ORIGINAL RESEARCH ARTICLE

Prevalence and Determinants of Noncommunicable Disease Risk Factors Among the Santal Tribe Residing in Mayurbhanj District, Odisha, India

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ABSTRACT

Background: Noncommunicable disease (NCD) risk factors are rising among tribal groups in India. Nevertheless, this issue remains largely unexamined among the Santal tribe in Mayurbhanj district, Odisha. The objective of the study was to assess the prevalence and determinants of behavioural and selected metabolic risk factors of NCDs among the Santals aged 18 to 69 years in Mayurbhanj district, Odisha.

Methodology: A cross-sectional study using the WHO STEPS instrument was conducted among 516 Santals between January to March 2023. R software was used to perform descriptive analysis and logistic regression.

Results: Tobacco and alcohol use were prevalent among 72.1% and 68.0% of participants, respectively, with higher rates in males and older adults. Low physical activity was reported by 12%, especially among the unmarried and unemployed. 99.2% had inadequate fruit and vegetable intake. 36.0% had hypertension, 29.7% were overweight, 19.6% had abdominal obesity, and 8.5% were obese. Risk factors were significantly associated with age, sex, marital status, employment, and education.

Conclusions: The study indicates a substantial burden of NCD risk factors among the rural Santals, highlighting the need for culturally appropriate interventions promoting dietary diversity, health education, and active lifestyles. Incorporating tribal-specific strategies within existing health programs can help prevent and control NCDs in this population.

Key-words: NCD risk factors, Santals, prevalence, determinants, WHO STEPS, Odisha

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Introduction

Noncommunicable diseases (NCDs) have emerged as the foremost drivers of premature mortality worldwide, contributing to nearly three-quarters of all deaths.[1] Cardiovascular illness, malignancies, chronic respiratory diseases, and diabetes are the four major types of NCDs, responsible for 80% of all premature deaths due to NCDs.[2] Common modifiable behavioural risk factors shared by these diseases include tobacco use, unhealthy diet, physical inactivity, and harmful alcohol drinking, which, over time, cause metabolic alterations significantly increase NCD risk.[3,4] The burden of NCDs is disproportionately higher in low- and middle-income countries, where 73% of these deaths occur.[2]

India is undergoing an epidemiological transition, with NCDs rapidly emerging as a major public health challenge,[5] contributing to 66% of all deaths in the country.[6] This shift is increasingly evident even among the most marginalized groups, especially tribal communities,[5] who comprise of 8.6% of the country's population[7] and largely reside in remote, isolated hilly and underserved regions.[5] There is increasing evidence of an early epidemiological transition in these communities, marked by a rising prevalence of NCDs including cancer, hypertension, and diabetes, driven by rapid urbanization, changing lifestyles, and environmental stressors.[8]

The state of Odisha, located in eastern India, has a substantial tribal presence, with tribal communities constituting 22.8% of the state's population.[7] It is home to 62 tribal groups, each culturally and socially distinct.[9] Among Odisha's progressive indigenous communities, the Santals constitute a major population, positioned as the second most populous tribal group, with 55.6% literacy, a figure exceeding the overall literacy level observed among tribal communities in the state.[10,11] Nearly three-fourths of Odisha's Santal population, resides in Mayurbhanj,[12] a tribal-dominated district home to 30 different tribes.[13] Here, Santals form the largest tribal group and are widely distributed across the landscape.[13] Agriculture remains their primary means of sustenance, often supported by seasonal collection of forest produce. In recent years, a growing number of Santals have been moving to towns and cities in search of livelihood opportunities and improved living conditions.[10,14]

Although NCDs are a growing public health concern in India, evidence on their risk factor burden among tribal populations remains limited. The Santals constitute the most populous indigenous community in Mayurbhanj district, Odisha, holding considerable cultural and demographic importance in this tribal-dominated district. As early signs of NCDs are increasingly recognised among tribal groups amidst India's epidemiological transition, community-specific data on NCD risk factors among tribal groups like the Santals in Mayurbhanj remains scarce. While some research has investigated select behavioural and metabolic risk factors like tobacco consumption, alcohol intake, and hypertension in select indigenous groups of Odisha, no studies have comprehensively assessed the noncommunicable disease risk factors among Santals living in Mayurbhanj using 'WHO STEP-wise approach to noncommunicable disease risk factors surveillance (STEPS)'.[15] Investigating the prevalence as well as the socio-demographic determinants like age, sex, marital status, educational attainment, occupational status, and family income of NCD risk factors is crucial for understanding both the burden and the underlying vulnerabilities. The insights may support in developing context specific targeted approaches and improve NCD prevention and control efforts among tribal groups, particularly the Santals.

The study aimed to assess the prevalence and socio-demographic determinants of common behavioural (tobacco consumption, alcohol use, poor diet, low physical activity) and select metabolic (hypertension and overweight/obesity) risk factors of noncommunicable diseases in Santal tribe residing in Mayurbhanj district, Odisha. This assessment was executed following the 'WHO STEPS'.[15]

This manuscript presents findings from the rural component of a larger study examining NCD risk factors among two distinct groups of the Santal tribal population having the same district of origin: Santal migrants settled and residing in urban areas (Bhubaneswar city), and non-migrant Santals living in rural areas of Mayurbhanj district, Odisha. The findings of the urban component have been published in the 'National Journal of Community Medicine'.[16] The current manuscript focuses exclusively on the rural setting, drawing on a separate set of participants, data, and analysis, with no overlap with the previously published work.

Methodology

Study design, Setting and Population: A community-based survey with cross-sectional design was undertaken between January and March 2023 among Santal tribe members aged 18 to 69 years, who were permanently living in the villages of Khunta block, Mayurbhanj district, Odisha.

Sample size and Sampling methods: The determination of the sample size was guided by a previously reported hypertension prevalence of 15.6% in tribal males from Odisha, based on the fourth round of the 'National Family Health Survey (NFHS-4)'.[17] Allowing a 5% margin of error and a design effect of 2, the initial estimate came to 404. However, to enable gender-specific analysis and adjust for an anticipated 7% non-response, the sample size was increased and finalised at 516. The study employed a multistage sampling approach. The Santals are widely dispersed across Mayurbhanj's rural landscape.[13] In the initial stage of sampling, Khunta block was randomly cho-

sen from among five blocks of Mayurbhanj, with high tribal concentration, where tribal residents constitute 70-80% of the population.[13] In the second stage, 10 villages were randomly selected from a pool of 102 villages of Khunta that had a population above 500, [18] to ensure adequate participant availability and enable smooth implementation of household-level sampling. In the third stage, Santal households were identified within these villages. In the final stage, 52 participants per village were selected from these households. All eligible individuals from the chosen households, who had given consent were included. The first household in each village was selected at random, after which consecutive households were visited until required sample size was achieved.

Data collection Instrument and Procedure: A structure survey was carried out using 'WHO-STEPS' (version 3.2) instrument.[15] The tool was adapted to suit the study area's context and translated in Odia language. A pilot-testing of the tool was done prior to the data collection. Risk factors were assessed in two successive steps. The first step involved in assessing the behavioural risk factors: tobacco and alcohol use, low physical activity and inadequate fruits and vegetables intake. In the second step, physical parameters were measured to estimate body mass index (BMI), abdominal obesity, and blood pressure (BP) was measured to detect hypertension. Trained investigators conducted face-to-face interviews with the eligible household members using KoBo Toolbox. All procedures strictly adhered to the WHO STEPS standard operating guidelines. Anthropometric measurement included height that was measured by portable stadiometer (precision: 0.1 cm) and weight, was recorded by a flat electronic weighing scale having accuracy to 100 grams. Waist circumference (WC) was assessed using a flexible, retractable measuring tape equipped with tension control, manufactured by SECA. Blood pressure measurements were obtained using digital sphygmomanometer (OMRON model HEM 7120). Three readings at three-minute intervals were recorded, and the average of the last two measurements was used to determine the participant's blood pressure level. All field investigators were trained uniformly based on standardized protocols before the data collection to ensure the reliability and validity of the data. Regular on-site supervision and systematic data validation was conducted during field work for maintaining inter-observer reliability and ensuring accuracy of the data.

Operational definitions used: In accordance with the cut-off values recommended in the WHO STEPS guidelines,[15] behavioural risk factors were defined. Participants were classified as current tobacco users if they had used smoked or smokeless tobacco, at any point in the past 30 days. Likewise, alcohol use was deemed current if the individual consumed any alcoholic drinks during the past 12 months. Fruit and vegetable intake was categorized as inadequate when consumption totalled fewer than five servings per day. Physical activity was measured documenting various activity types, intensity level of the activity and duration. These data were used to calculate 'metabolic equivalents' (METs). Based on these values, physical activity was grouped into three categories: low physical activity (<600 'MET-minutes/week'), moderate physical activity (600 - 2999 'MET-minutes/week'), and high physical activity (≥3000 'MET-minutes/week').[19] Nutritional status was evaluated using body mass index (BMI) cut-offs recommended for Asians. Individuals with a BMI ranging from 23.0 to and 24.99 kg/m^2 were categorised as overweight, while those with a BMI of 25 kg/m^2 or higher were classified as obese. Definitions of abdominal obesity were based on waist circumference cut-off values, specifically ≥90 cm for males and ≥80 cm for females.[20] Hypertension was characterised by having a systolic BP ≥140 mm Hg, or a diastolic BP ≥90 mm Hg, or ongoing use of prescribed medications to control blood pressure.[21]

Ethical Consideration: This research received formal clearance from the Doctoral Committee of SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu. Additionally, ethical permission was secured from the Institutional Ethics Committee at Kalinga Institute of Medical Sciences, Bhubaneswar (Ref: KIIT/KIMS/IEC/773/2021, dated 09 December 2021). Further approval was granted by the Research and Ethics Committee under the Department of Health and Family Welfare, Government of Odisha. Before initiating data collection, all participants provided informed consent after being informed of the study's purpose, their voluntary involvement, and their right to withdraw at any time.

Statistical Analysis: The data were initially compiled and cleaned using Microsoft Excel 2011, followed by statistical analysis using R statistical software (version 4.4.1). Descriptive summaries were generated to present the socio-demographic profile of participants. Group-wise differences were tested using the chi-square test. The prevalence of non-communicable diseases risk factors was estimated along with 95% confidence intervals to account for variation across subgroups.

Associations between NCD risk factors and socio-demographic characteristics were assessed using bivariate and multiple logistic regression analyses, calculating unadjusted and adjusted odds ratios (ORs and AORs) respectively. Variables having a *p*-value <0.10 during the bivariate phase were selected for entry into the multiple logistic regression analysis.

RESULTS

Although data were collected from 520 participants, analysis was performed on the pre-determined sample of 516 individuals.

Details of socio-demographic background of study participants of Khunta block, Mayurbhanj district,

Odisha are shown in Table 1. A significant proportion of participants (70.7%) fell within the 18 and 44 years age group, indicating a young and working-age population (average age: 38.58 years; SD=12.24 years). Males accounted for 58.1% of the respondents. Almost half of the respondents finished primary schooling, while about 22% had attained secondary or higher education. A significant gender difference was found in marital status, with a higher proportion of females currently married. Work participation was high (81.6%), and similar across genders. A significant income disparity was noted between males and females, with a larger proportion of females earning less than ₹1 lakh annually. For details, refer to Table 1.

Table 2 presents the prevalence of key noncommunicable disease risk factors among the surveyed population. Current tobacco use and alcohol consumption were highly prevalent and were reported by 72.1% (95% CI: 68.0-75.9) and 68.0% (95% CI: 63.8-72.0) of respondents, respectively, with significantly higher rates among males and older adults. A total of 12.0% (95% CI: 9.40-15.2) of respondents exhibited low levels of physical activity, with much greater rates among the unemployed and currently unmarried individuals. 99.2% (95% CI: 97.9–99.8) of respondents reported not eating adequate fruits and vegetables (< 5 servings per day). Hypertension was found in 36.0% (95% CI: 31.9 – 40.4%) of study population, with significantly higher rates among older and working individuals. 19.6% had abdominal obesity with significantly more common among females. 29.7% (95% CI: 25.8-33.8) of respondents were overweight, this was more prevalent in males and higher-income groups. Although obesity prevalence was lower (8.5%), it was notably higher among non-working individuals. Refer to Table 2 for detailed estimates and subgroup comparisons.

The relationship between socio-demographic characteristics and NCD risk factors is presented in tables 3 & 4. Older adults aged 45-69 years were more likely than younger participants to use tobacco (AOR: 6.56, 95% CI: 3.69 - 12.5) and alcohol (AOR: 4.19, 95% CI: 2.53 - 7.19), and to have hypertension. Male respondents had higher odds of tobacco use, alcohol consumption, and overweight, but were less likely to exhibit abdominal obesity, compared to females. Low physical activity was strongly associated with unemployment (AOR: 12.9, 95% CI: 6.24 -27.6). Furthermore, overweight was more prevalent among individuals with no formal education, and abdominal obesity was more common among married participants. Refer tables 3 and 4 for details.

For the outcome variables, "inadequate intake of fruits and vegetables" and "obesity," only a single predictor met the eligibility criterion ($p < 0.10$) in bivariate testing. As a result, these variables were excluded from further analysis using multiple logistic regression.

Table 1: Socio-demographic characteristics of Santal tribe respondents in Mayurbhanj district, Odisha

Variables	Female (n=216) (%)	Male (n=300) (%)	Total (N=516) (%)	*p* value
Age group (in years)				
18-44	139 (64.4)	226 (75.3)	365 (70.7)	0.007
45-69	77 (35.6)	74 (24.7)	151 (29.3)	
Educational Status				
No formal schooling	66 (30.6)	87 (29.0)	153 (29.7)	0.889
Primary school	102 (47.2)	148 (49.3)	250 (48.4)	
Secondary school & above	48 (22.2)	65 (21.7)	113 (21.9)	
Marital status				
Currently not married	50 (23.1)	99 (33.0)	149 (28.9)	< 0.001
Currently married	164 (75.9)	169 (56.3)	333 (64.5)	
Refused	2 (0.9)	32 (10.7)	34 (6.6)	
Working status				
Working	178 (82.4)	243 (81.0)	421 (81.6)	0.684
Not working	38 (17.6)	57 (19.0)	95 (18.4)	
Annual income				
Less than Rs. 1 lakh	209 (96.8)	257 (86.5)	466 (90.8)	< 0.001
Rs. 1 Lakhs and above	7 (3.2)	40 (13.5)	47 (9.2)	

DISCUSSION

This study reveals a high burden of modifiable noncommunicable disease (NCD) risk factors among the rural Santal tribal population in Mayurbhanj, Odisha. Among the various behavioral and metabolic risk factors assessed, inadequate fruit and vegetable intake, tobacco and alcohol use emerged as the most widespread and pressing concerns. These behaviors are particularly notable not only for their high prevalence, but also for their deep socio-cultural roots and potential for meaningful intervention through tailored public health strategies. While other risk factors such as hypertension, obesity and overweight were also present, the cultural entrenchment and ubiquity of poor dietary practices, tobacco and alcohol consumption warrant deeper analysis. Understanding the cultural, economic, and environmental factors driving these behaviors is essential for designing effective and context-specific public health strategies for the Santal community.

Table 2: Prevalence of risk factors of NCDs among Santal tribal respondents in Mayurbhanj district, Odisha (N=516)

Variables	Tobacco use (current) % (95% CI)	Alcohol use (current) % (95% CI)	Low physical activity % (95% CI)	Inadequate intake of fruits & vegetables % (95% CI)	Hypertension % (95% CI)	Abdominal obesity % (95% CI)	Overweight % (95% CI)	Obesity % (95% CI)
Age group (in years)								
18-44	64.4* (59.2 - 69.3)	61.1* (55.9 - 66.1)	15.1* (11.6 - 19.3)	99.7 (98.2 - 100.0)	32.1* (27.3 - 37.1)	17.5 (13.9 - 21.9)	35.9* (31.0 - 41.1)	9.6 (6.86 - 13.2)
45-69	90.7 (84.6 - 94.6)	84.8 (77.8 - 89.9)	4.6 (2.05 - 9.68)	98.0 (93.9 - 99.5)	45.7 (37.6 - 54.0)	24.5 (18.0 - 32.3)	14.6 (9.55 - 21.4)	6.0 (2.94 - 11.4)
Sex								
Female	63.4 *(56.6 - 69.8)	56.5* (49.6 - 63.1)	8.8 (5.52 - 13.6)	99.1 (96.3 - 99.8)	36.1 (29.8 - 42.9)	39.4* (32.9 - 46.2)	9.3* (5.89 - 14.1)	10.2 (6.63 - 15.2)
Male	78.3 (73.2 - 82.8)	76.3 (71.0 - 80.9)	14.3 (10.7 - 18.9)	99.3 (97.3 - 99.9)	36.0 (30.6 - 41.7)	5.3 (3.18 - 8.69)	44.3 (38.7- 50.2)	7.3 (4.76 - 11.0)
Educational Status								
No formal schooling	75.8 (68.1 - 82.2)	68.0 (59.9 - 75.1)	12.4 (7.83 - 19.0)	99.3 (95.9 - 100.0)	29.4*(22.5 - 37.4)	16.3 (11.0 - 23.4)	28.8 (21.9 - 36.7)	11.1 (6.80 - 17.5)
Primary school	69.2 (63.0 - 74.8)	69.2 (63.0 - 74.8)	10.4 (7.03 - 15.0)	98.8 (96.2 - 99.7)	46.4(40.1 - 52.8)	19.6(15.0 - 25.2)	32.8 (27.1 - 39.0)	8.0 (5.08 - 12.3)
Secondary school & above	73.5 (64.2 - 81.1)	65.5 (55.9 - 74.0)	15.0 (9.26 - 23.3)	100.0 (95.9 - 100.0)	22.1 (15.1 - 31.1)	23.9 (16.6 - 33.0)	23.9 (16.6 - 33.0)	6.2 (2.74 - 12.8)
Marital Status								
Currently married	72.7 (67.5 - 77.3)	68.5 (63.1 - 73.4)	6.3*(4.04 - 9.62)	99.1 (97.2 - 99.8)	38.7 (33.5 - 44.2)	24.6* (20.2 - 29.7)	21.9* (17.7- 26.8)	8.4 (5.76 - 12.1)
Currently not married	65.8 (57.5 - 73.2)	63.8 (55.4 - 71.4)	22.8 (16.5 - 30.6)	100.0 (96.9 - 100.0)	29.5 (22.5 - 37.6)	9.4 (5.42 - 15.6)	41.6 (33.7- 50.0)	9.4 (5.42 - 15.6)
Work Status								
Working	73.2 (68.6 - 77.3)	70.5*(65.9 - 74.8)	4.5* (2.81 - 7.08)	99.0 (97.4 - 99.7)	38.7*(34.1 - 43.6)	19.7 (16.1 - 23.9)	30.2 (25.9 - 34.8)	7.1* (4.94 - 10.1)
Not working	67.4 (56.9 - 76.4)	56.8 (46.3 - 66.8)	45.3 (35.1 - 55.8)	100.0 (95.2 - 100.0)	24.2 (16.3 - 34.3)	18.9 (11.9 - 28.6)	27.4 (19.0 - 37.6)	14.7 (8.58 - 23.8)
Annual Income								
Less than Rs. 1 lakh	71.2 (66.9 - 75.3)	67.4 (62.9 - 71.6)	11.8 (9.09 - 15.2)	99.1 (97.7 - 99.7)	36.3 (31.9 - 40.8)	20.4 (16.9 - 24.4)	27.9* (23.9- 32.2)	8.2 (5.91 - 11.1)
Rs. 1 Lakh and above	78.7 (63.9 - 88.8)	72.3 (57.1 - 83.9)	12.8 (5.30 - 26.4)	100.0 (90.6 - 100.0)	31.9 (19.5 - 47.3)	8.5 (2.76 - 21.3)	42.6 (28.6 - 57.7)	12.8 (5.30 - 26.4)
Overall	72.1 (68.0 - 75.9)	68.0 (63.8 - 72.0)	12.0 (9.40 - 15.2)	99.2 (97.9 - 99.8)	36.0 (31.9 - 40.4)	19.6 (16.3 - 23.3)	29.7 (25.8 - 33.8)	8.5 (6.33 - 11.4)

*Denotes a statistically significant (p<0.05) difference observed between sub-groups. CI: Refers to Confidence Interval

Table 3: Predictors of noncommunicable disease risk factors among Santal adults in Mayurbhanj district, Odisha: Results of bivariate logistic regression analysis (N=516)

Variables	Tobacco use (current)		Alcohol use (current)		Low physical activity		Inadequate intake of fruits & vegetables		Hypertension		Abdominal obesity		Overweight		Obesity	
	OR(95% CI)	*p*-value	OR(95% CI)	*p*-value	OR(95% CI)	*p*-value	OR(95% CI)	*p*-value	OR(95% CI)	*p*-value	OR(95% CI)	*p*-value	OR(95% CI)	*p*-value	OR(95% CI)	*p*-value
Age group (in years)																
18-44	1		1		1		1		1		1		1		1	
45-69	5.41(3.10-10.2)	<0.001	3.54(2.20-5.91)	<0.001	0.27(0.11-0.58)	0.002	0.14(0.01-1.07)	0.085	1.78(1.21-2.63)	0.003	1.53(0.96-2.41)	0.071	0.3(0.18-0.49)	<0.001	0.6(0.26-1.22)	0.2
Gender																
Female	1		1		1		1		1		1		1		1	
Male	2.08(1.41-3.09)	<0.001	2.49(1.71-3.64)	<0.001	1.73(0.99-3.13)	0.059	1.39(0.17-11.7)	0.7	1.0(0.69-1.43)	>0.9	0.09(0.05-0.15)	<0.001	7.8(4.77-13.4)	<0.001	0.7(0.37-1.30)	0.3
Educational Status																
Secondary & above	1		1		1		NA		1		1		1		1	
No formal schooling	1.13(0.65-1.98)	0.7	1.12(0.67-1.87)	0.7	1.73(0.99-3.13)	0.059	NA		1.47(0.84-2.60)	0.2	0.62(0.34-1.14)	0.13	1.29(0.74-2.26)	0.4	1.89(0.79-5.05)	0.2
Primary school	0.81(0.49-1.32)	0.4	1.18(0.74-1.89)	0.5	0.66(0.34-1.28)	0.2	NA		3.05(1.85-5.15)	<0.001	0.78(0.46-1.34)	0.4	1.55(0.95-2.61)	0.088	1.32(0.56-3.44)	0.5
Marital status																
Currently not married	1		1		1		1		1		1		1		1	
Currently married	1.38(0.91-2.09)	0.13	1.23(0.82-1.85)	0.3	0.23(0.13-0.41)	<0.001	NA		1.51(1.00-2.30)	0.052	3.15(1.77-5.99)	<0.001	0.39(0.26-0.60)	<0.001	0.89(0.46-1.78)	0.7
Work status																
Working	1		1		1		NA		1		1		1		1	
Not working	0.76(0.47-1.24)	0.3	0.55(0.35-0.87)	0.010	17.5(9.62-32.9)	<0.001	NA		0.51(0.30-0.83)	0.009	0.95(0.53-1.65)	0.9	0.87(0.52-1.42)	0.6	2.25(1.11-4.37)	0.019
Annual income																
< Rs. 1 lakh	1		1		1		NA		1		1		1		1	
≥ Rs. 1 Lakhs	1.49(0.75-3.25)	0.3	1.27(0.66-2.55)	0.5	1.09(0.40-2.52)	0.8	NA		0.82(0.42-1.54)	0.6	0.36(0.11-0.93)	0.058	1.91(1.03-3.52)	0.038	1.65(0.60-3.88)	0.3

OR: Unadjusted Odds Ratio, NA: Logistic regression was not conducted due to limited variability in the outcome variable.

Table 4: Predictors of noncommunicable disease risk factors among Santal adults in Mayurbhanj, Odisha: Results of multiple logistic regression analysis (N=516)

Variables	Current tobacco use AOR(95% CI)	Current alcohol use AOR(95% CI)	Low physical activity AOR(95% CI)	Hypertension AOR(95% CI)	Abdominal obesity AOR(95% CI)	Overweight AOR(95% CI)
Age group (in years)						
18-44	1	1	1	1	1	1
45-69	6.56*(3.69-12.5)	4.19*(2.53-7.19)	0.53(0.19-1.34)	2.05*(1.31-3.24)	1.25(0.73-2.13)	0.35*(0.18-0.62)
Gender						
Female	1	1	1	1	1	1
Male	2.66*(1.76-4.05)	3.13*(2.09-4.71)	1.31(0.65-2.69)	a	0.08*(0.04-0.15)	5.79*(3.43-10.2)
Educational Status						
Secondary school & above	1	1	1	1	1	1
No formal schooling	a	a	2.03(0.79-5.33)	1.02(0.54-1.97)	a	2.54*(1.26-5.29)
Primary school	a	a	1.71(0.74-4.10)	2.77*(1.61-4.94)	a	2.62*(1.41-5.05)
Marital status						
Currently not married	1	1	1	1	1	1
Currently married	a	a	0.6(0.29-1.26)	1.22(0.77-1.94)	2.62*(1.39-5.22)	0.54*(0.33-0.87)
Work status						
Working	1	1	1	1	1	1
Not working	a	0.67(0.41-1.09)	12.9*(6.24-27.6)	0.68(0.36-1.24)	a	a
Annual income						
Less than Rs. 1 lakh	1	1	1	1	1	1
Rs. 1 Lakh and above	a	a	a	a	0.84(0.22-2.64)	1.42(0.67-2.95)

AOR: Adjusted Odds Ratio, * denotes statistically significant p< 0.05 difference observed between sub-groups, a: Variables with *p*-value exceeding 0.1 in unadjusted model, were not retained in the multiple logistic regression analysis

A strikingly high proportion of the Santal population (99.2%) reported inadequate consumption of fruits and vegetables, mirroring a similar trend identified among the Kani tribe in Kerala,[19] where none of the participants met the recommended dietary criteria. This level of inadequacy also exceeded that reported for several tribal groups in northeastern India, including the rural tribe of Nagaland,[22] and the Mishing tribe of Assam[23]. The National NCD Monitoring Survey (NNMS, 2017-18),[24] reported that 98.4% of adults consumed less than the recommended five daily servings of fruits and vegetables, suggesting that this nutritional shortfall transcends population groups across India. However, the persistence of this deficiency among the Santals may be attributed to a distinct set of socio-cultural, economic, and environmental factors that warrant deeper attention. An anthropological study examining the food habits of the Santals in Mayurbhanj,[25] suggests that their dietary patterns are largely shaped by the availability of local resources and their dependence on seasonal subsistence farming and foraging. Other structural barriers, such as poverty, high market prices, and culturally ingrained dietary norms, which prioritize staples like rice and forest-derived foods, collectively restrict their intake of fruits and vegetables, reinforcing this persistent gap. Given the limited literature on the socio-cultural dimensions of tribal diets, particularly among the Santals, further exploratory qualitative research is essential to gain a comprehensive understanding of this dietary inadequacy and reduce long-term NCD risk factors in this population.

When contextualized within national data, the prevalence of tobacco use among Santals (72.1%) is more than double the national average of 32.8%,[24] indicating a severe, localized challenge. This rate is also higher than that reported for the general population of Odisha,[26] and tribal groups in Madhya Pradesh,[27] yet lower than the extreme levels documented among the Kani tribe in Kerala,[19] and the Nicobarese tribe[28]**.** Predominantly, one of the main reasons of high tobacco consumption among Santals may be due to its strong cultural acceptance and integration within traditional practices and social beliefs, patterns commonly seen across other tribes India.[29] To better understand these socio-cultural drivers, further ethnographic studies are required focusing social reinforcement of tobacco use within tribal contexts.

Similarly**,** use of alcohol among Santals (68%) far exceeded the national average of 15.9%,[24] and was also higher than that noticed among in other tribal groups, including the Mishing tribe of Assam**,** [23] the Kinnaur tribe of Himachal Pradesh,[30] and tribes in rural Nagaland.[22] Among Santals, men reported higher usage, mirroring trends seen among the Mishing, [23] and Kinnaur tribes.[30] Alcohol consumption rate among Santal males notably surpassed that observed in Odisha's overall male population.[31] This extensive use is likely driven by deep-seated cultural and traditional practices**,** such as the consumption of rice beer (*handia*) during festivals and rituals, leading to its social acceptability and routine use.[10] However, consumption levels in Santals remained substantially less compared to the Munda tribe of Odisha, where nearly universal consumption rates were documented.[32] Eventhough, both the Munda and Santal tribes belong to similar geographic and agro-ecological environments in Odisha, the Munda have a longer-documented cultural tradition of alcohol integration into daily life and social rituals. In addition to consuming *handia*, they also brew *mahuli*, at home by converting food grains making it more affordable and accessible thus reinforcing their routine consumption.[32]

Although overall low physical activity was less prevalent in this community, it was higher among the unemployed and slightly elevated in younger adults. The rate was lower than in Uttarakhand's Rang Bhotia tribe,[33] but higher than in Kerala's Kani tribe.[19] Unemployed Santals were more likely to report inactivity compared to their employed counterparts, suggesting that awareness campaigns, community games, and group exercises may help promote active lifestyles in these subgroups.

Hypertension prevalence among Santals in Mayurbhanj surpassed that of the Sabar and Munda tribes of Odisha,[34] rural Tripura tribes,[35] Assam's Mishing tribe,[23] as well as the national average,[24] yet remained below the rates reported for Uttarakhand's Bhutia tribe,[33] and tribal groups in Trissur, Kerala.[36] Santal men and women also showed higher prevalence than rural Odia counterparts, [31] but far lower than the levels in the Langia Saora tribe (63 % in men, 68 % in women).[37] As in tribal populations of Kashmir, hypertension rose sharply with advancing age in our sample.[38]

Abdominal obesity was found in approximately one-fifth of the study participants, with females having a much higher prevalence. The overall prevalence was higher than that reported in Assam's Mishing tribe,[23] it remained lower than rate of abdominal obesity documented in the Tripura's tribe.[35] The high prevalence of abdominal obesity among Santal women is consistent with the findings from study on tribe in Thrissur Kerala.[36]

About 30 % of Santals were overweight, higher than in Kerala's Kani tribe[19] and for tribes in Birbhum,[39] yet below than those observed in Assam's Rengma-Naga,[40] and Nagaland's Mokokchung populations[22]. Among all risk factors of NCDs, obesity emerged as the least frequetntly reported, with a marginally higher occurrence noted among the unemployed individuals, but still lower than rates observed in the Rengma-Naga tribe[40] and rural Odisha[31]. Although the probable causes of overweight among Santals were not assessed, underlying lifestyle or socioeconomic factors may have played contributory roles, and thus warrant further investigation

The Santals unlike Odisha's general population exhibit uniquely challenging NCD risk profile driven by a combination of cultural norms and socio-economic disadvantages. Increased alcohol consumption (handia) along with widespread social use of tobacco reflect deep-seated cultural practices reinforcing high-risk behaviors. Moreover, structural vulnerabilities such as low formal education, limited income, further exacerbate the situation likely contributing to poor health literacy and reduced uptake of healthy habits. This complex amalgamation of long-standing traditional practices and and systemic deprivation, makes the Santal population distinct highlighting the need for targeted and culturally informed public health strategies.

The nutritional inadequacies observed in our study point to the need for augmenting the promotion of dietary diversity and sustainable food practices such as kitchen gardens, as well as the intensification of nutrition-related awareness in tribal areas. Further strengthening of the already existing Poshan Abhiyan through the incorporation of a tribal-specific component, aligning with local food systems and cultural practices, could be attempted. Additionally, the high prevalence of tobacco consumption highlights the need to intensify existing regulatory efforts under the National Tobacco Control Programme (NTCP), with targeted enforcement and behavior change campaigns tailored to tribal contexts. Our study findings also emphasize the need to enhance the screening, early detection, and management of NCDs in tribal areas by incorporating culturally appropriate approaches within the existing National Programme for Prevention and Control of Noncommunicable Diseases (NP-NCD) to effectively address the unique health needs of tribal populations.

Limitations

As the study involved interviewer-administered questionnaires, some behavioural risk factors may have been underreported due to socially desirable responses. Respondents' self-reported health behaviours may also have introduced recall bias. These limitations were mitigated by: involving interviewers who had all been trained uniformly; using standardized WHO STEPS instrument for data collection; employing seasoned interviewers with post graduate qualification in public health or anthropology from the same district to enhance trust and rapport with the participants, thereby encouraging candid responses, and ensuring confidentiality by conducting one-to one interviews at household level. We acknowledge the limitation of insufficient variability in the outcome variable i.e. inadequate fruit and vegetable intake, for inclusion in regression analysis; accordingly, we suggest qualitative follow-up studies to explore the underlying determinants of this behaviour. We also acknowledge the limitation of the cross-sectional study design in inferring causality; therefore, we suggest longitudinal studies for future research.

Conclusion

The study revealed a high burden of noncommunicable disease risk factors among the Santal tribal population in rural Mayurbhanj, Odisha. The most prevalent were inadequate fruits and vegetables intake, tobacco use, and alcohol consumption, especially among older adults and males. Although low physical activity was less common overall, it was more prevalent among unemployed and unmarried individuals. Hypertension was another significant concern, especially among older adults and working people. Overweight and abdominal obesity were major problems,

particularly among men and women, respectively. Age, gender, employment status, marital status, and education were identified as key determinants influencing most of the NCD risk factors. These findings underscore the need for culturally appropriate interventions that focus on health education, dietary diversity, and promotion of active lifestyles, while recognizing education as a key contributor to long-term health improvement. The findings also advocate for augmenting nutrition awareness through initiatives like kitchen gardens under the tribal-specific Poshan Abhiyan; intensifying tobacco control within NTCP, and incorporating culturally appropriate strategies into the NP-NCD to enhance early detection and management of NCDs in tribal areas.

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Availability of Data: The Data that support the findings of this study are available upon reasonable request from the corresponding author due to privacy/ethical restrictions.

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