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Hemoglobin Status and Iron Deficiency in Non-Smoking Nicotine Consumers in Selected Area of Sugarcane Cutter Workers in Kolhapur and Pune District

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Abstract

The prevalence of anemia and its association with nutritional deficiency is known, but underlaying factors such as socio-cultural factors, nicotine consumption and consumption of food groups that inhibits absorption of iron by hemoglobin remains poorly studied. This study investigated the relationship between tobacco use, hemoglobin (Hb) levels, and nutritional status among sugarcane cutters in Kolhapur and Pune districts of Maharashtra.

Total 86 participants were considered as final sampling population [Kolhapur (N=48), Pune (N=38)]. Out of 86 participants, 54 were non-smoking but tobacco chewing nicotine consumers and 32 were nicotine non-consumers. The percentage of oxygen-saturated hemoglobin were measured using pulse oximeter and the hemoglobin measurements were recorded via the Hemo Spark Blood Hemoglobin Measuring Meter. Tobacco consumption patterns were assessed through questionnaire referred from Global Adult Tobacco Survey, the Fagerstrom Test for Nicotine Dependence Smokeless-Tobacco and the Tobacco Staining Index, which categorized dental stains based on visual assessment.

Tobacco consumers has a higher prevalence of severe anemia compared to non-consumers. Out of 54 chewing tobacco consumers, 34 were anemic, with 12 individuals falling into severe anemia category. In contrast, out of 32 non-tobacco consumers, 13 were anemic, with only 3 individuals falling into severe anemia category. Individuals who are chronic tobacco consumers with high GATS and TSI scores showed significantly lower hemoglobin levels. Dietary assessment showed that 15 tobacco users consumed high amount of iron inhibitor food products like tea, coffee and calcium rich food products had lowest mean hemoglobin value of 8.78 g/dL. 38 anemic individuals had education only up to primary level or were illiterate which limits their access to health related problems. Among females, 17 participants reported anemic and practicing cultural fasting at least once a week. This revels that, chronic smokeless tobacco use, along with poor nutrition and socio-cultural practices, is significantly associated with prevalence and severity of anemia.

Introduction

Anemia represents a widespread public health issue that impacts individuals across all age groups, with a global prevalence rate of 32.8% recorded in 2010 (Kassebaum et al, 2014). The peak prevalence of anemia occurred during the post-neonatal period, subsequently affecting children aged 1 to 4 years. The causes of anemia are varied and include nutritional factors such as deficiencies in iron, folic acid, and other micronutrients, genetic conditions affecting hemoglobin like thalassemia and hemoglobinopathy, as well as glucose-6-phosphate dehydrogenase (G-6-PD) deficiency, and infectious diseases, particularly parasitic infections (Balarajan et al., 2011). Worldwide, the primary contributor to anemia is iron deficiency, which is estimated to represent around 50% of all cases of anemia *(Chatpat Kongpan et.al., 2014.*

Anemia is characterized by a hemoglobin concentration of less than 11.5 g/dl in children aged 5 to 11.9 years and less than 12.0 g/dl in those aged 12 to 14.9 years (WHO, 2008). Anemia represents a significant public health challenge that affects individuals throughout their lifespan, particularly among school-aged children, with a global prevalence rate of 24.5% (WHO, 2008). Anemia poses a significant health challenge for women of reproductive age in developing nations. The global estimates of anemia prevalence by the World Health Organization averaged 56%, with variations between 35% and 75% based on geographic location *(Panyang et al., 2018).*

Iron is essential for hemoglobin synthesis. Without sufficient iron, hemoglobin levels decrease, leading to anemia, which impairs the body's ability to oxygenate tissues *(Hentze et al., 2010)*. Hemoglobin synthesis and iron absorption are regulated by erythropoietin and hepcidin. Vitamin C enhances absorption, while phytates and tannins inhibit it. In populations with diets low in bioavailable iron, deficiencies are common, particularly when combined with high physical activity demands *(Grotto, 2010)*. Without adequate iron, the body cannot produce sufficient hemoglobin, leading to anemia *(Hentze et al., 2010).*

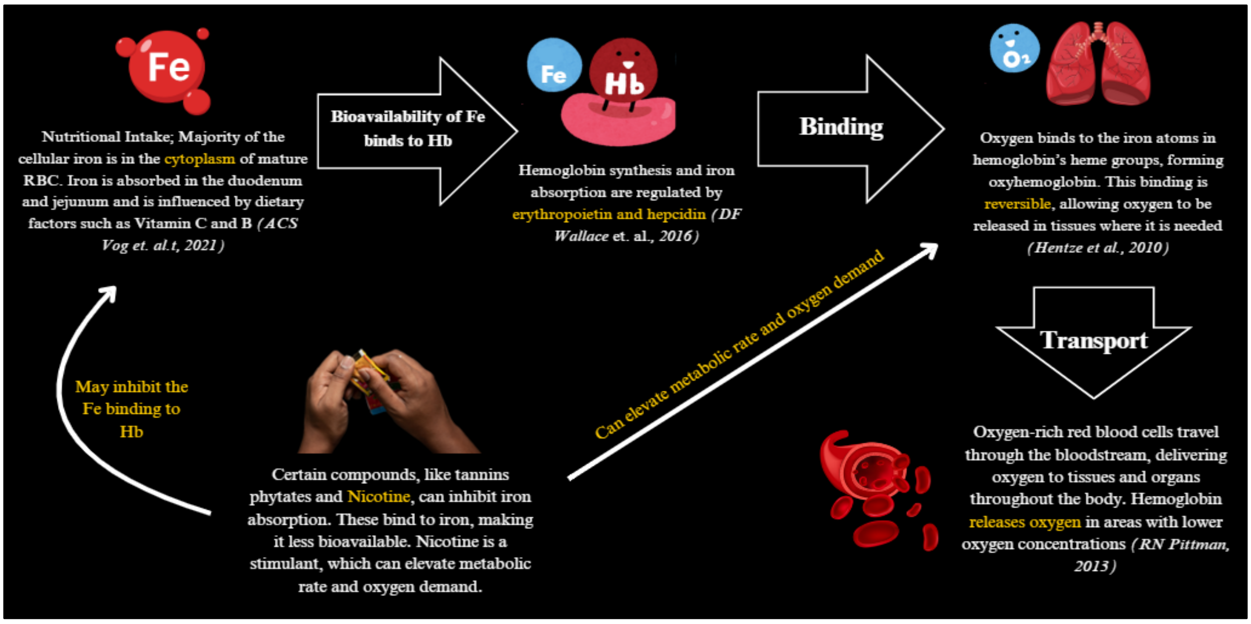

Fig. 1. Relation between Hemoglobin, Oxygen and Iron on cellular level

Hemoglobin is a protein comprised of four subunits: two alpha subunits and two beta subunits. Each subunit has a haem group in the center that contains iron and binds one oxygen molecule. This means each hemoglobin molecule can bind four oxygen molecules, forming oxyhemoglobin. Hemoglobin molecules with a greater number of oxygen molecules bound are brighter red. This is why oxygenated arterial blood is brighter red and deoxygenated venous blood is darker red. Hemoglobin changes shape based on the number of oxygen molecules bound to it. The change in shape also alters its affinity to oxygen. As the number of oxygen molecules bound to haemoglobin increases, the affinity of haemoglobin for oxygen increases. This is known as cooperativity *(Edelstein, 1975)*. When no oxygen is bound, the haemoglobin is said to be in the Tense State (T-state), with a low affinity for oxygen (Tape, 1999). At the point where oxygen first binds, the hemoglobin alters its shape into the Relaxed State (R-state), which has a higher affinity for oxygen (QH Gibson, 1999).

Tobacco is the dried and processed leaves of the nicotine rich plant *Tobacum Linn* which is cultivated in America and some West African countries. It is yellowish brown in colour with a strong odor and bitter taste. The main content of tobacco is nicotine. It has no use in Medicine though it is of val ue chiefly as an insecticide *(Feyerabend and Russell 1979)*. Tobacco snuff is in powered form with potash and sweeteners as the main additives. Nicotine has a stimulatory effect on the autonomic nervous system which causes raised blood pressure and pulse rates *(Cryer et al, 1976)*. It is a stimulant found in tobacco, affects cardiovascular and respiratory functions. It binds to nicotinic acetylcholine receptors, increasing dopamine release, and inducing a sense of alertness. However, nicotine's vasoconstrictive effects limit oxygen supply to tissues, reducing oxygen availability *(Benowitz, 2009)*.

The state of Maharashtra is divided into five distinct regions, each exhibiting variations in the health status of women. Anemia stands out as a significant health concern for women of reproductive age in Maharashtra, highlighting the necessity to investigate the regional differences within the state's various areas. Anemia represents a significant public health challenge worldwide, impacting individuals across all age groups in both developing and developed nations. Women who are of reproductive age, as well as those who are pregnant, face a significant risk of anemia, which can lead to increased maternal morbidity and mortality. Anemia stands out as a prevalent nutritional disorder, holding significant public health implications, particularly in developing nations such as India. Anemia stands as the most prevalent nutritional issue and frequently affects women of reproductive age. The occurrence of anemia in pregnant women, resulting in early delivery and reduced birth weight *(Rishipathak et al., 2018)*. The Marathwada area plays a crucial role in the overall count of individuals who engage in seasonal migration both within and beyond Maharashtra for the purpose of cane cutting. Annually, it is observed that 40 percent of migrants hailing from Maharashtra originate specifically from Beed, with Ahmednagar district contributing 14-15% to this demographic *(Oxfam International, 2020)*.

Maharashtra's sugarcane food industry, which employs 1.66 million workers annually, is majorly depends on seasonal migrants from the Marathwada region. These laborers are forced to work in harsh conditions and have little or no access to healthcare, face a higher risk of iron deficiency anemia (IDA). Along with labour issues of sugarcane cutters it would be important to highlight that sugarcane cutters are migrating along with their children. This is the reason where sugarcane cutters are away from micronutrients required for the body. These conditions of sugarcane cutter workers of Maharashtra raise few questions; What is the incidence of iron deficiency anemia among sugarcane cutter workers of the Marathwada region of Maharashtra? What are the dietary patterns of sugarcane cutters in the Marathwada region? How does the intake of iron-rich foods vary between sugarcane cutters who consume nicotine and tobacco and those who do not? How do occupational migratory patterns affect nutritional intake of the workers? Is there an association with nicotine use frequency and the iron deficiency anemia status among the sugarcane-cutter workers?

Methods

Study Design and Population

The study will include 86 participants from the population with a division based on nicotine use i.e. Nicotine consumers and non-nicotine consumers. Survey questionnaire was conducted with both male and female sugarcane cutters, including both nicotine consumers and non-consumers. The participants for these interviews were selected through a mixture of random and purposive sampling. The target population is the sugarcane cutter workers from selected rural areas of Kolhapur and Pune District of Maharashtra. This population was chosen because sugarcane cutting is a labor-intensive seasonal occupation, less nutrition and worst working conditions, which makes the population particularly vulnerable to iron deficiency anemia. Nicotine and tobacco consumption is prevalent in these communities. The sample size is 86 participants, consisting of both men and women involved in sugarcane cutter workers. These participants were divided into two groups based on their nicotine and tobacco consumption status:

a. **Nicotine Consumers:** 54 individuals who consume nicotine/tobacco products, (Both Men and Women)
b. **Non-Nicotine Consumers:** 32 individuals who do not consume nicotine/tobacco products (Both Men and Women)

Inclusion Criteria	**Exclusion Criteria**
Men and women between the ages of 18 and 60	Pregnant women
Participants must have worked as sugarcane cutters for at least one season	Individuals with known medical conditions
Participants must consume nicotine regularly (for the consumer group) or have no history of nicotine consumption (for the non-consumer group)	Individuals with injury

Table 1 – Inclusion and Exclusion criteria of the research

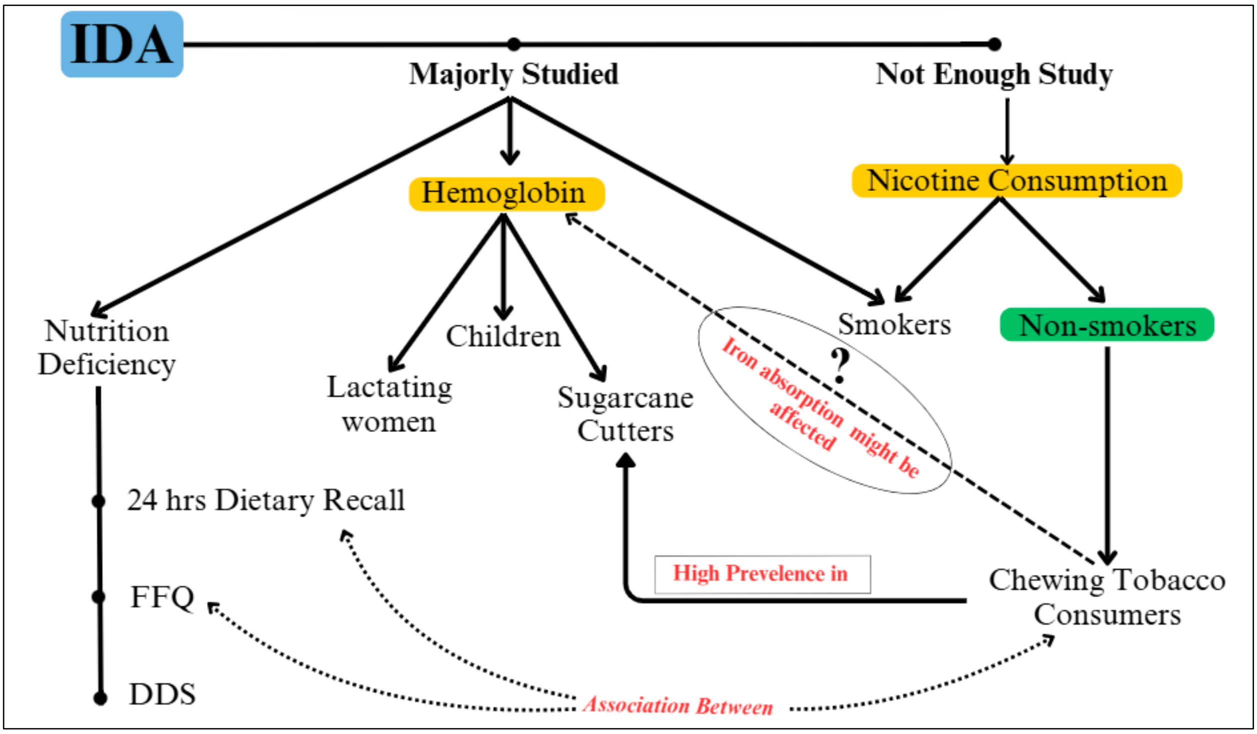

Fig. 2. IDA Problem and Nicotine Consumption

Hemoglobin concentration and 5-8 ml venous blood was collected from 86 participants from the following population (N=86) in various categories. 54 nicotine consuming, and 32 non-nicotine consuming, unrelated individuals from the population was recruited for the study after getting written consent. Related metadata was collected using a structured questionnaire.

Data from nicotine consumers and non-consumers were compared to analyze the differences in dietary intake. Differences between male and female participants were also examined. Dietary data were correlated with participants' hemoglobin and ferritin levels to understand the relationship between diet, nicotine use, and iron deficiency anemia. Descriptive statistics were used for the analysis of variables, including Hb levels, SpO_2 readings, nicotine use frequency, and dietary patterns assessed using Food Frequency Questionnaires (FFQ), and the Minimum Dietary Diversity Score (MDDS). SpO_2 measurements taken just before Hb testing provided insights into oxygen transport efficiency in nicotine consumers compared with non-consumers. Analytical methods were applied to perform various statistical tests, such as t-tests and chi-square tests. Independent t-tests compared Hb and SpO_2 levels between nicotine users and non-users, whereas chi-square tests identified associations between anemia prevalence, dietary patterns, and tobacco use. Correlation analyses revealed links among nicotine consumption, oxygen saturation, and Hb levels. Logistic regression was performed to predict anemia status using variables SpO_2, dietary diversity, and nicotine use frequency, while controlling for independent variables such as age and sex. Linear regression further explored how these predictors collectively influenced Hb levels, revealing the interplay between dietary sufficiency, oxygen transport, and physiological effects of nicotine. Dietary diversity and nutritional intake were analyzed to assess the mitigating or aggravating effects of tobacco on Hb and SpO_2 levels.

Statistical Analysis

Descriptive Analysis of variables

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Age	86	16	60	34.92	12.834
Blood Oxygen Level	86	93	99	97.94	1.182
Heart Rate	86	44	112	84.16	12.944
Blood Hemoglobin	86	4.5	17.7	11.038	3.1404
How long working years	86	1	55	13.93	12.414
How many months in	86	4	6	5.13	0.455
Workplace Distance	86	2	30	12.67	5.277
The percentage of teeth stained	86	0	3	0.86	0.842
The darkness level	86	0	3	1.03	1.023
TSI Score	86	0.0	3.0	0.948	0.8813

Table 2 – Descriptive statistical analysis of variables

The study had 86 participants, aged between 16 and 60 years. The average age was 34.92 years (SD = 12.834), reflecting a heterogeneous sample group of both younger and older participants. This age variance may have impacted health outcomes, especially with nicotine use and occupational exposure. The blood oxygen levels (SpO_2) of participants varied from 93% to 99%, with a mean of 97.94% (SD = 1.182). Although the majority of participants exhibited oxygen levels within the normal range, the lower spectrum indicated mild hypoxemia in few individuals. Heart rates ranged from 44 bpm to 112 bpm, with a mean of 84.16 bpm (SD = 12.944). This significant difference underscored the possibility for bradycardia (reduced heart rate) or tachycardia (elevated heart rate) among participants, potentially impacted by professional stress, physical exercise, or nicotine consumption. Blood hemoglobin (Hb) levels varied from 4.5 g/dL to 17.7 g/dL, with a mean of 11.038 g/dL (SD = 3.1404). The research population demonstrated a significant prevalence of anemia, with several individuals exhibiting hemoglobin levels below the normal ranges (13.0–17.0 g/dL for males and 12.0–15.0 g/dL for females). The participants' job experience exhibited considerable variation, spanning from 1 to 55 years, with a mean of 13.93 years (SD = 12.414).

This suggested that several individuals had dedicated a significant amount of their lives to this profession, thereby heightening their exposure to occupational dangers, including extended nicotine consumption. The duration of seasonal labor varied from 4 to 6 months, with a mean of 5.13 months (SD = 0.455), indicating that economic stability and health outcomes may have been affected by the characteristics of seasonal employment. The distance from home to employment varied from 2 km to 30 km, with a mean of 12.67 km (SD = 5.277). Certain individuals commuted considerable distances for employment, potentially impacting physical exertion and affecting general health metrics, including hemoglobin levels and oxygen saturation. The study evaluated nicotine consumption by measuring the percentage of tobacco use, the severity of teeth discoloration, and the Tobacco Staining Index (TSI). The mean proportion of tobacco usage among participants was 0.86 (SD = 0.842), but the average score for the darkness of teeth stains was 1.03 (SD = 1.023). The TSI score, which measured nicotine-induced dental discoloration, had a mean of 0.948 (SD = 0.8813). The observable staining indicated that a significant segment of the study population had a history of extended or regular nicotine consumption. Considering that nicotine intake may influence hemoglobin levels, oxygen saturation, and cardiovascular health, additional analysis investigated its effects on these physiological parameters.

The initial descriptive analysis indicated that anemia was prevalent among participants, with numerous individuals exhibiting hemoglobin levels beneath the normal limit. Moreover, fluctuations in SpO_2 and heart rate suggested possible cardiovascular hazards, especially in individuals with elevated nicotine intake. The TSI scores and the darkness of teeth stains shows qualitative degree of tobacco consumption, which was further assessed in relation to occupational trends and iron intake.

Distribution of oxygen saturation levels

Gender	Nicotine Consumption	SpO_2 Category	Count	% of Total
Female	No	Normal	21	63.6%
	Yes	Mild Hypoxemia	12	36.4%
	Total	Total	33	100.0%
Male	No	Normal	11	20.8%
	Yes	Mild Hypoxemia	3	5.7%
	Yes	Normal	39	73.6%
	Total	Total	53	100.0%

Table 3 – Distribution of Participants by Gender, Nicotine Consumption, and SpO_2 Category

Table 7 represents the relationship between nicotine consumption, blood oxygen levels (SpO_2), and sex, offering insights into how tobacco use influenced oxygen saturation among different groups. Blood oxygen levels are a critical physiological parameter, and nicotine consumption has been associated with impaired oxygen transport owing to its effects on lung function and hemoglobin binding affinity. Among female participants, the data revealed that 63.6% of non-nicotine consumers had normal oxygen saturation levels, while 36.4% of nicotine consumers also maintained normal SpO_2 levels. This suggests that a considerable proportion of female nicotine users still had oxygen saturation levels within the normal range. However, it is important to note that there were no cases of mild hypoxemia (reduced oxygen saturation) among females, regardless of nicotine use. Whereas male participants had greater variation in SpO_2 levels based on nicotine consumption. Among males who did not consume nicotine, 20.8% had normal oxygen saturation levels, whereas among nicotine consumers, a significantly higher proportion (73.6 %) exhibited normal oxygen levels. Interestingly, 5.7% of male nicotine consumers displayed mild hypoxemia, indicating that tobacco use could have contributed to lower oxygen saturation in some individuals. The exclusive presence of mild hypoxemia among male nicotine consumers (5.7%) was an important finding. Hypoxemia, characterized by reduced blood oxygen levels, can lead to fatigue, shortness of breath, and cardiovascular stress over time. While the overall percentage of mild hypoxemia cases was low, its occurrence solely in nicotine users raised concerns about the long-term respiratory effects of tobacco use, particularly among males engaged in physically demanding occupations such as sugarcane cutting.

From a physiological perspective, nicotine consumption leads to an increase in carboxyhemoglobin levels and reduces the oxygen-carrying capacity of hemoglobin. Additionally, nicotine-induced vasoconstriction can impair blood flow and oxygen delivery to tissues, which might explain the observed cases of hypoxemia in male tobacco users. However, the absence of hypoxemia among female tobacco users suggests possible sex-based differences in nicotine metabolism or compensatory mechanisms, which warrants further investigation. When considering the total study population, 96.5% of the individuals had normal SpO_2 levels, while 3.5% exhibited mild hypoxemia. Importantly, all cases of mild hypoxemia were observed only in nicotine consumers, reinforcing the hypothesis that tobacco use may have contributed to a reduction in oxygen saturation.

Distribution of anemia severity

Gender	Nicotine Consumption	Mild Anemia	Moderate Anemia	Normal	Severe Anemia	Total	% of Total
Female	No	4	5	9	3	21	63.6%
	Yes	3	3	3	3	12	36.4%
Male	No	2	2	7	0	11	20.8%

	Yes	9	6	18	9	42	79.2%
	Total	**18**	**16**	**37**	**15**	**86**	

Table 4 - Distribution of Participants by Gender, Nicotine Consumption, and Hemoglobin Status

Among the 33 female participants, 81.8% had some form of anemia, while only 36.4% of males were found to be anemic. Among non-nicotine-consuming females, 27.3% had normal hemoglobin levels, whereas the remaining participants had varying degrees of anemia (12.1% mild, 15.2% moderate, and 9.1% severe). In contrast, among nicotine-consuming females, only 9.1% had normal hemoglobin levels, while 27.3% exhibited anemia distributed equally across mild, moderate, and severe categories. This suggests that, while nicotine consumption might have contributed to anemia risk, additional factors such as dietary deficiencies, menstrual blood loss, and occupational conditions might also have played a role in the female population. Among the 53 male participants, the prevalence of anemia was significantly lower than that in the females. However, a strong correlation between nicotine consumption and anemia severity was observed. Non-nicotine-consuming males exhibited a higher proportion of normal hemoglobin levels (63.6%), while only 7.6% showed mild or moderate anemia. Notably, no cases of severe anemia were recorded among the non-nicotine consumers. On the other hand, 79.2% of the male participants were nicotine consumers, and among them, 66% had anemia (17% mild, 11.3% moderate, and 17% severe). The presence of severe anemia exclusively among nicotine-consuming males (17%) highlighted the potential negative impact of nicotine on hemoglobin levels and oxygen transport efficiency.

Anemia was a prevalent concern across the total study population (N = 86). 43.0% had normal hemoglobin levels, while the remaining 57% exhibited anemia (20.9% mild, 18.6% moderate, and 17.4% severe). When comparing nicotine users and non-users, non-nicotine users had a lower prevalence of severe anemia (3.5%), whereas nicotine consumers had a higher burden of severe anemia (14%). Furthermore, a decline in normal hemoglobin levels was observed among nicotine consumers (24.4% compared to 18.6% in non-users), reinforcing the hypothesis that nicotine use contributes to hemoglobin depletion.

Variations in nicotine use frequency

Nicotine Consumption	Gender	Frequency of Nicotine Consumption	Count	% of Total
Yes	Female	1	1	1.9%
		10	1	1.9%
		25	6	11.1%
		3	1	1.9%

		5	3	5.6%
		6	1	1.9%
		Total	**12**	**22.2%**
	Male	1	1	1.9%
		5	1	1.9%
		10	5	9.3%
		15	8	14.8%
		20	3	5.6%
		25	1	1.9%
		30	1	1.9%
		3	1	1.9%
		4	2	3.7%
		5	3	5.6%
		6	2	3.7%
		8	3	5.6%
		Total	42	77.8%
	Total	**Total**	**54**	**100.0%**

Table 5 - Gender-wise Distribution of Participants by Frequency of Nicotine Consumption

The frequency of use among participants who consume nicotine showed considerable variation. A majority of female nicotine users, specifically 50.0%, reported consuming nicotine three times daily, which translates to 6 out of the 12 female users in the study. Among females, additional frequency categories revealed that three participants (25.0%) reported using nicotine four times per day, whereas a smaller group indicated usage once per day, represented by one participant (8.3%). Notably, there were no female participants who indicated consuming nicotine at very high frequencies, such as 10, 15, or 20 times daily, suggesting that their usage patterns were generally more regulated or infrequent. Conversely, male nicotine users demonstrated a significantly broader spectrum of consumption frequencies, accompanied by an increased daily intake. The predominant frequency observed in males was three times daily (16.7%), succeeded by twice daily (11.9%) and once daily (9.5%). Nevertheless, certain male participants indicated an exceptionally high frequency of nicotine use, reaching as much as 10, 15, or even 20 times daily. This indicates that, although certain males consume nicotine in moderation, others partake in heavy or continuous use, potentially leading to serious health repercussions. The higher prevalence of nicotine use in males compared to females may stem from a range of influences, such as increased social acceptance, peer pressure, work-related stress, and long-established behavioral patterns.

The findings indicated notable variations between sexes regarding the occurrence and rate of nicotine use. Although most females refrain from using nicotine, those who do tend to engage in its use less frequently, averaging about three to four times daily. Conversely, males exhibit a higher propensity for nicotine consumption, engaging in it more frequently and with greater intensity. The occurrence of males in the highest tiers of nicotine consumption (≥ 10 times daily) indicates an elevated risk of developing nicotine dependence and related health issues.

The societal acceptance of nicotine use among men may significantly influence this trend. Tobacco consumption tends to be accepted among men in various rural and work environments, while women frequently encounter social stigmas or limitations that restrict their usage. Furthermore, men might turn to nicotine as a way to manage stress, alleviate work-related exhaustion, or foster social connections, which may explain their increased usage rates.

Chi-square Test for nicotine consumption and anemia status

Anemia Status & Nicotine Consumption Crosstabulation

			@301_Nicotine_Consumption		Total
			No	Yes	
Anemia Status	Anemic	Count	16	33	49
		Expected Count	18.2	30.8	49.0
		% within Nicotine Consumption	50.0%	61.1%	57.0%
	Normal	Count	16	21	37
		Expected Count	13.8	23.2	37.0
		% within Nicotine Consumption	50.0%	38.9%	43.0%
Total		Count	32	54	86
		Expected Count	32.0	54.0	86.0
		% within Nicotine Consumption	100.0%	100.0%	100.0%

Table 6 - Nicotine consumption is higher (54%) than non-consumption (32%) in the entire sample of 86 participants, indicating a strong association between nicotine use and anemia status.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.012[a]	1	.314		
Continuity Correction[b]	.609	1	.435		
Likelihood Ratio	1.009	1	.315		
Fisher's Exact Test				.371	.217
N of Valid Cases	86				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 13.77.

b. Computed only for a 2x2 table

Table 7 – Chi square test

Based on the cross-tabulation, out of the 86 participants, 54 reported nicotine consumption and 32 did not. Among nicotine consumers, 61.1% (33 out of 54) were anemic compared to 50.0% (16 out of 32) among non-users. Conversely, only 38.9% of nicotine users had normal hemoglobin levels compared to 50.0% of non-users. This showed a higher proportion of anemia among nicotine users. However, the chi-square test for independence yielded a Pearson Chi-Square value of 1.012 with a p-value of 0.314. Similar non-significant values were obtained for continuity correction (p = 0.435) and likelihood ratio test (p = 0.315). These p-values were all above the threshold of 0.05, indicating that the observed differences were not statistically significant.

The observed difference in anemia prevalence between nicotine users and non-users could have been due to chance rather than a real association. There might have been other factors at play, such as dietary iron intake, hydration levels, sex differences, and physical workload, that influenced anemia but were not controlled for in this analysis. Furthermore, the statistical power of this test might have been limited by the relatively small and uneven sample sizes between the two groups, reducing the likelihood of detecting a significant association, even if one existed in the population.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-.816	31.646		-.026	.979		
	Blood Oxygen Level	.095	.312	.036	.303	.762	.658	1.519
	Heart Rate	.033	.024	.135	1.336	.185	.895	1.118
	Nicotine Consumption	.403	.809	.062	.497	.620	.579	1.727
	Frequency of Nicotine	-.221	.060	-.470	-3.700	.000	.565	1.771
	Age	-.033	.026	-.135	-1.285	.203	.823	1.215
	Gender Code	3.009	.741	.469	4.058	.000	.682	1.467

a. Dependent Variable: Blood Hemoglobin Level

***Table 8** - Multiple Regression: A multiple linear regression was conducted to predict hemoglobin levels based on blood oxygen level, heart rate, nicotine consumption, frequency of nicotine use, age, and gender. The overall model revealed that frequency of nicotine consumption ($\beta = -0.221$, $p < 0.001$) and gender ($\beta = 3.009$, $p < 0.001$) were significant predictors. Increased frequency of nicotine use was associated with lower hemoglobin, and males had significantly higher hemoglobin levels compared to females. Other variables such as SpO_2, heart rate, general nicotine use, and age did not show statistically significant associations.*

Nutritional Analysis

4 food groups had been created based on the types of iron content in the food items:

1. Heme Iron Foods
2. Non-heme food group
3. Iron Absorption Inhibitors
4. Vitamin C Rich Foods

A systematic categorization was essential to effectively interpret the dietary patterns related to heme iron food consumption among participants. A data-driven approach was implemented, employing percentile-based classification rather than relying on arbitrary cutoffs. This approach facilitates a more precise depiction of the consumption behaviors of participants by categorizing them into three separate classifications: low, moderate, and high consumption.

The percentile method is commonly employed in nutritional studies as it facilitates the ranking of participants in relation to each other. Considering the characteristics of the dataset, the 33rd and 66th percentiles were selected as the thresholds to create significant differentiations. The 33rd percentile acts as a cutoff for low consumption, whereas the 66th percentile distinguishes between moderate and high consumption levels. This guarantees that every category represents a genuine separation grounded in empirical data instead of personal interpretation. After performing the calculations, it was determined that the value at the 33rd percentile was around 4, indicating that participants with a total heme iron food score of 4 or less were classified as having low consumption. The consumption of heme iron-rich foods among these individuals is either rare or minimal, which may have implications for their dietary iron status. The 66th percentile was identified as approximately 7, indicating that individuals with scores ranging from 5 to 7 are classified within the moderate consumption group. This group includes individuals who regularly consume foods rich in heme iron, albeit in moderate quantities. Ultimately, individuals scoring 8 or higher were categorized as high consumers, reflecting a regular consumption of foods rich in heme iron. This categorization plays a crucial role in comprehending eating habits, especially concerning iron levels. By categorizing participants into these three groups, it allows for an investigation into the potential correlation between increased heme iron consumption and improved hemoglobin levels or other health metrics. Furthermore, this categorization proves beneficial for subsequent statistical evaluations, including regression models, where dietary iron consumption can be regarded as a categorical variable to examine its influence on anemia risk. Percentile-based categorization shows a strong classification of dietary data. This approach derived significant comparisons among individuals and is consistent with established methodologies in nutritional epidemiology and public health studies. Utilizing this method allows for a more effective connection between heme iron intake and health results, enhancing the relevance and applicability of the findings within your research.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.218[a]	.047	.000	3.1396

a. Predictors: (Constant), @904_Vitamin_C_Rich_Foods_score, @902_Non_heme_food_group_score, @903_Iron_Absorption_Inhibitors_score, @901_Heme_Iron_Foods_score

Table 9 - Model Summary (R, R^2, Adjusted R^2)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13.041	2.042		6.385	.000
	@901_Heme_Iron_Foods_score	-.049	.146	-.046	-.337	.737
	@902_Non_heme_food_group_score	.003	.030	.011	.095	.925
	@903_Iron_Absorption_Inhibitors_score	-.097	.062	-.195	-1.567	.121
	@904_Vitamin_C_Rich_Foods_score	-.007	.108	-.008	-.067	.947

a. Dependent Variable: @103_Blood_Hemoglobin

Table 10 - Coefficients table (B, Beta, t-value, p-value)

The regression analysis aimed to determine the effect of dietary iron intake, iron inhibitors, and vitamin C-rich foods on hemoglobin (Hb) levels. However, the results indicate that the model has very weak explanatory power. The R-value (0.218) suggests a weak correlation between dietary factors and Hb levels, while the R^2 value (0.047) shows that only 4.7% of the variation in Hb levels can be explained by these dietary variables. The adjusted R^2 value (0.000) further confirms that when adjusted for the number of predictors, the model does not significantly explain Hb variation. Additionally, the standard error of

3.14 suggests substantial unexplained variability in Hb levels, reinforcing the idea that other factors may play a more significant role.

Looking at the coefficients table, none of the dietary predictors show a significant effect on Hb. The heme iron score (-0.049, p = 0.737) and non-heme iron score (0.003, p = 0.925) do not have meaningful contributions to Hb levels, which is unexpected given that these are the primary sources of iron intake. Similarly, the iron absorption inhibitors score (-0.097, p = 0.121) shows a slightly negative trend, implying that inhibitors may reduce Hb levels, but this effect is not statistically significant. Interestingly, vitamin C-rich foods (-0.007, p = 0.947) do not show any positive influence on Hb levels, even though vitamin C is known to enhance non-heme iron absorption.

Severity of anemia in relation to nicotine consumption

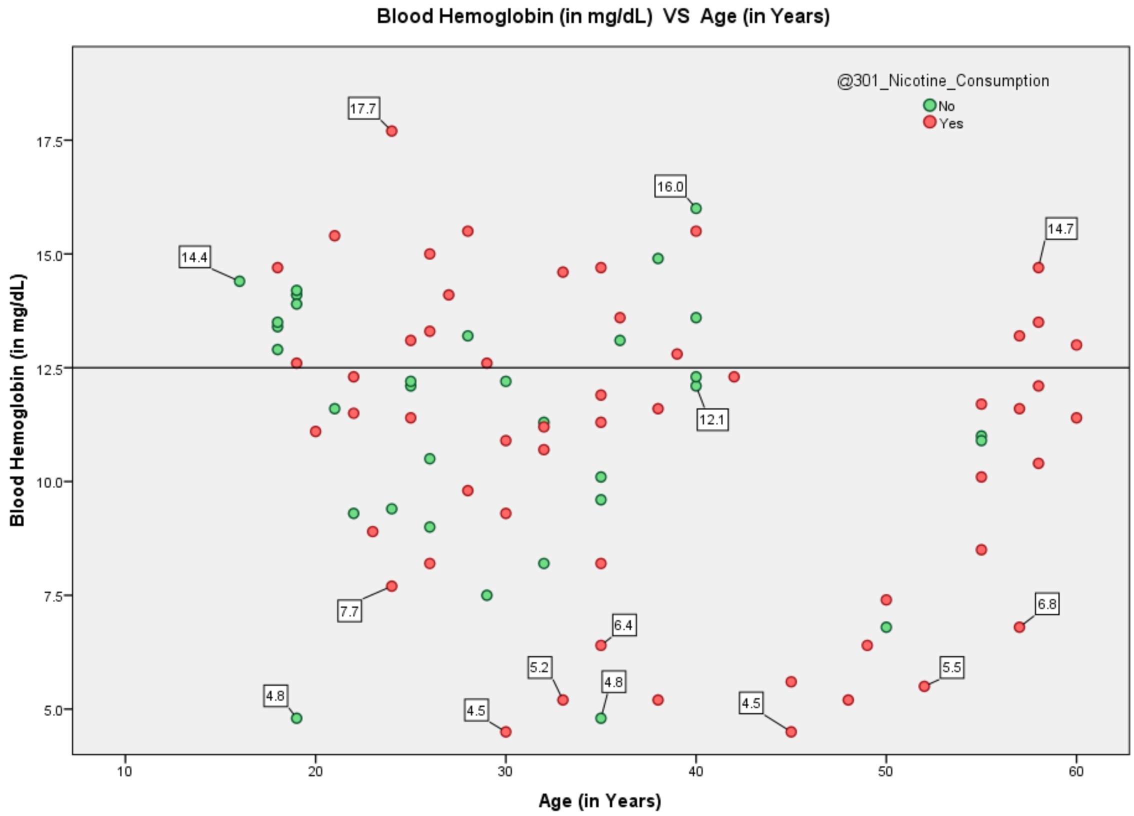

Fig. 3. – Individuals who consume nicotine (red dots) tend to cluster more frequently below the normal hemoglobin threshold (12.5 g/dL), suggesting a higher prevalence of anemia. Non-nicotine users (green dots) are more evenly distributed above and below the threshold.

The scatter plot depicts the correlation between Blood Hemoglobin (Hb) levels (g/dL) and Age (years), highlighting nicotine consumption as a key differentiating element. The horizontal axis indicates age, whereas the vertical axis denotes hemoglobin levels. The data points are distinguished by color: red indicates nicotine consumers, while green represents non-consumers. Additionally, certain values are annotated for clarity.

The dataset reveals Hb levels varying from a minimum of 4.5 g/dL to a maximum of 17.7 g/dL, with the majority of individuals exhibiting levels between 7 g/dL and 15 g/dL. Younger individuals, specifically those under 20 years, exhibit elevated Hb values, reaching up to 14.4 g/dL. In contrast, middle-aged individuals, aged 20 to 40 years, demonstrate a broader range, with values fluctuating between 4.5 g/dL and 16.0 g/dL. Individuals over the age of 50 display a wide variation, although they generally present with lower hemoglobin levels, with some exceptions, including a notable instance of 14.7 g/dL in a person aged 60 and above. A distinct trend is observed in relation to nicotine usage. Individuals who use nicotine (red points) exhibit a wider range of variability in hemoglobin levels, showcasing both significant highs and lows. Certain individuals who use nicotine exhibit significantly low levels of hemoglobin, indicating possible negative impacts of tobacco consumption on iron levels and overall hemoglobin concentration. Nonetheless, some individuals who consume nicotine exhibit elevated Hb values, suggesting that additional elements—like nutrition, genetic predispositions, and professional environments—could affect hemoglobin concentrations. Conversely, non-consumers (green points) exhibit a more centralized distribution, characterized by a reduced number of instances with extremely low Hb values. While a clear linear relationship between age and hemoglobin levels is not readily apparent, instances of severe anemia (Hb < 7 g/dL) are more commonly found in middle-aged and older populations.

Intensity of tobacco consumption and hemoglobin concentration

The primary observation from this graph indicates that with increasing severity of tobacco use—especially in cases of chronic and regular consumption—there is a noticeable reduction in hemoglobin levels, particularly in female participants. Conversely, individuals who refrain from tobacco use demonstrate notably elevated and more consistent hemoglobin levels in both males and females.

Fig. Severity of Tobacco Use VS Hemoglobin Levels

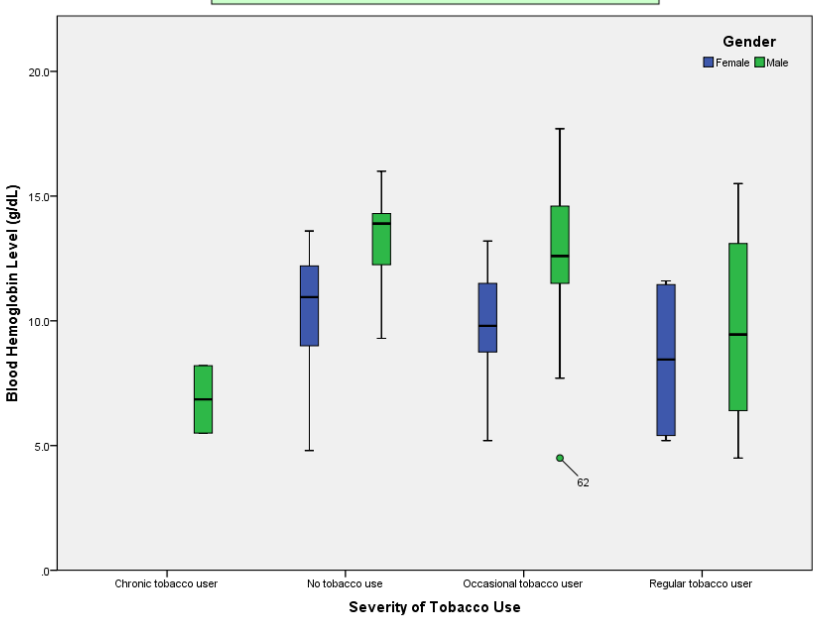

Fig. 4. – A decreasing trend in hemoglobin levels with increasing severity of tobacco use. Non-tobacco users, both male and female, generally have higher and more stable hemoglobin levels. In contrast, chronic and regular users, particularly males, exhibit lower hemoglobin values and greater variability

The boxplot shows hemoglobin levels (g/dL) on the Y-axis and categories of tobacco use on the X-axis. Participants are grouped as no tobacco use, occasional users, regular users, and chronic users, further split by gender—blue boxes for females and green boxes for males. Among chronic tobacco users, males exhibit extremely low hemoglobin levels (around 6–8 g/dL), indicating severe anemia. Regular tobacco-using females also show low levels, with median values below 10 g/dL. In contrast, both male and female non-users have higher median Hb levels, typically above 12 g/dL. Occasional users present a wider range of hemoglobin levels, but their medians still fall below the non-user group. The observed visual trend suggests a significant relationship between heightened tobacco consumption and diminished hemoglobin levels, particularly among those who use it chronically and regularly. The influence of gender is significant—females appear to be more impacted, consistently showing lower Hb levels compared to males within the same tobacco use categories. Instances like the low Hb value noted in occasional users highlight possible nutritional or physiological weaknesses in specific individuals. Additionally, individuals who do not engage in usage exhibit the smallest interquartile range, indicating greater uniformity and more favorable hemoglobin levels among that population.

Discussion

Iron Deficiency Anemia (IDA) continues to be a significant public health issue, especially in communities engaged in labor-intensive activities, where nutritional deficiencies coincide with the demands of physically strenuous work and substance use patterns. This study investigates the link between nicotine intake, particularly through non-smoking methods like gutkha, and the prevalence of anemia in sugarcane cutters in Maharashtra. The primary objective was to evaluate the impact of nicotine consumption on hemoglobin levels and to explore the complex relationship among anemia, tobacco usage, and dietary iron intake. This research centers on a rural working-class community involved in seasonal agricultural work, highlighting a demographic frequently overlooked in conventional public health discussions, even though they endure significant physiological and occupational challenges. The results indicated a higher prevalence of anemia in individuals who reported nicotine consumption compared to those who did not engage in such behavior. Out of 86 participants, 54 indicated they used nicotine, and within this subset, 61.1% were identified as anemic, whereas the anemia prevalence among non-users stood at 50.0%. The observed difference, while indicative of a potential trend, did not achieve statistical significance, as demonstrated by the Pearson's chi-square test ($p = 0.314$). Comparable nonsignificant results were noted in the continuity correction and likelihood ratio assessments. Although these trends may not hold substantial importance, they are still noteworthy. The increased prevalence of anemia in individuals who use nicotine suggests that nicotine may contribute to the impairment of hemoglobin synthesis or the absorption of iron. This is corroborated by earlier biomedical studies that connect tobacco components to gastrointestinal disturbances and changes in iron metabolism.

In the group of male participants, severe anemia was observed solely in those who used nicotine, indicating a more profound physiological effect within this specific subgroup. None of the non-consuming males exhibited severe anemia, suggesting a potentially more significant impact of prolonged nicotine exposure. Furthermore, these individuals frequently indicated significant physical activity, dehydration, and limited dietary variety, elements that can individually lead to anemia, but may be intensified by tobacco consumption. Among the female participants, while anemia was prevalent among nicotine users, the pattern exhibited a bit more complexity. The physiological characteristics of females, especially in relation to menstrual blood loss and the increased iron requirements during their reproductive years, inherently make them more susceptible to anemia. Nicotine might have introduced an additional level of risk for these women, even though the findings did not reach statistical significance. These findings align with national statistics (NFHS-5, 2021), indicating that approximately 57% of Indian women of reproductive age are affected by anemia.

This investigation indicates that although statistical data does not permit a conclusive assertion regarding nicotine's involvement in anemia, the observed qualitative and quantitative trends imply a likely connection. It is crucial to acknowledge that various elements, including hydration levels, physical demands, infections, and, most importantly, the intake of dietary iron, can interact in intricate manners. In the absence of biochemical indicators like serum ferritin, transferrin saturation, or accurate dietary recalls, the present study was unable to identify nicotine as the exclusive factor. Furthermore, the limited and inconsistent sample size probably diminished the effectiveness of the statistical analyses, constraining the capacity to identify meaningful differences. This constraint is significant as it could conceal nuanced yet important connections, especially when examining biological results affected by various factors.

Another factor to examine is the social and behavioral backdrop of nicotine consumption. In the context of sugarcane cutters, tobacco is frequently utilized due to its believed effects in curbing hunger, combating fatigue, and enduring extended periods of labor. The societal acceptance of tobacco consumption by both genders presents challenges for intervention strategies. Neglecting the fundamental socioeconomic and occupational factors influencing substance use could hinder the effectiveness of health interventions. The observation that mild or moderate anemia was fairly prevalent among non-users indicates that underlying structural factors, including inadequate nutrition, limited access to healthcare, and physical fatigue, likely represent the foundational circumstances that nicotine exacerbates, rather than being an independent cause.

Considering these intricacies, subsequent investigations should focus on obtaining larger, more equitable samples that encompass various genders and ages, preferably with longitudinal tracking, to more effectively determine causal relationships. Incorporating biochemical parameters like ferritin, serum iron, and transferrin levels would enhance the understanding of iron deficiency-related anemia. Additionally, thorough evaluations of dietary habits and in-depth interviews investigating the motivations and prevalence of tobacco consumption would enhance the results and provide practical guidance for intervention strategies. Research can also investigate seasonal changes, as levels of iron and patterns of nicotine use may vary with farming cycles and migration trends.

The present investigation does not yield statistically significant evidence connecting nicotine intake directly to anemia; however, the identified trends and contextual observations underscore a intersection between substance use and adverse health outcomes within marginalized labor populations. The results highlight the necessity for specific public health strategies that emphasize not just quitting tobacco but also enhancing dietary habits and workplace environments. By enhancing sampling techniques, gathering biochemical data, and improving contextual comprehension, forthcoming studies can expand upon this groundwork to investigate the intricate ways in which lifestyle elements like nicotine consumption affect anemia in at-risk groups.

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