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Food Consumption Pattern and Nutritional Status of Tribal Adolescents (Aged 10-18 Years) in Palghar District of Maharashtra

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Abstract: ***Background: Adolescence is a critical phase of growth and development, and nutritional inadequacies during this period can have long-term health implications. Tribal populations remain particularly vulnerable due to socio-economic and environmental disparities. This study aimed to assess the nutritional status, dietary intake, food consumption patterns, and hemoglobin levels of tribal adolescents in Palghar district, Maharashtra.***
Methods: A cross-sectional descriptive study was conducted among 197 tribal adolescents aged 10–18 years, using random sampling. Data collection included socio-demographic profiling, anthropometric measurements (height, weight, BMI), BMI-for-age Z-scores, and Height-for- Age Z-scores (HAZ), Total body fat %. A 24-hour dietary recall and food frequency questionnaire were used to evaluate dietary intake and food consumption. Hemoglobin levels were measured in a subsample. Statistical analysis involved ANOVA and Chi-square tests to assess age and gender differences.
Results: Undernutrition was widespread, with a high prevalence of thinness and stunting, particularly among girls and those aged 13–15 years. Energy and micronutrient intake (iron, calcium, zinc, and vitamin B12) fell significantly below recommended levels, despite adequate protein intake. Cold, cough, and fatigue were common health complaints across all age groups.Anemia was more prevalent among girls. Meal-skipping, frequent consumption of processed foods, and poor awareness of unhealthy food choices were also noted.
Conclusion: Tribal adolescents in Palghar face significant nutritional deficits, driven by chronic undernutrition, inadequate dietary practices, and limited nutrition literacy. Girls and mid- adolescents are especially at risk. There is an urgent need for culturally appropriate, school- and community-based interventions to improve nutritional intake, raise awareness, and reduce anemia and related morbidities.
Keywords: Tribal adolescents, nutritional status, dietary intake, hemoglobin, anemia, food consumption patterns, nutrition knowledge.

I. INTRODUCTION

Scheduled Tribes (STs) in India form a culturally rich and demographically varied section of the population. As per the 2011 Census, they make up about 8.6% of the total population, amounting to more than 104 million individuals. The Scheduled Tribes category includes 705 officially listed tribes, each with its own unique customs, languages, and cultural practices.The population share of Scheduled Tribes (STs) differs significantly across regions—for example, over 85% in states like Mizoram and Nagaland, but under 2% in states such as Bihar. Since the 2021 Census has been postponed, data from 2011 remains the latest official source for nationwide statistics on Scheduled Tribes. These communities are typically concentrated in geographically remote and ecologically sensitive regions such as forests, hilly terrains, and plateaus, which significantly shape their lifestyle, food systems, and access to basic services. Due to their relative isolation from mainstream society, tribal populations have preserved unique cultural traditions, languages, belief systems, and food habits that set them apart from other demographic groups (Basu et al., 2010). The dietary intake among tribal populations is largely determined by the availability of local agricultural outputs and forest-based produce. As a result, their consumption patterns are highly seasonal and subject to ecological variations, including rainfall patterns, soil fertility, and forest resource availability (Biswa et al., 2022). Wild edible plants, roots, tubers, seasonal fruits, and traditional grains such as millets and sorghum often form the backbone of their traditional diets. However, this reliance on nature also makes them particularly vulnerable to environmental stressors such as deforestation, climate change, and biodiversity loss, all of which threaten food security and dietary adequacy (Rao et al., 2006).

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Moreover, the rapid pace of modernization and the penetration of market-based food systems have contributed to the erosion of traditional food practices. As younger generations are increasingly exposed to processed and convenience foods through migration, schooling, or media, there is a noticeable decline in the transmission of indigenous food knowledge. This cultural shift not only impacts dietary quality but also weakens the community's food sovereignty and resilience (Kshatriya & Acharya, 2016). Understanding the intricate link between tribal culture, ecology, and nutrition is crucial for planning interventions that are both effective and respectful of their way of life. Culturally appropriate nutrition strategies that reinforce traditional food systems while addressing modern health challenges are necessary to improve nutritional outcomes in these communities. Adolescence is a transitional phase between childhood and adulthood, marked by rapid physical, psychological and social development. The World HealthOrganization(WHO) defines an adolescent as any person between 10 and 19 years age group, (WHO, 2020) (ICMR, 2020). It is a unique stage of human development and an important time for laying the foundations of good health. Proper nutrition is fundamental to human survival, development, and overall well-being. It is not only essential for sustaining life but also for enhancing its quality by supporting physical growth, cognitive development, immune function, and long-term health outcomes (Norgan, 2002). The human body requires a balanced and adequate intake of nutrients for proper physiological functioning. Any significant deviation—whether in the quantity or quality of nutrients consumed can adversely impact growth trajectories, cognitive capabilities, and longevity. This is particularly critical during certain life stages where nutritional demands are elevated, such as adolescence. Adolescents experience rapid physical, cognitive and psychosocial growth. This affects how they feel, think, make decisions, and interact with the world around them. Although adolescence is often regarded as a healthy stage of life, it is marked by substantial morbidity, mortality and risk of injury. During this phase, adolescents establish patterns of behaviour – for instance, related to diet, physical activity, substance use, and sexual activity – that can protect their health and the health of others around them, or put their health at risk now and in the future. The period of adolescence is significant in view of rapid growth and maturation, during which the nutrient requirements are relatively high. Moreover, adolescence is a window of opportunity for health promotion and the prevention of long-term lifestyle-related disorders such as obesity, diabetes, and cardiovascular diseases. Establishing healthy eating behaviors, adequate physical activity, and positive mental health practices during this formative phase can lay the groundwork for a healthy adulthood. However, the onset of adolescence also introduces challenges such as increased autonomy over food choices, peer pressure, exposure to unhealthy food environments, body image concerns, and risky behaviors like substance abuse all of which may compromise nutritional health (Story et al., 2002). Tribal adolescents both girls and boys, face a range of challenges, including nutritional deficiencies, physical strain from labour and psychological stress. Boys frequently face the demands of work and migration while girls face additional pressures from early marriage, household duties, gender-based disparities and sanitation issues; these challenges are compounded by socio-economic constraints, limited access to nutritious food, inadequate health services, and cultural norms that may restrict dietary diversity. The lack of effective government policies reaching these communities and the difficulties associated with migration for education further exacerbate these issues. These combined factors contribute to physical health problems, emotional distress and increased vulnerability to malnutrition and mental health concerns. Therefore, targeted interventions that consider the biological, social, and environmental context of adolescence are essential to address both immediate and future nutritional needs. (Mihalyi, et al., 2024). Nutritional needs and nutritional status of adolescents is a crucial determinant of health, particularly during adolescence, a period marked by rapid growth and development. This stage is critical for setting the foundation for lifelong health and well-being. Nutritional requirements of healthy individuals depend on various factors, such as age, sex, and activity. Hence, recommended values of dietary intakes vary for each group of individuals. (Elia M, et al., 2017). In India , the Indian Council of Medical Research (ICMR) provides national guidelines for nutrition through the Recommended Dietary Allowances (RDA) , which outline the nutritional needs of various population groups across different stages of life. These guidelines serve as a reference for addressing the nutritional requirements and improving the health status of the Indian population. An imbalance in nutritional intake leads to malnutrition, which may present as either undernutrition or overnutrition, both of which are associated with substantial health risks. The word 'malnutrition' is defined in multiple ways, leading to lack of consensus on a single, universally accepted definition. As per WHO guidelines, malnutrition encompasses three categories, namely, Undernutrition (low weight-for-height, low height-for-age, and low weight-for-age),Micronutrient (vitamins and minerals) deficiency or excess, and Overnutrition (overweight, obesity, and other diet-related health conditions(Mueller C, et al.,2011). In India, tribal adolescents, including those from Palghar District of Maharashtra, face unique challenges that can impact their nutritional status. These challenges stem from socio-economic factors, cultural practices, and inadequate availability of healthcare and nutritional resources. Regular assessment helps in identifying specific nutritional deficiencies and implementing targeted interventions to address them.

Nutritional vulnerability during adolescents - Adolescence represents a nutritionally vulnerable phase, as it is characterized by accelerated physical growth, hormonal changes, and increased cognitive and psychosocial development. This period is marked by heightened physiological demands, including increased requirements for energy, proteins, and essential micronutrients to facilitate the growth of skeletal structures, lean muscle mass, and reproductive systems (Patton et al., 2016). If these elevated nutritional needs are unmet, it may lead to adverse outcomes such as stunted growth, delayed puberty, iron-deficiency anemia, and weakened immune function, all of which can negatively impact academic achievement and long-term productivity (Sawaya et al., 2014). In India, the age- and sex specific nutritional benchmarks established by the ICMR-National Institute of Nutrition (2020) serve as critical guidelines for public health and dietary policy frameworks.Inregions like the Palghar District of Maharashtra, tribal groups encounter a range of nutritional challenges. Factors such as remoteness, seasonal agricultural dependency, economic limitations, and poor access to health services and food diversity hinder adequate nutrient intake (NNMB, 2009). Traditional customs and socio-cultural norms also influence eating behaviors. In many instances, food taboos or inequitable food distribution within households can result in insufficient nutrient consumption, particularly among adolescent girls (Kumar et al., 2015). Anemia is a widespread nutritional concern during adolescence, a life stage characterized by accelerated growth and increased iron requirements (WHO, 2021). It occurs when there is a drop in the number of red blood cells or hemoglobin levels in the blood, which reduces the body's capacity to transport oxygen effectively and can lead to symptoms such as tiredness, poor concentration, and reduced physical performance (UNICEF, 2019).As adolescents go through puberty, both sexes face a heightened demand for iron boys due to muscle growth and girls primarily because of menstrual blood loss (Patel et al., 2022). When their diets fail to meet these elevated nutritional needs, the risk of developing iron-deficiency anemia increases. This issue is particularly relevant in tribal populations, where dietary diversity is often lacking and consumption of iron-rich foods remains limited (Khan et al., 2021).Traditional eating habits in these communities frequently rely on staple grains and cereals that are low in bioavailable iron and high in substances like phytates, which can inhibit iron absorption (Gupta et al., 2022). Additional factors such as poor hygiene, parasitic infections, and food-related cultural beliefs can further reduce the body's ability to absorb or retain iron (Muthayya et al., 2013).To address this issue, national programs like Anemia Mukt Bharat (AMB) and the National Iron Plus Initiative (NIPI) aim to prevent and control anemia through iron-folic acid supplementation, deworming campaigns, and awareness generation (Ministry of Health and Family Welfare, 2020). However, challenges such as limited health infrastructure, shortage of trained personnel, and difficult terrain in tribal regions often restrict the effectiveness of these efforts (Singh et al., 2020). In recent years, changing lifestyles, increased exposure to market-based foods, and the influence of media and peer groups have gradually begun to reshape the dietary habits of adolescents, even within rural and tribal settings.This shift marks a gradual departure from traditional food systems that historically emphasized home-grown and foraged foods. Traditional food habits, once centered around home-cooked meals and seasonal, locally available ingredients, are increasingly being replaced by more modern, market-influenced consumption patterns.The role of media exposure, peer influence, and changing family structures cannot be overlooked in this dietary transition. Adolescents today are more frequently exposed to food marketing through television, mobile devices, and advertisements, which shape their perception of what constitutes desirable or modern food.In some tribal areas where local markets are expanding, accessibility to packaged and processed foods has increased, sometimes at the expense of traditional food knowledge and practices (Khan et al., 2023).Food choices among adolescents are also influenced by social norms, school environments, and household food security. Cultural practices including food taboos and gender-based food distribution play a significant role in shaping what and how much adolescents eat, particularly for girls in tribal households.Factors such as school attendance, participation in mid-day meal programs, and family meal patterns contribute to daily dietary intake. Adolescents may skip meals due to time constraints, academic pressures, or lack of food variety at home or school, leading to irregular eating patterns (Patel et al., 2022). Need of the study: Tribal adolescents have higher nutrient requirements, but high rates of both stunting and overweight are observed. This highlights the need to study their nutritional status and factors affecting their health. Studies indicate that tribal adolescents often experience inadequate dietary intake due to issues like food scarcity, limited access to nutritious options, poor dietary choices, unhealthy eating patterns, insufficient consumption, low economic capacity, and poor decision-making in food selection—all of which negatively impact their health and nutritional outcomes. Evaluating the nutritional status of adolescents in tribal communities is crucial to identify health risks, such as frequent illnesses, and to contribute to the scientific understanding of the nutritional challenges faced by tribal populations.It is important to identify both direct and indirect factors that influence nutritional deficiencies, including nutritional status, food habits, food consumption patterns, intake of outside and unhealthy foods. Studies indicate that adolescents are at a higher risk of iron deficiency anemia due to unbalanced diets. Some findings reveal that poor eating habits, such as consuming low quality diets, unhealthy foods high in empty calories, contribute to iron and micronutrient deficiencies, in underweight and normal-weight individuals.

This highlights the need of studying and assessing hemoglobin levels in tribal adolescents. Aim of the study was to assess Food Consumption Pattern & Nutritional Status of Tribal Adolescents in Palghar District of Maharashtra. The objective of the study was to study the food habits and food consumption of tribal adolescents from Palghar district. To assess the nutritional status of tribal adolescents residing in Palghar district .To estimate the hemoglobin levels of tribal adolescents from Palghar district

II. METHODOLOGY

This study aims to assess their food consumption patterns, nutritional status, and hemoglobin levels to identify potential health risks and contribute to a deeper understanding of the nutritional issues faced by tribal communities. Ethical clearance for the study was obtained from the Inter System Biomedical Ethics Committee, Mumbai. The study was initiated only after the ethics approval was granted, and all procedures were conducted with the ethical standards of human research. Participants were assured that the procedures are safe, and all personal information will remain confidential. Participants were briefed on the study's objectives and provided their informed consent prior to data collection. The study's goals and procedures were explained in their local language, and participants were informed that their participation was voluntary and that all information would be kept confidential. Study Design-This study employed a cross-sectional research design aimed at assessing the food consumption patterns, nutritional status, and hemoglobin levels of tribal adolescents residing in Palghar district, Maharashtra. The primary objective was to understand the dietary habits, nutritional well-being, and anemia risk within this vulnerable population group. Data collection was conducted during the period from January, 2025 to January, 2026. The study was conducted in selected tribal-dominated areas within Palghar district, Maharashtra. This location was selected based on official administrative divisions and demographic characteristics indicating a high tribal population.The researchers initially approached 200 tribal adolescents from various regions of Palghar district, Maharashtra, all aged between 10 and 19 years. The adolescents were identified as members of Scheduled Tribes, as recognized by the Government of India, and primarily belonged to families from lower socio-economic backgrounds. Out of the 200 adolescents approached, 197 adolescents participated in the study; the remaining were excluded as they did not meet the predefined inclusion criteria. Of the 197 participants, 92 were male and 105 were female. A random sampling method was employed to select villages, schools, and individual participants based on predefined inclusion criteria. The selection focused on areas with a high concentration of tribal populations and adolescents from low socio-economic backgrounds. This non-probability approach was appropriate for targeting a specific population relevant to the study objectives (Acharya et al., 2013). Inclusion Criteria- Tribal adolescents aged 10-19 years, both male & female adolescents. Tribal adolescents residing in the tribal areas of Palghar district , Maharashtra as defined by local administrative boundaries. Tribal adolescents from recognized Scheduled Tribes communities as per the Government of India's classification. Tribal adolescents from low socio-economic background as per Kuppuswamy scale. Tribal adolescents who are willing to participate in the study and provide informed assent (with parental consent for minors) and not suffering from any diseases. Exclusion Criteria- Tribal adolescents who were temporarily residing in the study area (seasonal migrant workers or students). Tribal adolescents with any serious physical or psychological health conditions, disabilities or illness. Tribal adolescents involved in other concurrent studies that may affect their nutritional status or study outcomes (e.g. clinical trials, dietary interventions). Family history of haemolyticanaemia or bleeding disorder in the tribal adolescents or family. Tools Used for Data Collection: A case record form was administered for data collection using an interview technique. The following sections were included.

1. Socio-demographic Data: Socio-demographic details such as age, gender, tribe, education level, working status, parental income, occupation, purchasing patterns, and caste classification were collected using a structured questionnaire.

2. Socio-economic Data: Modified Kuppuswamy Scale. Socio-economic status (SES) was assessed using the Modified Kuppuswamy Scale through structured interviews with the parents. This scale evaluates SES based on three key parameters:

- Education level of the head of the family,
- Occupation, and
- Total monthly family income.

Each parameter is assigned a specific score, and the sum of these scores classifies families into different socio-economic classes ranging from upper to lower. The scale is widely used in Indian settings to provide a standardized measure of socio-economic status (Javalkar et al., 2024).Anthropometric measurements involve evaluating physical characteristics of the human body—such as height, weight, and Body Mass Index (BMI)—to assess an individual's nutritional condition and potential health risks (Gibson et al., 2005). These measurements are crucial in both clinical practice and research for detecting issues like malnutrition, obesity, and irregular growth patterns (WHO, 2008).

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For this study, the following anthropometric measurements were recorded: Height (cm), Weight (kg) , Hip Circumference (cm) ,Waist Circumference (cm). Based on these measurements, the following indices were calculated: Body Mass Index (BMI), expressed in kg/m² , ● BMI-for-Age Z-score , ● Height-for-Age Z-score ,● Waist-to-Hip Ratio (WHR).
In addition to these, body composition parameters were assessed - Total body fat percentage, measured using a digital Tanita body composition analyzer based on bioelectrical impedance analysis (BIA).

1) Measurement of Height :-Height was measured using a stadiometer positioned securely against a flat wall on a firm, level surface. Participants stood barefoot with their heels together, feet flat on the floor, arms relaxed at their sides, and head facing forward. The stadiometer's headpiece was carefully lowered to rest on the top of the participant's head without applying pressure. The measurement was recorded in centimeters, rounded to the nearest whole number, while the participant maintained an upright posture.

2) Measurement of Weight - A Tanita digital weighing scale was placed on a flat, hard surface and reset to zero before each use. Participants were instructed to remove their shoes, heavy garments, and any items from their pockets prior to stepping onto the scale. They were asked to stand upright in the center of the scale, remaining still with arms relaxed at their sides. Weight was recorded once the display stabilized. The scale was rechecked for zero after each reading to ensure accuracy across all measurements.

3) Measurement of Waist and Hip Circumference - Waist Circumference (cm): Measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, using a non-stretchable measuring tape. The participant stood upright with feet together, arms relaxed, and the measurement was taken at the end of a normal expiration, following WHO (2008) guidelines. Hip Circumference (cm): Measured at the widest part of the buttocks, ensuring the tape was level and snug without compressing the skin, as recommended by the World Health Organization (2008).

4) Computation of Body Mass Index - Body Mass Index (BMI) served as an indicator to evaluate weight in relation to height among the participants. It was calculated by dividing each individual's weight in kilograms by the square of their height in meters (kg/m²). BMI is a screening measure and it is commonly used in both clinical practice and research to evaluate nutritional status and potential health risks; however, it does not differentiate between fat mass and muscle mass (CDC, 2022).Inthis study, BMI values were interpreted using the World Health Organization (WHO) 2007 Growth Reference for children and adolescents aged 5 to 19 years. Based on age- and sex specific BMI-for-age z-scores & Height-for-Age Z-score participants were classified into categories.These classifications were determined using WHO AnthroPlus software, which is specifically designed to assess growth and nutritional status in school-aged children and adolescents.

BMI classification	WHO perc. scores for children and adolescents
Underweight	< 15
Normal weight	≥ 15 to < 85
Overweight	≥ 85 to < 97
Obesity	≥ 97

Fig 1: BMI Classification as per WHO For Adolescents

5) BMI-for-Age Z-score - BMI-for-Age Z-scores were computed to assess weight status in relation to age and sex. These scores provided a standardized measure to classify participants as severely thin (< –3 SD), thin (≥ –3 to < –2 SD), normal (≥ –2 to ≤ +1 SD), overweight (> +1 to ≤ +2 SD), or obese (> +2 SD). Classifications were based on the WHO 2007 Growth Reference for children and adolescents aged 5–19 years. The values were calculated using WHO AnthroPlus software, which enables accurate analysis of nutritional status in school-aged populations (WHO, 2007).

6) Height-for-Age Z-score -Height-for-Age Z-scores were used to evaluate linear growth and detect stunting among adolescents. A Z-score below –2 SD was considered indicative of stunting, and below –3 SD as severe stunting, while scores ≥ –2 SD were classified as normal height-for-age. These measurements were generated using WHO AnthroPlus software, which applies the WHO 2007 Growth Reference standards for global use in assessing child and adolescent growth (WHO, 2007)

7) Waist-to-Hip Ratio (WHR)-Waist-to-Hip Ratio (WHR) is an anthropometric indicator used to assess the distribution of body fat, particularly central or abdominal obesity. It is calculated by dividing the waist circumference by the hip circumference.

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WHR is recognized as a valuable tool for identifying individuals at risk for metabolic and cardiovascular conditions, as it provides insight into fat accumulation patterns rather than total body weight alone. Compared to BMI, WHR offers a more direct assessment of central fat deposition, which is more strongly associated with adverse health outcomes. It is simple to compute, requires minimal equipment, and can be applied effectively across different age groups and populations. A WHR above 0.90 in males and 0.85 in females adolescents is generally considered indicative of increased health risk (WHO, 2008). In the absence of standardized, age-specific WHR cut-offs for adolescents, reference thresholds recommended by the World Health Organization (WHO, 2008) for adults were applied.

8) Estimated Total body fat percentage -Body fat percentage was measured using a digital Tanita body composition analyzer based on bioelectrical impedance analysis (BIA). Participants were asked to remove their shoes and any metallic accessories before measurement. They were instructed to stand upright on the scale's footplates, ensuring proper contact with the electrodes. The device estimated body fat percentage using built-in age- and sex-specific predictive algorithms.

9) General Medical History data - Information regarding general health was also collected through the questionnaire.. Participants were asked about the frequency of illness, including how often they experienced common ailments such as colds, infections, or fatigue. They reported how frequently they visited a doctor (monthly, quarterly, annually), whether they were currently taking any medications, and if they had received nutritional or dietary supplements in the past three months. This section helped identify any underlying health conditions that could influence their nutritional status. Data on Food habit and food consumption-Data on food habits and consumption patterns were collected using a pre-validated, structured questionnaire along with a Food Frequency Questionnaire (FFQ). These tools were designed to gather detailed information on the participants' dietary behaviors. Key aspects evaluated included meal frequency (number of main meals and snacks consumed per day), regularity and timing of meals, and instances of meal skipping. Additionally, the questionnaire captured food preferences such as vegetarian or non vegetarian dietary choices, as well as the frequency of consumption of processed foods, fast foods, and other commonly consumed food groups. The combination of these tools allowed for a comprehensive assessment of habitual dietary patterns among the participants. Food Frequency Questionnaire (FFQ)-The Food Frequency Questionnaire (FFQ) was used to assess the participants' habitual intake of various food items over the past one month. Participants were asked to indicate how frequently they consumed different food groups, with response options including daily, weekly, monthly, rarely, or never. 24-Hour Diet Recall-A detailed 24-hour dietary recall was conducted to estimate nutrient intake. Hemoglobin Estimation-Capillary blood was collected using a finger-prick method, a minimally invasive procedure performed by a trained technician. The samples were analyzed by a NABL-accredited laboratory (Thyrocare Technologies Ltd.) following standard protocols. Out of the 197 adolescents who participated in the study, only 130 individuals (comprising 66 females and 64 males) underwent hemoglobin testing. The remaining participants did not complete the test due to reasons such as fear of needles, discomfort, and minor health concerns at the time of data collection, which are common among school-aged children. Data Collection- Data were collected from tribal adolescents through face-to-face interviews, conducted in their regional languages (Hindi or Marathi) to ensure clear understanding and accurate responses. Each participant was interviewed once, with the interview lasting approximately 25 minutes. The data were recorded by the researcher in English using a structured case record form. Statistical Analysis-Descriptive statistics were used to summarize the characteristics of the study population. Specifically, the following tests were used: Analysis of Variance (ANOVA)- Applied to determine whether there were statistically significant differences in mean values of a continuous variable across three or more independent groups. Chi-square test- Used to assess the association between categorical variables, such as nutritional status and socio-demographic characteristics. Independent Sample t test- Employed to compare the means of a continuous variable between two independent groups.·Pearson Correlation- Used to evaluate the strength and direction of the linear relationship between two continuous variables. All statistical analyses were performed using SPSS Statistics software version 20 and a significance level of p value < 0.05 was considered statistically significant.

III. RESULT & DISCUSSION

The study was conducted to understand the nutritional status, dietary intake, food consumption patterns, and hemoglobin levels of tribal adolescents.The findings derived from the field data, which include detailed observations on the participants' socio-demographic characteristics, medical history, dietary behaviors, anthropometric indices, and biochemical markers.**Table 1.1** highlights key sociodemographic features of tribal adolescents across three age groups, separately for girls and boys. The majority of girls (58.3%) and boys (46.8%) belonged to the 13–15 years age group. The Warli tribe was the most represented among both genders (girls: 96.3%; boys: 91.7%), consistent with the dominant tribal population in Palghar district.

Educationally, secondary school attendance was highest among 13–15 year olds in both groups (girls: 65.0%; boys: 84.1%), indicating progression through the education system in mid-adolescence. Joint families were common among girls aged 10–12 (63.0%) and boys aged 13–15 (56.7%), reflecting the traditional household structure prevalent in tribal communities. Most participants came from families with 4–6 members (girls: 47.5%; boys: 51.7%) and had 1–2 siblings (girls: 72.5%; boys: 51.7%). Notably, a large proportion of families had two earning members (girls: 50.0%; boys: 36.7%), yet nearly all participants (girls: 97.7%; boys: 93.3%) belonged to the upper-lower socioeconomic class as per the Kuppuswamy scale. This suggests that despite dual incomes, low education and informal or seasonal labor likely limit economic mobility. Regarding housing, pucca homes were reported by most participants (girls: 68.2%; boys: 65.0%), although some still lived in semi-pucca or kutcha houses due to economic constraints and limited infrastructure. A significant majority of adolescents lived more than 3 km away from school (girls: 70.5%; boys: 73.3%), indicating potential barriers to daily school attendance. Walking was the most common mode of transport (girls: 50.0%; boys: 46.7%), followed by public transport (girls: 34.1%; boys: 36.7%). This reflects poor access to school transport facilities and longer commuting time, which may negatively impact education and nutritional status. The sociodemographic characteristics reflect structural vulnerabilities faced by tribal adolescents. The predominance of the upper-lower class suggests widespread economic deprivation despite having two income earners, likely due to irregular, low-paying occupations such as agricultural labor or daily wage work. Semi-pucca or kutcha housing is still common in such communities, pointing to systemic neglect in rural development.

The high proportion of adolescents commuting over long distances on foot reflects inadequate infrastructure in tribal regions, echoing findings from studies in Odisha and Madhya Pradesh (Kumar et al., 2019; Singh & Bharti, 2020). These conditions not only increase physical exertion but also reduce time for rest and meals, which may contribute to undernutrition. The persistence of joint family systems and limited educational attainment among caregivers may also influence dietary diversity and health practices, necessitating targeted educational and welfare interventions.

Table 1.1: Sociodemographic characteristics of the study participants

Characteristics	Girls (n= 103) (n%)			Boys (n= 94) (n%)		
	10-12 yrs (n=27, 26.2%)	13-15 yrs (n=60, 58.3%)	16-18 yrs (n=16, 15.5%)	10-12 yrs (n=40,42.6%)	13-15 yrs (n=44,46.8%)	16-18 yrs (n=10,10.6%)
Tribes						
Kathari	0	0	0	0	0	1(10.0;1.1^)
Kolam	0	1(1.7;1.0^)	1(6.3;1.0^)	0	0	0
Madia	0	2(3.3;1.9^)	0	0	0	2(20.0;2.1^)
Warli	26(96.3;25.2^)	55(91.7;53.4^)	15(93.8;14.6^)	31(77.5.;33.0^)	32(72.7;34.0^)	7(70.0;7.4^)
MalharKohli	1(3.7;1.0^)	0	0	7(17.5;7.4^)	10(22.7;10.6^)	0
Konkani	0	2(3.3;1.9^)	0	2(5.0;2.1^)	1(2.3;1.1^)	0
Kathya	0	0	0	0	1(2.3;1.1^)	0
Education Status (Grades)						
Primary School (Grades 1-5)	15(55.6;14.6^)	2(3.3;1.9^)	0	4(10.0;4.3^)	3(6.8;3.2^)	0

Middle School(Grade 6-8)	12(44.4;11.7^)	39(65.0;37.9^)	4(25.0;3.9^)	36(90.0;38.3^)	37(84.1;39.4^)	0
Secondary School/High School (Grade 9-10)	0	19(31.7;18.4^)	12(75.0;11.7^)	0	4(9.1;4.3^)	10(100.0;10.6^)
Family Type						
Nuclear family	7(25.9;6.8^)	22(36.7;21.4^)	6(37.5;5.8^)	10(25.0;10.6^)	17(38.6;18.1^)	8(80.0;8.5^)
Joint family	17(63.0;16.5^)	34(56.7;33.0^)	10(62.5;9.7^)	20(50.0;21.3^)	22(50.0;23.4^)	2(20.0;2.1^)
Extended family	3(11.1;2.9^)	4(6.7;3.9^)	0	10(25.0;10.6^)	5(11.4;5.3^)	0
Number of Family members						
<4	1(3.7;1.0^)	1(1.7;1.0^)	0	1(2.5;1.1^)	3(6.8;3.2^)	0
4-6	11(40.7;10.7^)	31(51.7; 30.1^)	9(56.3; 8.7^)	19(47.5;20.2^)	26(59.1;27.7^)	8(80.0;8.5^)
>6	15(55.6; 14.6^)	28(46.7; 27.2^)	7(43.8; 6.8^)	20(50.0;21.3^)	15(34.1;16.0^)	2(20.0;2.1^)
Number of siblings						
0	0	1(1.7; 1.0^)	0	2(5.0;2.1^)	3(6.8;3.2^)	0
1-2	13(48.1;12.6^)	31(51.7; 30.1^)	6(37.5; 5.8^)	29(72.5;30.9^)	31(70.5;33.0^)	6(60.0;6.4^)
3 -4	11(40.7;10.7^)	22(36.7; 21.4^)	5(31.3; 4.9^)	7(17.5;7.4^)	8(18.2;8.5^)	2(20.0;2.1^)
>4	3(11.1; 2.9^)	6(10.0; 5.8^)	5(31.3; 4.9^)	2(5.0;2.1^)	2(4.5;2.1^)	2(20.0;2.1^)
Number of earning members in family						
1	12(46.2; 11.8^)	34(56.7; 33.3^)	7(43.8; 6.9^)	13(32.5;13.8^)	10(22.7;10.6^)	5(50.0;5.3^)
2	9(34.6; 8.8^)	22(36.7; 21.6^)	8(50.0; 7.8^)	20(50.0;21.3^)	30(68.2;31.9^)	5(50.0;5.3^)
3	5(19.2; 4.9^)	4(6.7; 3.9^)	1(6.3; 1.0^)	3(7.5;3.2^)	4(9.1;4.3^)	0
>4	0	0	0	4(10.0;4.3^)	0	0
Residence Type						
Kutcha house (temporary structure)	11(40.7; 10.7^)	21(35.0; 20.4^)	8(50.0; 7.8^)	20(50.0;21.3^)	14(31.8;14.9^)	4(40.0;4.3^)

Pucca house(permanent structure)	15(55.6; 14.6^)	39(65.0; 37.9^)	6(37.5; 5.8^)	18(45.0;19.1^)	30(68.2;31.9^)	6(60.0;6.4^)
Semi- pucca house (semi-permanent structure)	1(3.7;1.0^)	0	2(12.5;1.9^)	2(5.0;2.1^)	0	0
Distance from school						
Less than 1 km	2(7.4; 1.9^)	2(3.3;1.9^)	1(6.3;1.0^)	2(5.0;2.1^)	2(4.5;2.1^)	1(10.0;1.1^)
1-3 km	7(25.9;6.8^)	14(23.3;13.6^)	6(37.5;5.8^)	15(37.5;16.0^)	11(25.0;11.7^)	3(30.0;3.2^)
More than 3 km	18(66.7;17.5^)	44(73.3;42.7^)	9(56.3;8.7^)	23(57.5;24.5^)	31(70.5;33.0^)	6(60.0;6.4^)
Primary Mode of Transportation to School						
Walking	4(14.8; 3.9^)	10(16.7; 9.7^)	2(12.5; 1.9^)	7(17.5;7.4^)	5(11.4;5.3^)	1(10.0;1.1^)
Bicycle	0	0	0	0	1(2.3;1.1^)	0
Public transport(auto/train)	7(25.9; 6.8^)	22(36.7; 21.4^)	11(68.8; 10.7^)	20(50.0;21.3^)	15(34.1;16.0^)	3(30.0;3.2^)
School/college vans services	0	0	0	0	1(2.3;1.1^)	0
Private vehicle (car/ motor bike/)	16(59.3; 15.5^)	28(46.7; 27.2^)	3(18.8; 2.9^)	13(32.5;13.8^)	22(50.0;23.4^)	6(60.0;6.4^)
Socioeconomic Class**						
Upper (I)	0	0	0	0	0	0
Upper Middle (II)	0	1(1.7;1.0^)	0	0	1(2.3; 1.1^)	0
LowerMiddle(III)	0	2(3.3; 1.9^)	1(6.3;1.0^)	0	0	0
UpperLower (IV)	26(96.3; 25.2^)	56(93.3; 54.4^)	15(93.8; 14.6^)	40(100.0; 42.6^)	43(97.7; 45.7^)	10(100.0; 10.6^)
Lower (V)	1(3.7; 1.0^)	1(1.7;1.0^)	0	0	0	0

**As per Kuppuswamy scale)
Percentages without ^ are within the age category
^Percentages are out of total number of participants gender wise

Table 1.2 highlights important growth patterns and nutritional status of girl participants across age groups. In the 10–12 years group, the mean BMI was 14.9 ± 1.6 kg/m^2 and body fat percentage 15.5 ± 2.6%, both reflecting undernutrition. Girls aged 13–15 years demonstrated improvement in height and BMI (16.4 ± 1.9 kg/m^2), though values remained below WHO references. Among 16–18-year-old girls, BMI reached its highest mean (17.6 ± 2.1 kg/m^2), but total body fat remained statistically unchanged across age groups ($p = 0.390$). Waist-to-hip ratio also remained stable (~0.84–0.85), indicating proportional fat distribution rather than central adiposity. The findings indicate that while anthropometric parameters improve with age among tribal girls, undernutrition remains prevalent across all age groups. The consistently low BMI, especially in the youngest group, reflects chronic energy deficiency, a concern echoed in tribal studies from Maharashtra and Chhattisgarh (Verma et al., 2020). The absence of significant variation in fat percentage with age may suggest inadequate dietary fat intake or delayed pubertal fat accumulation. Stability in WHR implies that weight gain occurred proportionally rather than through abdominal fat, which is typically a risk in overnutrition. These results point toward a need for interventions focused not just on calorie adequacy but also on quality and diversity of food intake.

Table 1.2: Anthropometric Indices and Total Body Fat Percentage of the Girl participants

Anthropometric indices	Girls (n= 103)				
Age(yrs)*	10-12 yrs (n=27)	13-15 yrs (n=60)	16-18 yrs (n=16)	F value	P value
Height(cm)	138.9±6.0	148.3±5.1	146.1±5.2	32.01	0.000
Weight(kg)	28.8±4.3	36.0±5.2	39.4±5.8	27.52	0.000
BMI(kg/m2)	14.9±1.6	16.4±1.9	17.6±2.1	11.86	0.000
Waist circumference(cm)	60.4±5.4	65.0±5.6	67.6±3.2	11.55	0.000
Hip circumference(cm)	71.8±4.4	76.6±5.7	79.1±4.1	12.01	0.000
Waist- Hip ratio (%)	0.84±0.04	0.85±0.08	0.85±0.04	0.28	0.760
Total Body fat %	15.5±2.6	16.4±2.6	16.2±3.6	0.95	0.390

All values are mean ±SD

Table 1.3: Anthropometric Indices and Total Body Fat Percentage of the Boy participants

Anthropometric indices	Boys (n= 94)				
Age(yrs)*	10-12 yrs (n=40)	13-15 yrs (n=44)	16-18 yrs (n=10)	F value	P value

Height(cm)	139.4 ± 7.7	151.9±11.0	162.8±11.0	30.62	0.000
Weight(kg)	27.7 ± 4.4	36.8 ± 11.1	46.5 ± 10.2	22.50	0.000
BMI(kg/m2)	14.2± 1.5	15.7± 3.3	17.4± 2.1	7.67	0.001
Waist circumference(cm)	57.3±4.9	63.5±9.9	65.4±4.2	8.63	0.000
Hip circumference(cm)	66.4±5.4	75.1±9.9	79.0±2.8	18.34	0.000
Waist- Hip ratio (%)	0.86±0.05	0.84±0.05	0.82±0.04	3.60	0.031
Total Body fat %	13.2±3.9	9.4±7.4	12.7±3.2	4.78	0.011

All values are mean ±SD

Table 1.3 highlights the age-wise progression in growth parameters among the boy participants. In the 10–12 years age group, the mean BMI was 14.2 ± 1.5 kg/m^2, which is indicative of thinness as per WHO standards. This could be attributed to inadequate calorie intake, high physical activity levels, or early signs of chronic undernutrition. Total body fat percentage in this group was 13.2 ± 3.9%, reflecting low energy reserves in early adolescence. In the 13–15 years group, boys showed improvements in height (151.9 ± 11.0 cm) and BMI (15.7 ± 3.3 kg/m^2), though still below healthy reference values, suggesting continued nutritional inadequacy during mid-adolescence. Interestingly, this group showed the lowest body fat percentage (9.4 ± 7.4%), possibly due to increased energy expenditure during school commutes and physical work. In the 16–18 years group, BMI was 17.4 ± 2.1 kg/m^2, and body fat recovered to 12.7 ± 3.2%, reflecting better growth outcomes but still insufficient for optimal adolescent development. Waist-to-hip ratio (WHR) slightly declined with age, indicating more favorable fat distribution. The anthropometric trends indicate that although boys demonstrate physical growth with age, the persistently low BMI across all groups reflects underlying nutritional stress. The sharp decline in fat percentage during the 13–15 years period could be due to a mismatch between dietary intake and increased physiological demands of puberty and physical activity. This trend is consistent with findings from tribal regions in Jharkhand and Gujarat, where adolescent boys commonly presented with BMI values below −2 SD (ICMR-NIN, 2020; Singh et al., 2021). The marginal recovery in BMI and fat percentage in the 16–18 years group suggests some degree of catch-up growth; however, the levels remain below optimal, indicating unresolved nutritional gaps. The lower WHR in older boys suggests balanced fat distribution rather than central obesity, which is preferable from a metabolic standpoint. These findings emphasize the need for age-specific, culturally adapted nutrition programs focusing on increasing caloric and protein intake among adolescent boys in tribal regions to support healthy growth and body composition.

Table 1.4 highlights the distribution of girl participants based on WHO BMI-for-age Z-scores, indicating the categories of nutritional status that they belong to. In the 10–12 years group, over half of the girls (55.6%) were classified as severely thin, and an additional 40.7% were thin, indicating that nearly all in this group were undernourished. This could be attributed to inadequate dietary intake during early adolescence, coupled with poor food quality and insufficient meal frequency. In the 13–15 years group, 36.7% were severely thin and 40.0% were thin, showing a slight decline in severe undernutrition but continued high prevalence of thinness. This age is often marked by increased energy demands due to growth spurts and hormonal changes, which may not be met due to limited household food security. In the 16–18 years group, 50.0% of the girls were still thin, while the percentage of severely underweight thin girls reduced to 12.5%, suggesting partial nutritional improvement with age. However, normal BMI-for-age was achieved by only a small fraction, and just one girl was classified as overweight, indicating that overweight and obesity are rare in this population. The three groups showed a statistically significant difference with p=0.015. The high prevalence of thinness and severe thinness among tribal girls across all age groups reflects a sustained burden of chronic undernutrition.

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Early adolescence (10–12 years) appears to be the most vulnerable stage, potentially due to neglect of girls' nutritional needs during childhood and transition into puberty. Studies from tribal communities in Madhya Pradesh and Jharkhand have reported similar findings, with over 50% of adolescent girls falling below −2 SD for BMI-for-age (Bhagwat et al., 2019; Patil et al., 2021). The persistence of thinness in mid and late adolescence indicates that nutritional interventions may be either inadequate or poorly targeted. Growth spurts and increased physical demands during the 13–15 years stage exacerbate the need for balanced nutrition, which may be lacking in tribal diets that are often cereal-based with low diversity. The marginal improvement in the 16–18 years group could reflect late catch-up growth or reduced energy expenditure due to reduced physical activity. **Table 1.5** highlights the nutritional status of boy participants based on BMI-for-age Z-scores, revealing a striking pattern of undernutrition across all age groups. In the 10–12 years group, a staggering 72.5% were classified as severely thin, and 22.5% as thin, meaning nearly all boys in this group were underweight. This extreme level of thinness likely stems from a combination of poor dietary intake, high physical activity (e.g., walking long distances to school), and early onset of nutritional deprivation during childhood. Among boys aged 13–15 years, severe thinness remained high at 54.5%, with 40.9% being thin, again pointing to insufficient nutritional support during a period of accelerated growth. These figures suggest that mid-adolescence is a continued window of nutritional vulnerability, potentially worsened by increased school workload or physical responsibilities within the family. In the 16–18 years group, 60.0% were classified as thin, while 30.0% had normal BMI-for-age. Although a slight improvement is seen in terms of severe thinness reduction, most boys still failed to achieve a healthy BMI. Overweight and obesity were observed only in isolated cases, both in the youngest group, indicating their rarity in this population. The three groups showed a statistically significant difference with p=0.001. **Table 1.5** shows a persistently high prevalence of thinness and severe thinness among tribal boys, especially in the 10–12 years group, where over 95% were undernourished. This aligns with findings from tribal regions of Odisha and Maharashtra, where over half of adolescent boys fell below −2 SD for BMI-for-age (Choudhury et al., 2018; Patnaik et al., 2020). Mid-adolescents (13–15 years) also showed continued nutritional deficits, consistent with NFHS-5 and reports by Sheth et al. (2019), which attribute poor BMI to limited dietary diversity and high physical activity levels. Though there was a modest reduction in severe thinness in the 16–18 years group, most still remained underweight. Comparable studies from Madhya Pradesh and Rajasthan report similar trends, indicating little recovery during late adolescence (Tiwari et al., 2021). These findings point toward long-standing and cumulative nutritional inadequacies, echoing previous research on the lasting effects of early childhood malnutrition in tribal populations (Singh & Jain, 2018).

Table 1.4: Classification of the Girl Participants Based on WHO (BMI-for-Age Z-Score)

WHO BMI-for-Age Z Score	WHO BMI for-Age Z Score Cutoffs	Girls (n= 103) (n%)			
		10-12 yrs (n=27)	13-15 yrs (n=60)	16-18 yrs (n=16)	Pearson Chi square P value
Severely Thin: (n= 39)	BMI < -3 SD	15(55.6;14.6^)	22(36.7;21.4^)	2(12.5;1.9^)	0.015
Thin (Underweight): (n=43)	BMI between -3 SD and -2 SD	11(40.7;10.7^)	24(40.0;23.3^)	8(50.0;7.8^)	

Normal Weight: (n=20)	BMI between -2 SD and +1 SD	1(3.7;1.0^)	14(23.3;13.6^)	5(31.3;4.9^)	
Overweight: (n=1)	BMI between +1 SD and +2 SD	0	0(;^)	1(6.3;1.0^)	
Obese: (n=0)	BMI > +2 SD	0	0	0	

Percentages without ^ are within the age category
^Percentages are out of total number of girl participants

Table 1.5: Classification of the Boy Participants Based on WHO (BMI-for-Age Z-Score)

WHO (BMI-for-Age Z Score	WHO BMI-for Age Z-Score Cutoffs	Boys (n= 94) (n%)			
		10-12 yrs (n=40)	13-15 yrs (n=44)	16-18 yrs (n=10)	Pearson Chi square P value
Severely Thin: (n= 54)	BMI < -3 SD	29(72.5;30.9^)	24(54.5;25.5^)	1(10.0;1.1^)	0.001
Thin (Underweight): (n= 33)	BMI between -3 SD and -2 SD	9(22.5;9.6^)	18(40.9;19.1^)	6(60.0;6.4^)	
Normal Weight: (n=5)	BMI between -2 SD and +1 SD	0	2(4.5;2.1^)	3(30.0;3.2^)	
Overweight: (n=1)	BMI between +1 SD and +2 SD	1(2.5;1.1^)	0	0	
Obese: (n=1)	BMI > +2 SD	1(2.5;1.1^)	0	0	

Percentages without ^ are within the age category
^Percentages are out of total number of boy participants

The height-for-age classification of girl participants across different age groups based on WHO Z-scores. In the 10–12 years age group, 19 girls (70.4%) were found to have normal stature, 5 girls (18.5%) were moderately stunted, and 3 girls (11.1%) were severely stunted. In the 13–15 years group, 29 girls (48.3%) had normal height-for-age, while 13 girls (21.7%) were moderately stunted and 18 girls (30.0%) were severely stunted—the highest burden of stunting in this group.

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Among girls aged 16–18 years, 11 (68.8%) had normal stature, 2 (12.5%) were moderately stunted, and 3 (18.8%) were severely stunted. Across the entire sample of 103 girls, 59 were classified as having normal stature, 20 as moderately stunted, and 24 as severely stunted. This distribution shows that stunting affected over 40% of girls overall, with severe stunting most concentrated in the 13–15 years group. In the 10–12 years age group, a majority of boys (32; 80.0%) had normal stature, while 8 boys (20.0%) were stunted and none were severely stunted, indicating relatively better linear growth in early adolescence. In the 13–15 years group, 30 boys (68.2%) showed normal height-for-age, while 9 boys (20.5%) were moderately stunted and 5 boys (11.4%) were severely stunted—this group showed the highest proportion of overall stunting. In the 16–18 years group, 8 boys (80.0%) had normal stature, none were stunted, and 2 boys (20.0%) were severely stunted.

Table 1.8 highlights the detailed comparison of mean intake and standard deviations for macronutrients among girl participants across three age groups. Energy intake remained relativelysimilar across groups: 1232 kcal (±54.8) in 10–12 years, 1235 kcal (±71.7) in 13– 15 years, and 1200 kcal (±87.5) in 16–18 years. Despite the apparent stability, these values fall significantly short of ICMR EAR recommendations for all age groups. The difference in the mean energy intake of the three age groups was not statistically significant ($p = 0.215$), likely due to shared dietary patterns centered around low-calorie, staple-based meals. Additionally, the comparatively lower energy intake observed in the oldest age group (16–18 years) may also be attributed to the smaller number of participants in this category, which could have influenced the group mean. Protein intake showed a statistically significant increase ($p = 0.000$), rising from 35.5 g (±7.2) in the youngest group to 40.4 g (±2.7) in 13–15 years, with a slight decrease to 39.2 g (±3.4) in the oldest. The youngest girls met 131.6% of their protein EAR, while the middle and oldest age groups met 115.5% and 106.0% protein EAR, respectively. This may reflect both changes in requirements and differences in total food intake, although the overall adequacy declined with age. Carbohydrate intake was nearly identical across groups: 160 g (±6.4), 160 g (±7.4), and 159 g (±6.9) in increasing age order, with no statistical significance ($p = 0.751$), again indicating dietary uniformity. Fat intake showed a minor, non-significant decline from 34 g (±6.6) in 10–12 years to 32 g (±4.5) and 30 g (±4.0) in the older groups ($p = 0.124$), reflecting limited consumption of fat-rich foods. A sharp decline was noted in the percentage of energy EAR met ($p = 0.000$), from 59.8% (±2.7) in the 10–12 years group to 51.4% (±3.0) in 13–15 years and 48.0% (±3.5) in the 16– 18 years group, suggesting that as nutritional needs increased with age, intake failed to keep pace. This decline was accompanied by an increase in the percentage of energy derived from protein, rising from 12.8% (±2.2) in the youngest group to 14.6% (±0.3) in 13–15 years and 14.5% (±0.4) in the oldest. Meanwhile, the percentage of energy from fats showed a steady decline from 27.3% (±4.4) to 25.8% (±2.7) and 25.1% (±2.0). Carbohydrate contribution remained relatively stable across groups (58.0% to 58.6%), with a slight peak in the oldest adolescents. The lack of statistical significance in total energy, carbohydrate, and fat intake may reflect dietary homogeneity, with a predominant reliance on cereals and pulses and minimal dietary diversity. Furthermore, the small sample size in the 16–18 years group ($n = 16$) may have limited the power to detect statistically significant differences across age groups. The findings from Table 1.8 show that protein intake differed significantly across age groups, with the highest intake observed in the 13–15 years group. This trend aligns with studies by Venkaiah et al. (2019) and Rao et al. (2021), which reported slightly better protein consumption among older tribal adolescents due to increased school-based nutrition exposure and greater autonomy in food choices. However, the youngest group had the highest percentage of protein EAR met (131.6%), likely due to lower absolute protein requirements (27 g/day), which were more easily achieved despite limited diet diversity. Energy intake remained consistently low across all age groups and significantly below the ICMR EAR levels, a pattern supported by findings in tribal regions of Odisha and Chhattisgarh (Das et al., 2018; Tiwari et al., 2020). This could be attributed to monotony in dietary patterns, as most adolescents consumed cereal-pulse based meals with minimal fat and protein sources. Similar results were observed by Mishra et al. (2017), where staple-heavy diets led to nutrient inadequacies irrespective of age. The small sample size in the 16–18 years group further limited statistical power to detect meaningful differences.

Table 1.8: Daily Energy and Macronutrient intake and Percentage of Energy EAR met by the Girl participants

Macronutrients and Percentage of Energy and EAR met	Girls (n= 103)

	10-12 yrs (n=27)	13-15 yrs (n=60)	16-18 yrs (n=16)	F value	P value
Energy(kcal)	1232±54.8	1235±71.665	1200±87.504	1.56	0.215
Protein(g)	35.5±7.2	40.4±2.7	39.2±3.4	11.41	0.000
Carbohydrate(g)	160±6.4	160±7.4	159±6.9	0.29	0.751
Fats(g)	34±6.6	32±4.5	30±4.0	2.13	0.124
Dietary Fiber (g)	11.9±0.8	12.1±1.4	12.3±2.2	0.53	0.589
% of Energy EAR met	59.8±2.7	51.4±3.0	48.0±3.5	100.5	0.000
% of Protein EAR met	131.6±26.8	115.5±7.7	106.0±9.1	16.36	0.000
% of Energy from protein	12.8±2.2	14.6±0.3	14.5±0.4	-	-
% of Energy from carbohydrate	58.0±0.9	57.7±1.2	58.6±2.6	-	-
% of Energy from fats	27.3±4.4	25.8±2.7	25.1±2.0	-	-

EAR – Estimated Average Requirement, All values are mean ±SD

Table 1.9 highlights the detailed comparison of mean intake and standard deviations for macronutrients among boy participants across three age groups. Energy intake remained relatively consistent across groups: 1266 kcal (±76.0) in 10–12 years, 1263 kcal (±68.2) in 13–15 years, and 1196 kcal (±168.4) in 16–18 years. Despite the slight decline with age, these values fall significantly short of the ICMR EAR recommendations, and the difference in the energy intake of three age groups was not statistically significant ($p = 0.067$), likely due to similar dietary patterns based on low-calorie staple foods. Additionally, the comparatively lower energy intake observed in the oldest age group (16–18 years) may also be attributed to the smaller number of participants in this category, which could have influenced the group mean. Protein intake showed a statistically significant difference , increasing from 38.0 g (±5.5) in 10–12 years to 40.6 g (±3.2) in 13–15 years, before decreasing to 39.2 g (±4.3) in 16–18 years. The youngest boys met 144.9% of their protein EAR, while the middle and oldest age groups met 112.8% and 87.2% protein EAR, respectively .This decline in adequacy with age may reflect the inability of their diets to keep pace with growing protein needs. Carbohydrate intake showed minimal variation across age groups—163 g (±5.7), 162 g (±7.25), and 158 g (±39.5)—with no statistically significant difference , indicating a shared dietary pattern. Fat intake also remained statistically unchanged, ranging from 31 g (±2.97) in 10–12 years to 30 g (±4.5) in 16–18 years. A notable and statistically significant decline was seen in the percentage of energy EAR met , dropping from 57.1% (±3.4) in the youngest group to 44.2% (±2.4) in 13–15 years and 36.1% (±5.1) in 16–18 years, suggesting increasing inadequacy with age. The energy contribution from protein increased from 12.4% in 10–12 years to 13.5% in 16– 18 years .Carbohydrates contributed 55.0%, 54.1%, and 54.5% across the three groups respectively , while fats accounted for 30.6%, 30.8%, and 30.0%. These changes reflect subtle shifts in dietary composition with age, despite an overall decline in total intake.

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Table 1.9: Daily Energy and Macronutrient intake and Percentage of Energy EAR met by the Boy participants

Macronutrients and Percentage of Energy and EAR met	Boys (n= 94)				
	10-12 yrs (n=40)	13-15 yrs (n=44)	16-18 yrs (n=10)	F value	P value
Energy(kcal)	1266± 76.0	1263±68.2	1196±168.4	2.78	0.067
Protein(g)	38.0±5.5	40.6±3.2	39.2±4.3	3.47	0.035
Carbohydrate(g)	163±5.7	162±7.25	158±39.51	0.59	0.558
Fats(g)	31±2.97	31±2.95	30.± 4.50	0.49	0.610
Dietary Fiber (g)	11.9±0.8	12.2±1.09	13.0±3.8	1.86	0.162
% of Energy EAR met	57.1±3.4	44.2±2.4	36.1±5.1	257.24	0.000
% of Protein EAR met	144.9±22.6	112.8±9.0	87.2±9.5	68.26	0.000
% of Energy from protein	12.4±1.8	13.1±0.7	13.5±0.7	-	-
% of Energy from carbohydrate	55.0±2.2	54.1±1.4	54.5±6.5	-	-
% of Energy from fats	30.6±1.9	30.8±1.5	30.0±2.6	-	-

EAR – Estimated Average Requirement ,All values are mean ±SD

In the present study, the intake of energy and macronutrients such as protein, carbohydrate, and fats did not exhibit a consistent increase with age among tribal boys. Energy intake was highest in the 10–12 years group (1266±76.0 kcal) and declined in the 16–18 years group (1196±168.4 kcal), although the difference was not statistically significant ($p = 0.067$). Similarly, protein intake was marginally higher in the 13–15 years group (40.6±3.2 g) compared to the younger (38.0±5.5 g) and older (39.2±4.3 g) groups, with a statistically significant variation observed across the three age categories ($p = 0.035$). Carbohydrate and fat intakes remained statistically comparable among all groups ($p > 0.05$). Despite similar intake levels, the percentage of EAR met for both energy and protein showed a sharp and significant decline with age ($p = 0.000$). Energy adequacy dropped from 57.1% in the 10–12 years group to 36.1% in the 16–18 years group, and protein adequacy decreased from 144.9% to 87.2% across the same age groups. These findings underscore a widening gap between dietary intake and physiological requirements as age advances, likely due to increasing nutritional needs during late adolescence not being met by a proportionate increase in food intake. These patterns contrast with findings from studies by Singh et al. (2020) and ICMR-NIN (2021), which reported increased macronutrient intake among older boys due to heightened appetite and activity levels. In the present study, however, the data suggest that food access, dietary monotony, or lifestyle constraints may limit the capacity of older adolescents to meet their nutritional requirements, despite their higher physiological demands.

Table 1.10 presents the mean intake and percentage of RDA met for selected micronutrients among girl participants across three age groups. Iron intake was uniformly low across groups: 8.8 mg (±0.5) in 10–12 years, 8.8 mg (±0.6) in 13–15 years, and 8.7 mg (±0.7) in 16–18 years, with no statistically significant difference (p = 0.705). However, the percentage of iron RDA met declined progressively from 31.3% (±1.6) in 10–12 years to 27.1% (±2.2) in and this decline was statistically significant (p = 0.000), suggesting increased inadequacy in older adolescents despite similar intake levels. Calcium intake remained consistently low across age groups (154.9 mg in 10–12 years to 156.6 mg in 13–15 and 16–18 years), far below the RDA of 800–1050 mg. The percentage of calcium RDA met dropped from 18.2% in the youngest to 15.7% in the oldest girls (p = 0.000), reflecting widespread inadequacy in calcium-rich food intake. Zinc intake was also insufficient across all groups (4.3 mg in 10–12 and 13–15 years to 4.2 mg in 16–18 years**),** with the percentage of RDA met declining from 50.2% in 10–12 years to 33.4% in 13–15 years and 29.5% in 16–18 years to 29.5% (p = 0.000), indicating poorer intake in older age groups. Although the difference in the intake of dietary folate and vitamin B12 by the three groups was statistically non-significant (p > 0.7), the percentage of dietary folate RDA met showed a sharp decline: from 100.3% in 10–12 years to 83.4% in 16–18 years (p = 0.000), pointing to increasing gaps in meeting folate needs with age.

Table 1.10: Micronutrient intake and Percentage of RDA met by the Girl participants

Micronutrients andpercentage of RDA met	Girls (n= 103)				
	10-12 yrs (n=27)	13-15 yrs (n=60)	16-18 yrs (n=16)	F value	P value
Iron (mg)	8.8±0.5	8.8±0.6	8.7±0.7	0.35	0.705
Calcium (mg)	154.9±6.4	156.6±9.9	156.6±12.3	0.32	0.727
Dietary Folate (µg)	225.7±10.5	226.4±13.1	225.1±18.2	0.07	0.936
Zinc (mg)	4.3±0.2	4.3±0.3	4.2±0.5	0.55	0.580
Vitamin B12 (µg)	0.6±0.3	0.6±0.3	0.6±0.2	0.32	0.726
% of Iron RDA met	31.3±1.6	29.3±1.9	27.1±2.2	24.68	0.000
% of Calcium RDA met	18.2±0.7	15.7±1.0	15.7±1.2	68.22	0.000
% of Dietary FolateRDA met	100.3±4.6	92.4±5.4	83.4±6.7	50.26	0.000
% of Zinc RDA met	50.2±2.9	33.4±2.5	29.5±3.1	434.46	0.000

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% of Vitamin B12 RDA met	27.3±10.3	28.5±11.5	26.1±11.1	0.32	0.726

RDA – Recommended Dietary Allowances ,All values are mean ±SD

In the present study, micronutrient intake among tribal adolescent girls was found to be substantially below the Recommended Dietary Allowances (RDA), particularly for iron, calcium, and zinc. Iron intake remained consistent across age groups but the percentage of iron RDA met declined progressively with age, highlighting an increasing inadequacy during later adolescence. This pattern is concerning given the higher physiological iron requirements in menstruating girls and their increased vulnerability to anemia. Similar iron inadequacies have been documented in tribal adolescent populations in Maharashtra and Odisha, where dietary intake was frequently reported to fall below 60% of the EAR (Verma et al., 2021; Kulkarni et al., 2019). In the present study, calcium inadequacy consistently observed across all age groups, may be attributed to low consumption of dairy products, limited availability of fortified foods, and poor dietary diversity. This is consistent with findings from Das et al. (2020), who documented significantly low calcium intake among tribal girls in central India, raising concerns about long term bone health and growth potential. In the present study, zinc intake was also notably below recommended levels, with the percentage of RDA met decreasing steadily with age. This likely reflects low intake of animal source foods and pulses, which are the primary sources of bioavailable zinc.**Table 1.11** highlights the mean intake and percentage of RDA met for selected micronutrients among boy participants across three age groups. Iron intake increased slightly with age—8.8 mg (±0.5) in 10–12 years, 8.9 mg (±0.5) in 13–15 years, and 9.1 mg (±2.9) in 16–18 years. However, the percentage of iron RDA met declined significantly with age (p = 0.000), from 54.9% (±3.2) in 10–12 years to 40.4% (±2.4) in 13–15 years and 34.9% (±11.1) in 16–18 years, suggesting that iron requirements are not being met adequately as boys grow older. Calcium intake remained low and fairly stable across all three groups: 155.4 mg in 10–12 years, 156.7 mg in 13–15 years, and 159.2 mg in 16–18 years, respectively.The percentage of RDA met showed a statistically significant decline (p = 0.000), falling from 18.3% in 10-12 years to 15.7% in 13–15 years and 15.9% in 16- 18 years , indicating persistent calcium deficiency during adolescence likely due to low dairy consumption. The intake of dietary folate in the present study remained relatively constant (227.8 µg in 10– 12 years, 226.3 µg in 13–15 years, and 224.5 µg in 16–18 years), but its adequacy sharply declined with age—falling from 103.5% in 10–12 years to 66.0% in 16–18 years (p = 0.000). This reflects that although intake did not reduce, the growing folate needs of older adolescents were not being met. Zinc intake was relatively consistent (4.2 to 4.3 mg), but the percentage of RDA met decreased significantly (p = 0.000) from 49.9% in 10–12 years to 29.9% in 13–15 years and just 24.0% in 16–18 years, suggesting that the typical diet was insufficient to support increasing zinc requirements. Vitamin B12 intake showed a small increase (from 0.6 µg in 10–12 years to 0.7 µg in 13–18 years) and , while its adequacy slightly improved, this change was not statistically significant (p = 0.281), indicating consistently low intake likely due to limited consumption of animal source foods.

Table 1.11: Micronutrient intake and Percentage of RDA met by the Boy participants

Micronutrients and percentage of RDA met	Boys (n= 94)				
	10-12 yrs (n=40)	13-15 yrs (n=44)	16-18 yrs (n=10)	F value	P value
Iron (mg)	8.8±0.5	8.9±0.5	9.1±2.9	0.36	0.699
Calcium (mg)	155.4±6.9	156.7±8.4	159.2±28.5	0.46	0.632
Dietary Folate (µg)	227.8±15.0	226.3±14.2	224.5±24.1	0.20	0.816

Zinc (mg)	4.2±0.2	4.3±0.3	4.2±0.5	0.18	0.837
Vitamin B12 (µg)	0.6±0.2	0.7±0.2	0.7±0.3	1.29	0.280
% of Iron RDA met	54.9±3.2	40.4±2.4	34.9±11.1	150.24	0.000
% of Calcium RDA met	18.3±0.8	15.7±0.8	15.9±2.8	53.66	0.000
% of Dietary Folate RDA met	103.5±6.8	79.4±4.9	66.0±7.1	241.32	0.000
% of Zinc RDA met	49.9±2.7	29.9±2.1	24.0±3.1	850.74	0.000
% of Vitamin B12 RDA met	27.5±10.1	30.7±11.1	32.3±12.0	1.29	0.281

RDA – Recommended Dietary Allowances ,All values are mean ±SD

The results of Table 1.11 indicate substantial and consistent micronutrient inadequacies among tribal boys, particularly for iron, calcium, zinc, and folate. The percentage of iron RDA met declined from 54.9% in 10–12 years to 34.9% in 16–18 years. This pattern suggests increased physiological needs during adolescence that were not matched by adequate dietary improvements. Similarly, calcium adequacy dropped from 18.3% to 15.9%, and zinc adequacy from 49.9% to 24.0%, highlighting substantial age-wise decline. The most notable fall was in folate adequacy, which dropped from 103.5% to 66.0% across the three age groups. These trends are consistent with studies conducted in tribal regions of Maharashtra and Jharkhand, where intake of micronutrient-rich foods is limited due to poor dietary diversity, low access to animal-source foods, and lack of nutrition education (Rao et al., 2021; Das et al., 2019). Vitamin B12 adequacy remained low across all groups, reflecting limited consumption of animal-based foods. These persistent deficiencies underscore the need for comprehensive nutrition interventions, especially in mid-to-late adolescence, when requirements rise sharply but dietary quality remains inadequate.

Among girls aged 10–12 years, 9 (33.3%) missed breakfast 1–2 times per week. In the 13–15 years group, 26 (43.3%) skipped breakfast 1–2 times weekly, while in the 16–18 years group, 7 girls (43.8%) reported skipping breakfast at the same frequency. This suggests that skipping breakfast is a common pattern, particularly among older adolescents. Snacks were also irregularly consumed. In the 10–12 years group, 1 girl (3.7%) missed snacks daily, 19 (70.4%) skipped it 3–4 times per week, and 7 (25.9%) missed it 1–2 times weekly.Among 13–15 years, 8 (13.3%) girls skipped snacks daily, 35 (58.3%) skipped them 3–4 times, and 15 (25.0%) missed them 1–2 times per week. In the 16–18 years group, 2 girls (12.5%) missed snacks daily, 7 (43.8%) skipped them 3–4 times, and 6 (37.5%) missed them 1–2 times per week, indicating inconsistent snack intake across all age groups. In contrast, lunch and dinner were the least skipped meals. All girls across all age categories consumed lunch daily. Dinner was never skipped by any girls in the 16–18 years group.This pattern of irregular meal frequency may compromise overall nutrient intake and metabolic balance, particularly for adolescents undergoing rapid growth.

A similar trend was observed in a study conducted by Singh et al. (2020) among tribal adolescents in Chhattisgarh, where over 70% of participants regularly skipped early morning or mid-morning meals, attributing this to early school timings and lack of food availability at home. The study concluded that skipping mid-meals contributes significantly to daily nutrient gaps, especially when not compensated for later in the day. weekly meal skipping behavior among boy participants across three age groups. Early morning meals were the most commonly skipped mid-meal, with 39 boys (97.5%) in the 10–12 years group, all 44 boys (100%) in the 13–15 years group, and all 10 boys (100%) in the 16–18 years group reporting daily skipping of early morning intake. Breakfast skipping was also prevalent. Among 10–12-year-old boys, 15 (37.5%) skipped breakfast 1–2 times weekly.

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This trend remained consistent in older age groups, with 15 boys (34.1%) in the 13–15 years group and 3 boys (30.0%) in the 16–18 years group missing breakfast 1–2 times weekly.Lunch skipping was minimal & Dinner was regularly consumed by most participants(Boys). Whole wheat flour was consumed daily by all girls, Pulses and legumes showed daily consumption across all age groups (above 85%), reinforcing their role as a major protein source. Vegetables and green leafy vegetables (DGLVs) were commonly consumed 2–4 times weekly. The inclusion of other nutritious food groups, such as milk, fruits, and nuts, was limited, and statistically significant differences were noted in nut consumption across age groups. Despite low overall diversity, it is notable that some girls consumed animal-source foods like chicken and fish at least once or twice per week. This suggests that while access may be inconsistent, there is cultural acceptance and dietary inclusion of non- vegetarian foods. tribal adolescent girls primarily consume staple foods like wheat, rice, and pulses on a daily basis, indicating a diet centered around affordability and availability. However, the inclusion of other nutritious food groups, such as milk, fruits, and nuts, was limited, and statistically significant differences were noted in nut consumption across age groups in boys.Whole wheat flour was universally consumed daily by 100% of boys across all three age groups, confirming its position as a staple food. Pulses and legumes were reported to be consumed daily by 93%. Milk and milk product intake was largely limited to once a week, with 93% of both 10–12 and 13–15 years boys reporting this pattern. Among non-vegetarian foods, chicken and fish were the most frequently consumed. Weekly fish consumption was reported by 72.5% of 10–12 years, 68% of 13–15 years, and 80% of 16–18 years boys. These patterns suggest that although overall dietary diversity is low, chicken and fish are relatively accessible and culturally preferred protein sources. The mean hemoglobin values of girls (Total n = 66) and boys (Total n = 64) across three age groups. Among girls, the hemoglobin levels were relatively low across all groups: 11.2 g/dl (±0.1) in 10–12 years, 11.4 g/dl (±0.8) in 13–15 years, and 11.2 g/dl (±0.4) in 16–18 years. These values suggest a mild, yet consistent, prevalence of anemia, and the differences were not statistically significant ($p = 0.484$). This may be due to shared dietary patterns, limited intake of iron-rich foods, and poor bioavailability of non-heme iron in predominantly vegetarian diets. For boys, the mean hemoglobin levels remained identical across all age groups at 11.9 g/dl, with slight variations in standard deviations. The differences were statistically non-significant ($p = 0.960$), indicating homogeneity in hemoglobin status across ages. These values, while slightly higher than girls, are still borderline when compared to standard thresholds for adolescent boys, and may reflect similar environmental and dietary influences. A study by Toteja et al. (2006) reported widespread anemia among tribal adolescents, especially among girls, attributing it to inadequate dietary iron intake, menstrual losses, and low socioeconomic status. The lack of statistical significant difference among the three age groups in both genders may also be linked to small group sizes, especially in the 10–12 and 16–18 year age categories, which limits the power to detect differences.

The study concludes that tribal adolescents in Palghar face considerable nutritional and health challenges, driven by chronic dietary inadequacies, lack of dietary diversity, and insufficient awareness of healthy eating practices. Mid-adolescents (13–15 years) and girls emerged as particularly vulnerable subgroups, both in terms of nutritional status and anemia prevalence. While protein intake met recommended levels, energy and key micronutrient deficiencies remained pervasive. The presence of frequent general health complaints further highlights the interplay between undernutrition, low immunity, and poor health-seeking behavior. To address these gaps, there is a pressing need for integrated and culturally sensitive nutrition interventions. These should include school-based nutrition programs, mid-day meals, adolescent health education, and community outreach focused on anemia prevention, dietary diversification, and healthy food recognition. Policymakers and public health practitioners must prioritize this population to prevent long-term consequences related to physical growth, cognitive development, and future productivity.Strengthening awareness at the family and school levels, improving access to diverse foods, and integrating adolescent-friendly health services will be key to achieving sustainable improvements. Continuous monitoring and tailored strategies are essential to ensure long-term impact and to bridge the persistent gaps in tribal adolescent nutrition and health.

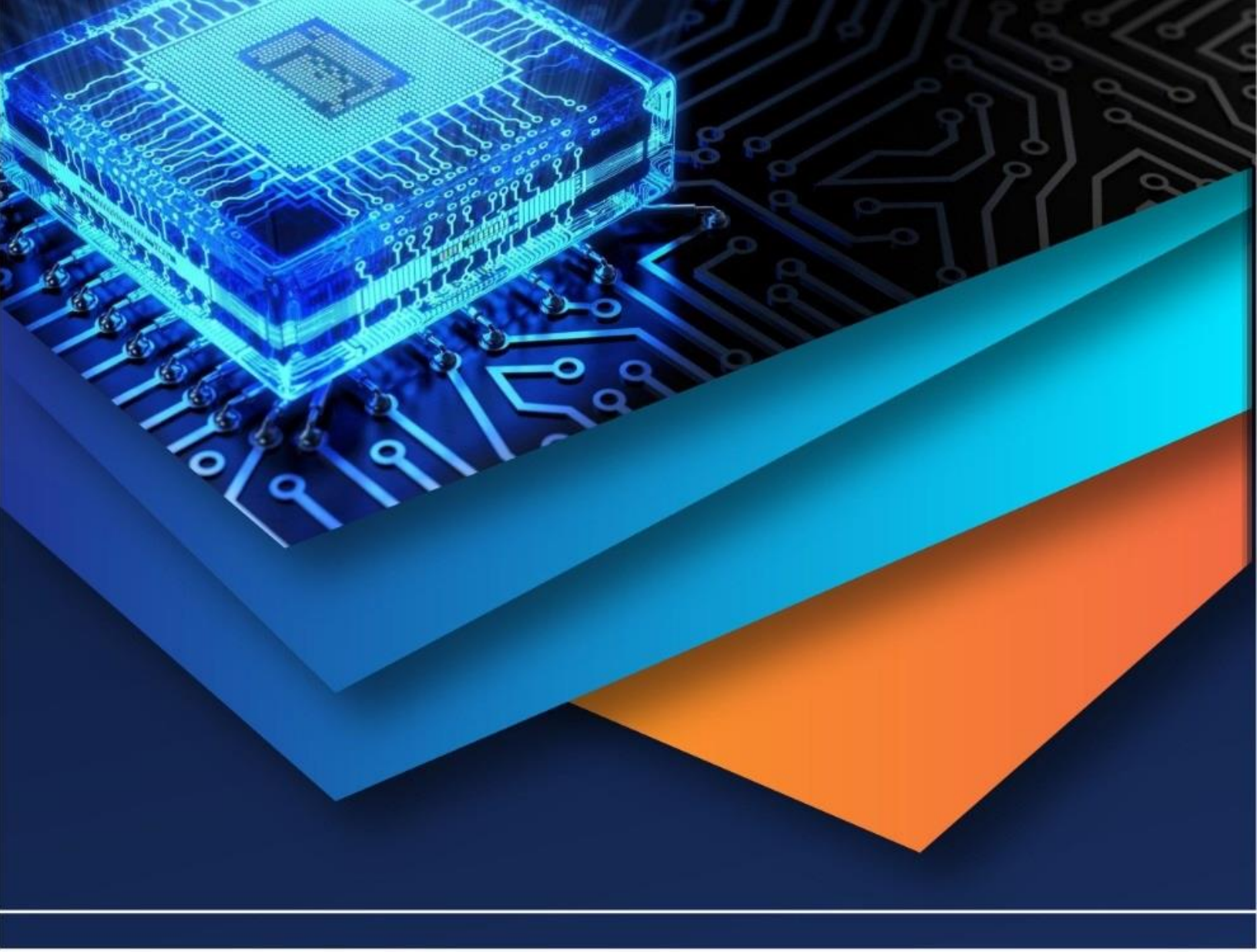
1) Strengths of the Study- First-hand field data collected from a vulnerable and underrepresented tribal population. Age- and gender-wise stratified sampling allowed for comparative analysis. Comprehensive assessment covering anthropometry, dietary intake, hemoglobin, and food behavior. Integration of both quantitative (measurements) and qualitative (dietary habits, food knowledge) aspects.
2) Limitations of the Study- Limited sample size may restrict the generalizability of findings. Hemoglobin estimation was done only in a sub-sample due to logistical constraints. Dietary data was collected using a single 24-hour recall method, which may not fully reflect habitual intake. The sample was restricted to selected residential schools in Palghar district, which may not represent all tribal adolescents in the region.
3) Future Scope of the Study- Expansion of the study to a larger and more diverse tribal population. Longitudinal research to track nutritional outcomes over time. Evaluation of intervention strategies like mid-day meal enhancement, anemia control programs, and nutrition education. Inclusion of biochemical markers beyond hemoglobin to assess micronutrient deficiencies.

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