.001	51 (18.4)	0.001
	15-19	61 (27.5)		42 (8.2)		15 (6.8)	
Family type	Nuclear family	55 (33.5)	0.001	55 (18.5)	0.001	12 (4.0)	0.001
	Joint family	108 (65.9)		104 (51.8)		54 (27.4)	
Socioeconomic Status (SES)	Low SES	121 (33.2)	0.37	118 (32.3)	0.907	50 (13.7)	0.678
	Middle SES	43 (33.1)		40 (30.8)		16 (12.3)	
	High SES	0 (0)		1 (0.5)		0 (0)	
PHI	Poor	86 (42.6)	0.001	87 (43.1)	0.01	45 (22.3)	0.001
	Good	78 (26.3)		72 (24.2)		21 (7.1)	
DHI	Poor	68 (29.8)	0.21	120 (32.6)	0.05	52 (14.1)	0.369
	Good	96 (35.4)		39 (29.8)		14 (10.7)	
DWI	Poor	97 (19.4)	0.27	90 (28.8)	0.057	34 (10.8)	0.06
	Good	67 (13.4)		69 (37.1)		32 (17.3)	
Open defecation	Yes	132 (33.3)	0.53	126 (31.8)	0.55	54 (13.6)	0.182
	No	31 (31.6)		33 (32.7)		11 (11.2)	
Diet diversity score	Low diversity	117 (37.7)	0.003	111 (35.2)	0.04	47 (14.9)	0.171
	High diversity	47 (24.9)		48 (26.1)		19 (10.3)	

*P value: significance at the level of 0.05

Bivariate logistic regression analysis identified several sociodemographic, dietary, and hygiene-related factors associated with undernutrition (Table 4). Female

adolescents had higher odds of stunting than males (OR=1.39; 95% CI: 0.95-2.03; p=0.05), whereas males had significantly higher odds of thinness (OR=1.92; 95%

CI: 1.30-2.81; $p=0.001$). Early adolescents (10-14 years) were more likely than late adolescents (15-19 years) to be stunted (OR=1.56; 95% CI: 1.06-2.29) and thin (OR=3.13; 95% CI: 2.07-4.73) and to experience the coexistence of stunting and thinness (OR=3.11; 95% CI: 1.69-5.70) ($p<0.05$ for all). Family structure was also significantly associated with nutritional outcomes. Adolescents from joint families had higher odds of stunting (OR = 4.29), thinness (OR=4.74), and coexisting stunting and thinness (OR=9.00) than those from nuclear families. Poor personal hygiene was another significant predictor, with adolescents reporting poor personal hygiene having approximately twofold higher odds of

stunting (OR=2.08; 95% CI: 1.42-3.04) and thinness (OR=2.36; 95% CI: 1.60-3.47) and nearly fourfold higher odds of coexisting stunting and thinness (OR=3.76; 95% CI: 2.16-6.55). Low dietary diversity was significantly associated with increased odds of stunting (OR=1.72; 95% CI: 1.15-2.57) and thinness (OR=1.54; 95% CI: 1.03-2.30), although its association with the coexistence of stunting and thinness did not reach statistical significance. Socioeconomic status, the Domestic Household Hygiene Index (DHI), and the Drinking Water Index (DWI) were not significantly associated with undernutrition.

Table 4: Bivariate logistic regression results from unadjusted odds ratios for stunting and thinness among adolescents.

Variables	Description	Stunting			Thinness			Stunting and thinness		
		UOR	P value	95% CI	UOR	P value	95% CI	UOR	P value	95% CI
Sex	Male®									
	Female#	1.396	0.05	0.95-2.03	1.918	0.001	1.30-2.81	1.108	0.69	0.66-1.86
Age in years	10-14									
	15-19®	1.562	0.02	1.06-2.29	3.134	0.001	2.07-4.73	3.114	0.001	1.69-5.70
Family Type	Nuclear®									
	Joint	4.296	0.01	0.43-5.51	4.744	0.001	3.16-7.11	9.00	0.001	4.66-17.36
SES	Low SES									
	Middle SES®	1.04	0.82	0.68-1.60	1.08	0.71	0.70-1.66	1.171	0.608	0.64-2.13
PHI	Good®									
	Poor	2.08	0.001	1.42-3.04	2.36	0.001	1.60-3.47	3.76	0.001	2.16-6.55
DHI	Good®									
	Poor	0.913	0.67	0.59-1.39	0.906	0.60	0.62-1.32	0.922	0.759	0.547-1.55
DWI	Good®									
	Poor	0.798	0.24	0.54-1.17	0.684	0.06	0.466-1.006	0.546	0.054	0.345-0.978
Diet diversity	High diversity®									
	Low diversity	1.722	0.05	1.15-2.57	1.54	0.03	1.03-2.30	1.523	0.146	0.86-2.68

*P value: significance at the level of 0.05; #Reference category for thinness

Table 5: Logistic regression results (adjusted odds ratio) for stunting, thinness, and co-existence of both among adolescents of Madhya Pradesh.

Variables	Description	Stunting			Thinness			Stunting and thinness		
		AOR	P value	95% CI	AOR	P value	95% CI	AOR	P value	95% CI
Sex	Male®									
	Female#	1.756	0.01	1.13-2.71	1.93	0.003	1.26-2.97	1.108	0.69	0.66-1.86
Age in years	10-14									
	15-19®	1.32	0.205	0.85-2.04	3.03	0.001	1.93-4.76	2.45	0.01	1.28-4.68
Family type	Nuclear®									
	Joint	2.15	0.516	0.21-21.61	4.66	0.001	3.03-7.17	8.08	0.001	4.13-15.81
SES	Low SES									
	Middle SES®	1.04	0.82	0.68-1.60	1.08	0.71	0.70-1.66	1.171	0.608	0.64-2.13
PHI	Good®									
	Poor	1.90	0.005	1.23-2.94	1.90	0.003	1.24-1.93	2.99	0.001	1.65-5.43
DHI	Good®									
	Poor	0.765	0.23	0.49-1.17	0.999	0.996	0.65-1.52	0.950	0.86	0.54-1.67
DWI	Good®									
	Poor	0.803	0.32	0.51-1.24	0.646	0.42	0.42-0.99	0.542	0.23	0.345-0.978
Diet diversity	High Diversity®									
	Low Diversity	1.86	0.02	1.07-2.64	1.443	0.106	0.92-2.25	1.312	0.384	0.71-2.41

*P value: significance at the level of 0.05; #Reference category for thinness

After adjusting for sociodemographic variables, female adolescents remained significantly more likely to be stunted than males (AOR=1.76; 95% CI: 1.13-2.71; $p=0.01$), whereas males continued to have significantly higher odds of thinness (AOR=1.93; 95% CI: 1.26-2.97; $p=0.003$). Early adolescence remained independently associated with thinness (AOR=3.03; 95% CI: 1.93-4.76) and the coexistence of stunting and thinness (AOR=2.45; 95% CI: 1.28-4.68), although its association with stunting was no longer statistically significant. Family type remained an important determinant of nutritional status. Adolescents from joint families had significantly higher odds of thinness (AOR=4.66; 95% CI: 3.03-7.17) and coexisting stunting and thinness (AOR=8.08; 95% CI: 4.13-15.81), whereas the association with stunting was not statistically significant after adjustment. Among the WASH indicators, poor personal hygiene remained independently associated with all three nutritional outcomes. Adolescents with poor personal hygiene had higher odds of stunting (AOR=1.90; 95% CI: 1.23-2.94), thinness (AOR=1.90; $p=0.003$), and the coexistence of stunting and thinness (AOR=2.99; 95% CI: 1.65-5.43). Neither the Drinking Water Index nor the Domestic Household Hygiene Index showed significant independent associations with undernutrition after adjustment. Low dietary diversity remained an independent predictor of stunting (AOR=1.86; 95% CI: 1.07-2.64; $p=0.02$). However, its associations with thinness and the coexistence of stunting and thinness were attenuated after adjustment and were no longer statistically significant (Table 5).

DISCUSSION

This community-based study among Gond tribal adolescents demonstrated a high burden of stunting, thinness, and their coexistence. Low dietary diversity and poor personal hygiene emerged as the most consistent modifiable determinants, while age, sex, and family type were important sociodemographic predictors.

The overall prevalence of stunting was 32.6%; the prevalence of stunting among Gond adolescents is consistent with NFHS-4 (9, 10) and a study by Bhargava et al. The prevalence of thinness in the present study was reported to be 31.8%, in line with the prevalence of thinness among adolescents in Madhya Pradesh as per the CNNS report (2019), but still much higher compared to the national prevalence of thinness, i.e., 24.1%.^{23,24} Regarding the coexistence of stunting and thinness, it was reported at 13.2%. The higher prevalence of undernutrition reported in the present population may be due to the fact that tribal communities are mostly neglected and discriminated against because of their socioeconomic status; they have a high dependence on agriculture and an uncertain food supply.¹⁵ A substantial burden of undernutrition may adversely affect adulthood in terms of mental development, educational attainment, and long-term health outcomes.²⁵

We found that females had a significantly higher prevalence of stunting (36.6%) and had a 1.39 times higher risk for stunting. The present study's findings are similar to those of several other studies conducted in national and regional settings.^{7,26,14,5} The higher prevalence of stunting among females may be due to females growing more slowly after age 14, thereby bearing a greater burden of stunting.⁷ Whereas the prevalence of thinness was higher among males as compared to females (38.7% vs. 24.8%), the previously available literature also shows that the prevalence was higher among adolescent males compared to females, such as in a study conducted among adolescents in Uttar Pradesh and Bihar and a study among rural adolescents of Darjeeling, West Bengal.^{5,27} The higher prevalence of thinness among adolescent males might be attributed to the rapid increase in males' height relative to females.⁷

These results suggest a large burden of undernutrition among the Gond adolescents. The stunting and thinness among adolescents reflect the rearing of adolescents with infection, inadequate nutrition, and accumulation of environmental stress from birth to early adulthood.²⁸ This higher prevalence among Gond adolescents calls for continuous monitoring of state performance in compliance with government initiatives such as POSHAN Abhiyaan (2018), State Nutrition Policy (2020-2030), Ladli Laxmi Yojana (2007), and Bal-Sabhas (NHM). All these policies and schemes were launched to improve the nutritional status of girls, reduce the risk of undernutrition, and enhance their health and educational outcomes. However, most schemes focus on maternal and child health and adolescent girls, whereas adolescent boys are left out. Therefore, it also calls for action to address the needs of adolescent boys and tribal adolescents.

There are multiple factors associated with undernutrition. In terms of socio-demographic variables, stunting and thinness were higher among early adolescents (10-14 years) than among late adolescents (15-19 years). There was a significant increase in the odds of stunting by 1.56 times, the risk of thinness increased by 3.13 times, and the coexistence of both increased by 3.11 times among early adolescents. One possible reason for undernutrition among early adolescents is that thinness encompasses both height and weight, and early adolescents experience a greater growth spurt than late adolescents. Other reasons could include a higher deficiency in calorie intake among early adolescents.^{29,30}

Adolescents' stunting and thinness were significantly associated with various socio-demographic factors, such as family type, WASH, and diet. In the present study, the family type was significantly associated with stunting and thinness. A higher prevalence of stunting and thinness was reported in joint families; the odds of stunting, thinness, and their coexistence increased significantly among participants from joint families. A similar trend was reported in studies conducted in the Gudeya Bila

district (Ethiopia) and Telangana (South India).^{31,32} This might be because joint families have large family sizes, and adolescents might not be able to get enough diet and dietary care. Also, overcrowding could lead to the spread of infectious diseases that can immediately cause undernutrition.^{31,32}

Another crucial factor in determining undernutrition is Water, Sanitation, and Hygiene (WASH). The association between WASH and malnutrition has been examined previously; however, the results have been mixed, and this relationship has not been widely studied among tribal adolescents, limiting validation of the present study's findings.³³ The present study documented WASH practices and examined their association with undernutrition. It was found that the Drinking Water Index (DWI) has been improved in rural settings among the tribal population. Most importantly, 98.2% of households have improved water, and 99.6% have access to drinking water, but only 81.2% have water facilities outside the premises. Our findings corroborate with a study conducted among adolescent girls in poverty pockets of eastern India and the NFHS-4 survey (2015-2016).¹³ However, providing a water supply within household premises could indirectly improve adolescents' nutritional status.³⁴

The present study's findings on sanitation practices contradicted the aim of implemented government policies, specifically the Swachh Bharat (Clean India) Mission. As per the reports, Madhya Pradesh has been declared Open Defecation-Free (ODF) by the GOI, but in the present study, it was found that 78.6% of households have unimproved sanitation facilities, 79.8% of participants practise Open Defecation (OD), and 89.2% have fully open drainage facilities or no drainage facilities.³⁵ The prevalence of open defecation was higher than in the previously published study among rural households in Bhopal, Madhya Pradesh.³⁶ However, possible reasons for OD include a lack of water on the premises, incompletely constructed toilets, poor accessibility, and their habits.³⁷ Therefore, the government should focus on addressing the root cause of water scarcity, completing toilet construction, raising awareness of the harmful effects of OD on health, and involving local representatives and health workers. Further, that will help improve personal hygiene practices crucial to reducing the risk of infectious disease and decreasing the public health burden.

Hygiene is another important component of WASH; the present study found that 40.6% of participants had poor personal hygiene. Similar to our study, a study conducted in the slums of Pune and among adolescent girls in Lucknow reported poor personal hygiene, which accounted for 80% of the listed morbidities.^{20,38} The present study found that poor WASH practices were associated with a higher prevalence of stunting, thinness, and their coexistence. However, a significant association was found between the Personal Hygiene Index and

undernutrition: participants. A similar trend was reported in studies by Kumar et al, 2023 and Chattopadhyay et al (2021) among adolescents in Uttar Pradesh and Bihar and in a study of slum areas in Nagpur, Maharashtra.²⁶ The odds of stunting and thinness increase with poor personal hygiene, such as not washing hands with soap after defecation and before eating; these findings are consistent with various other studies conducted in rural settings.^{5,13,26} Delving into various studies, it was found that personal unhygienic conditions expose adolescents to the risk of infections that can adversely affect gut health, even in the absence of diarrhoea; these infections can negatively impact adolescents' nutrition and growth.²⁶

Finally, the present study found that low dietary diversity was associated with a higher prevalence of undernutrition, and after adjustment for sociodemographic factors, it remained an independent predictor of stunting. These findings are consistent with previous studies reporting that inadequate dietary diversity increases the risk of undernutrition among adolescents.^{39,40} A lack of dietary diversity may result in insufficient intake of essential macro- and micronutrients required for optimal linear growth and development. In many tribal communities, diets are predominantly cereal-based, with limited access to nutrient-rich foods such as fruits, vegetables, dairy products, and animal-source foods because of poverty, food insecurity, and poor affordability.^{41,42}

This study has few public health implications. Specifically, this study examines the nutritional status of tribal community adolescents, whereas most studies have been conducted among school adolescents. Moreover, the cutoffs used for the high prevalence of thinness (>20%) and stunting (>30%).⁴³ The present study reports a high prevalence of thinness and stunting. As per Tanner's phrase, "Growth is a mirror of the condition of society".⁴⁴ This high prevalence of undernutrition reflects deprivation and poverty in the community. Therefore, the intervention shall target reducing thinness and stunting and addressing their coexistence while also considering dietary and hygiene factors.

This study has few limitations. Firstly, the cross-sectional study design limits the possibility of a cause-and-effect relationship. Secondly, convenience sampling may have introduced selection bias and limits the generalizability of the findings. Thirdly, DDS indicated the diversity of food items, but the quantity was not captured; it relied on a recall method, which increased the bias in the record. Diet is also affected by season; it can affect diversity. Despite some limitations, the study has a few strengths, such as adding to knowledge about tribal undernutrition and its predictors, which are limited in the literature. Factors such as WASH and diet are important predictors, but they are mostly not included as risk factors in the literature. This study examined the co-existence of stunting and thinness among adolescents.

CONCLUSION

This community-based study demonstrates a substantial burden of undernutrition among Gond tribal adolescents in Madhya Pradesh, with stunting, thinness, and their coexistence affecting a considerable proportion of the study population. The findings highlight that adolescent undernutrition in this underserved tribal community is shaped by interconnected sociodemographic, dietary, and hygiene-related factors. In particular, poor personal hygiene was independently associated with stunting, thinness, and their coexistence, while low dietary diversity remained an independent predictor of stunting. Early adolescence and family structure were also important determinants of selected nutritional outcomes. By examining dietary diversity and WASH practices alongside sociodemographic characteristics in a community-based tribal population, this study extends existing evidence that has predominantly focused on school-based adolescent populations. The findings underscore the need for culturally appropriate, community-based strategies that integrate nutrition education, dietary diversification, improved hygiene and sanitation practices, and regular nutritional screening. Such an integrated approach may help address the multiple and overlapping determinants of adolescent undernutrition and contribute to improving the long-term health and developmental outcomes of tribal adolescents in Madhya Pradesh.

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