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Machine Learning-Based Analysis of BMI, Tobacco Use and Oral Health Outcomes Among Chennai Construction Workers: Insights for Targeted Interventions

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Abstract **Background:** This study investigates the complex relationship between Body Mass Index (BMI), tobacco consumption and oral health status among construction workers in Chennai, India. Using a neural network model, the study aims to identify significant predictors of oral health outcomes. **Methods:** A cross-sectional study was conducted among 812 construction workers in Chennai. Data on BMI, tobacco usage patterns and oral health indicators such as the Oral Hygiene Index-Simplified (OHI-S), Decayed, Missing and Filled Teeth (DMFT) index, Gingival Index and loss of attachment (LOA) were collected. A pretested, interviewer-administered questionnaire was used to gather demographic and behavioral information. BMI was calculated using participants' height and weight. Data were analyzed using SPSS software, with a neural network model employed to identify complex interactions among variables. **Results:** The neural network analysis revealed significant positive correlations between BMI and oral health indicators such as DMFT, Gingival Index and missing teeth. Additionally, a negative correlation was identified between BMI and tooth brushing frequency. Notably, education emerged as the most influential predictor, followed by age, gender, BMI and tobacco consumption. The neural network model demonstrated superior predictive accuracy of 87%, outperforming traditional statistical methods in identifying complex, non-linear relationships. **Conclusion:** The study highlights the intricate interplay between BMI, tobacco use and oral health outcomes, underscoring the need for targeted interventions. Emphasis should be placed on improving nutrition, promoting tobacco cessation and enhancing oral health awareness among construction workers. The findings demonstrate the value of machine learning in public health research and emphasize the need for future longitudinal studies to establish causal links and explore additional factors such as occupational stress, dietary patterns and healthcare access.

Key Words Oral Health, BMI, DMFT, gingival index, neural network analysis, machine learning, tobacco use

INTRODUCTION

Construction workers are pivotal in shaping the rapidly expanding urban landscape of cities like Chennai, India. However, their physically demanding work environment, coupled with exposure to environmental hazards and limited access to healthcare, places them at an increased risk of various health problems. Among these, the relationship between Body Mass Index (BMI), tobacco consumption and oral health status is a significant public health concern that warrants deeper exploration. Despite its critical role in overall well-being, oral health remains a neglected aspect, especially in labor-intensive occupations like construction work [1,2].

Tobacco use, in both smoking and smokeless forms, is prevalent among construction workers and is a key contributor to poor oral health. It is strongly linked to periodontal disease, oral lesions and dental cavities. Simultaneously, BMI, a widely recognized marker of nutritional and metabolic health, is closely tied to systemic and oral health outcomes. Both underweight and obese individuals are known to experience higher risks of oral

diseases. While underweight individuals often face nutritional deficiencies that weaken immune responses, obesity has been linked to systemic inflammation, further aggravating periodontal conditions [3,4]. These associations indicate the need for exploring how BMI and tobacco consumption collectively influence oral health outcomes.

This study utilizes neural network analysis, a powerful machine-learning technique that effectively identifies complex, non-linear relationships between health factors. Unlike traditional statistical methods, neural networks uncover hidden patterns, enabling improved risk prediction and targeted intervention strategies. This approach is particularly valuable in examining the multifaceted links between tobacco use, BMI and oral health. Neural networks have proven to offer greater accuracy in predicting oral health outcomes and assessing population risk profiles [5,6].

The vulnerability of construction workers, especially in Chennai's urban setting, demands focused attention. Predominantly rural migrants, these workers often face poor healthcare awareness, stressful working conditions and unhealthy behaviors like tobacco consumption. Nutritional deficiencies and inadequate oral hygiene practices further increase their risk of developing oral health issues. Given the high prevalence of tobacco use and variable BMI patterns in this group, identifying the underlying predictors of poor oral health is critical [7,8].

This study aims to assess the interplay between BMI, tobacco consumption and oral health status among Chennai construction workers using a neural network model. The findings aim to guide policymakers, healthcare professionals and occupational health programs in designing evidence-based interventions that focus on improving oral hygiene awareness, promoting healthier nutritional practices and encouraging tobacco cessation. By addressing these key risk factors, this research seeks to improve the overall health, well-being and productivity of this essential workforce .

METHODS

Study Design and Population

This cross-sectional study was conducted among construction workers in Chennai, India, between May 2024 and August 2024. The study assessed Body Mass Index (BMI), oral hygiene practices, oral health status and indicators such as the Decayed, Missing and Filled Teeth (DMFT) index, Gingival Index and missing teeth. The study population comprised 812 participants, including 695 males (85.6%) and 117 females (14.4%). A diverse sample was ensured by randomly selecting three construction companies from a list obtained from the Builder's Association of India.

Ethical Clearance

Ethical approval was obtained from the Scientific Review Board of Saveetha University to ensure the study followed ethical research protocols.

Informed Consent

Participants were provided with detailed oral and written explanations of the study objectives and procedures. Each participant signed an informed consent form prior to participation. Confidentiality was strictly maintained and personal information was anonymized to ensure privacy.

Inclusion Criteria

Participants aged 18 years or older, employed at the construction site for at least one year and residing in shelters provided by the construction authority were included. Only those who consented to participate were enrolled.

Exclusion Criteria

Individuals with systemic illnesses or those who could not be reached after three consecutive visits were excluded.

Sample Size Calculation

The sample size was determined using the formula:

$$N = Z^2 P(1-P) / L^2 N = Z^2 P(1-P) / L^2 N = Z^2 P(1-P) / L^2$$

Based on a previous study, with an expected prevalence of 63.5% and an allowable error of 5%, the final sample size was 812 participants.

Data Collection

Data was collected through

- A pretested interviewer-administered questionnaire covering demographics, behavioral habits and oral hygiene practices
- Anthropometric measurements to determine BMI using participants' height and weight
- Oral health assessments using validated tools such as the Oral Hygiene Index-Simplified (OHI-S), DMFT index, Gingival Index and missing teeth count

To ensure data accuracy, the author conducted two visits to each construction site, maximizing participation from all eligible individuals.

Clinical Examination

All clinical examinations were performed by a single trained examiner from the Department of Public Health Dentistry, Saveetha Dental College, Chennai. Intra-examiner reliability was established with a k-value of 0.71. Dental examinations followed World Health Organization (WHO) standards and were conducted under natural light with participants in a supine position using a mouth mirror and CPI probe. Each examination lasted approximately 15 minutes and all instruments were sterilized following established protocols.

Periodontal Assessment

Periodontal status was evaluated using the Community Periodontal Index (CPI), which assessed DMFT, gingival health, missing teeth and loss of attachment (LOA). Participants requiring treatment were referred to Saveetha Dental College for further care and findings were reported to relevant authorities for appropriate intervention.

Handling of Missing Data

Any missing data in participant records were addressed using appropriate imputation techniques to minimize bias and maintain data integrity.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS software (version 24). Descriptive statistics, correlation analysis and neural network modeling were employed to identify complex, non-linear relationships between BMI, tobacco use and oral health status. The model's performance was evaluated using prediction accuracy metrics, ensuring robust interpretation of findings.

RESULTS

The present study was conducted on a study population of 812 participants in which 85.6% (n = 695) of the participants were males and 14.4% (n = 117) of the participants were females.

Table 1 shows the distribution of study participants according to their age, gender, BMI, education, occupation, smoking status and smokeless tobacco consumption.

The study population consisted predominantly of young adults, with 50.5% falling in the age group of 18-25 years. The mean age of the construction workers was 27.05±8.01 years. Educational attainment revealed that nearly half (48.2%) had completed middle school and the majority (93.3%) were engaged as workers or on the production line.

Regarding BMI distribution, 19.7% (n = 160) of the participants were underweight, 57.8% (n = 470) had normal weight and 22.1% (n = 180) were overweight. Only a small fraction, 0.2% (n = 2), were classified as obese. The mean BMI of the population was 21.96±3.21.

Tobacco consumption was notably high among the workers. More than half (57.1%, n = 464) reported using smokeless tobacco, while 46.1% (n = 374) were current smokers. Non-smokers comprised 40.4% (n = 328) of the population and 13.5% (n = 110) identified as former smokers.

Table 2 presents the distribution of the study population based on their oral hygiene practices. The majority of participants (83.2%, n = 676) reported brushing their teeth once a day, while 15.2% (n = 124) brushed less frequently and only 1.6% (n = 12) brushed twice daily. Most workers used a toothbrush (81.4%, n = 662) and toothpaste (79.4%, n = 646) for oral cleaning. Additionally, 75% (n = 612) of the participants indicated that they replaced their toothbrushes every 6 to 12 months.

Table 1: Sociodemographic variables and tobacco habits of the study population

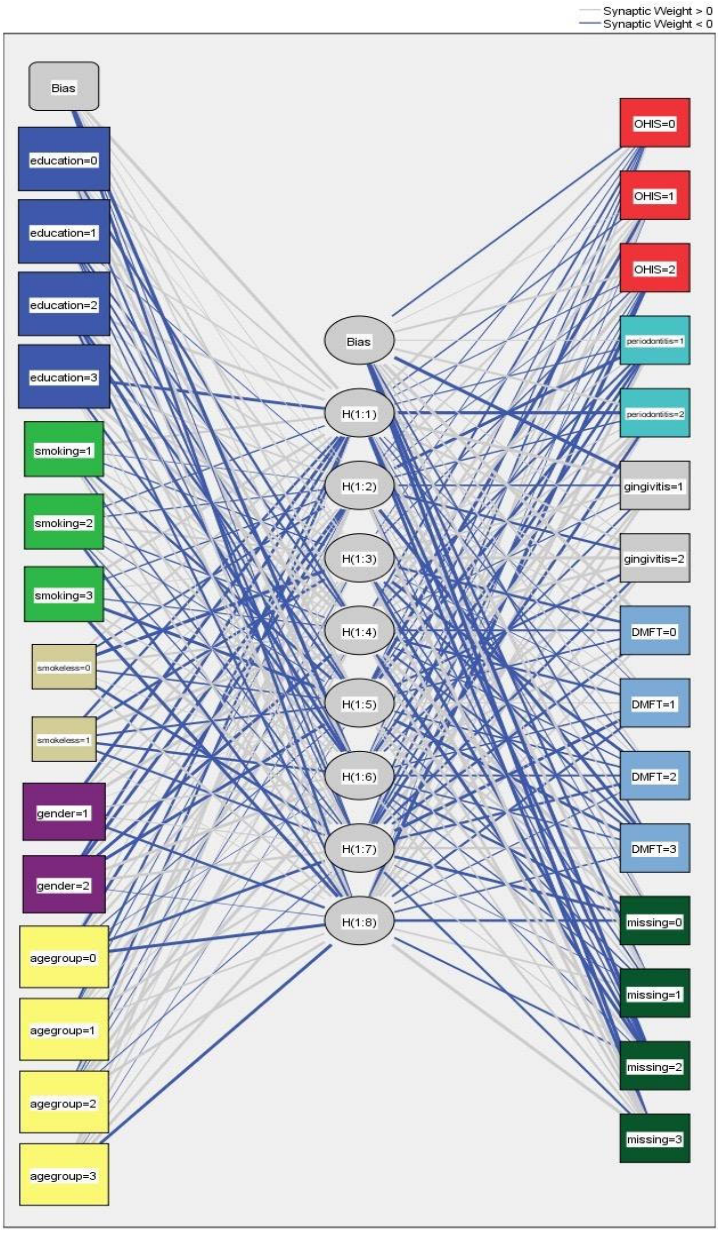
Variables	N (%)
Age	
18-25 years	410 (50.5%)
25-35 years	270 (33.2%)
35-45 years	102 (12.5%)
45-60 years	30 (3.6%)
Gender	
Male	695 (85.6%)
Female	117 (14.4%)
BMI groups	
Underweight	160 (19.7%)
Normal	470 (57.8%)
Overweight	180 (22.1%)
Obese	2 (0.2)
Education	
Primary school	270 (33.2%)
Middle school	392 (48.2%)
High school	123 (15.1%)
Graduate	27 (3.3%)
Occupation	
Workers/production line	758 (93.3%)
Administrative	54 (6.7%)
Smoking status	
Non smoker	328 (40.4%)
Former smoker	110 (13.5%)
Current smoker	374 (46.1%)
Smokeless tobacco consumption	
Yes	464 (57.1%)
No	348 (42.9%)

Table 2: Oral hygiene habits of the study population

Variables	N (%)
Toothbrushing frequency	
<once a day	124 (15.2%)
Once a day	676 (83.2%)
Twice a day or more	12 (1.6%)
Tooth cleaning Aid used	
Finger	64 (7.8%)
Brush	662 (81.4%)
Chewstick/Others	86 (11%)
Frequency of changing brush	
Once in <6 months	35 (4.3%)
Once in 6-12 months	612 (75.3%)
Whenever brush is of no use	165 (20.4%)
Tooth cleaning material used	
None	54 (6.6%)
Toothpaste	646 (79.4%)
Toothpowder	112 (14%)

Table 3 provides an overview of the oral health status of the study participants. More than half of the participants (54.4%, n = 442) were found to have fair oral hygiene. In terms of periodontal health, 40% (n = 324) had a Community Periodontal Index (CPI) score of 2, indicating the presence of calculus, while 20.9% (n = 169) showed periodontal pockets measuring 4-5 mm.

Regarding Loss of Attachment (LOA), the majority (62.5%, n = 508) exhibited an LOA of 0-3 mm, whereas 20.9% (n = 169) presented with an LOA of 4-5 mm. Additionally, 69% (n = 567) had a Decayed, Missing and Filled Teeth (DMFT) index score between 3 and 5, while 15% (n = 112) had a DMFT score ranging from 6 to 10 (Figure 1).



Hidden layer activation function: Hyperbolic tangent

Output layer activation function: Softmax

Independent Variable Importance

	Importance	Normalized Importance
education	.262	100.0%
smoking	.187	71.4%
smokeless tobacco	.097	37.0%
gender	.207	79.1%
age group	.247	94.2%

Figure 1: Neural network analysis illustrating the influence of input covariates on oral health outcomes such as OHIS, periodontitis, gingivitis and DMFT scores

Table 3: Oral health status of the study population

Variables	N (%)
OHI-S	
Poor	232 (28.5%)
Fair	442 (54.4%)
Good	138 (16.9%)
Periodontitis	
Healthy	57 (7%)
Bleeding	171 (21%)
Calculus	324 (40%)
4-5 mm pocket	229 (28.3%)
>6 mm pocket	31 (3.7%)
LOA	
0-3 mm	508 (62.5%)
4-5 mm	169 (20.9%)
6-8 mm	91 (11.1%)
9-11 mm	44 (5.5%)
DMFT	
0-2	54 (6.6%)
3-5	567 (69%)
6-10	112 (15%)
>10	79 (9.4%)

To evaluate the relationship between biases in covariates (input layer) and hidden covariates (hidden layer), a neural network analysis was conducted. This analysis revealed that these unknown biases significantly influenced Oral Hygiene Index-Simplified (OHIS) scores, periodontitis, gingivitis and DMFT scores.

The analysis identified the percentage contribution of key independent variables affecting these oral health outcomes. Education emerged as the most influential variable (100%), followed by age group (94%), gender (79.1%), BMI (71.4%) and tobacco consumption (37%). Furthermore, the neural network analysis indicated the presence of eight hidden factors affecting plaque index, OHIS scores and gingival index scores. These hidden factors, influenced by the identified covariates, warrant further investigation to fully understand their role.

DISCUSSION

The findings from this neural network analysis provide valuable insights for enhancing public health strategies, particularly for vulnerable occupational groups such as construction workers. The study confirmed that both smoking cessation and weight management are crucial for improving oral health outcomes. The neural network model revealed notable interaction effects between smoking and BMI, identifying that obese smokers exhibited the poorest oral health outcomes. This underscores the compounded impact of multiple risk factors in this population.

Construction workers play a vital role in India's economic progress, with the unorganized sector contributing significantly to the nation's workforce. According to the National Sample Survey Organization (NSSO) report, approximately 92% of India's workforce is employed in the unorganized sector, highlighting the urgent need for targeted healthcare strategies in such groups [1].

The challenging nature of construction work, along with limited access to healthcare services, increases susceptibility to oral and general health risks [2]. Unlike developed nations, India lacks a dedicated national oral healthcare system, restricting access to preventive care [3].

Our study found that 28.5% of participants had poor oral hygiene, aligning with similar findings from studies in Belagavi (36.9%) [4] and Chennai (46.3%) [6,9]. Notably, 57.1% of participants consumed smokeless tobacco and 46.1% were current smokers, which mirrors patterns seen in Puducherry's construction workers [7]. These findings highlight the urgent need for targeted interventions focused on tobacco cessation and improved oral hygiene practices.

The strong association between BMI, tobacco use and oral health established in this study aligns with previous findings, which demonstrated that smoking cessation significantly improved oral health outcomes [8]. Similarly, weight management interventions have been shown to reduce periodontal disease risk, as reported by Chaffee and Weston [10]. The compounded effects of tobacco use and abnormal BMI on oral health further emphasize the importance of multifaceted intervention strategies [11].

Our neural network model successfully revealed non-linear relationships between these variables, providing insights often missed in traditional statistical methods [12]. Importantly, the model's ability to identify hidden risk patterns emphasizes its utility in public health research.

Underweight workers in our study may experience nutritional deficiencies, increasing their vulnerability to periodontal disease and dental caries [13]. Conversely, obese individuals often suffer from systemic inflammation and metabolic imbalances, compounding their risk of poor oral health outcomes [14]. The neural network's identification of education as the strongest predictor highlights the impact of awareness and knowledge in influencing oral health behaviors.

The prevalence of poor oral hygiene among Chennai's construction workers correlates with findings that 93% of workers brushed only once daily and over 80% had never visited a dentist [15]. Tobacco consumption further exacerbated oral health risks, reinforcing the need for tailored interventions for this workforce [16].

BMI's relationship with oral health is complex; in Tamil Nadu, obesity-often linked to high sugar intake and sedentary lifestyles-has been associated with oral health challenges [17]. Conversely, underweight individuals, common in labor-intensive jobs, may face poor oral health due to inadequate nutrition [18,19].

Education levels significantly influence oral health outcomes, as shown in a comparative study where engineers exhibited better oral hygiene practices than site workers [20]. This highlights the importance of customized educational programs targeting low-literate populations to improve preventive dental care practices [15].

Research by Chaffee and Weston [10] demonstrated a U-shaped relationship between BMI and oral health, where both obesity and underweight conditions increased susceptibility to periodontal disease. Findings by

White *et al.* [21], Al-Zahrani *et al.* [22] and Al-Zahrani *et al.* [23] also confirm that the combined effects of smoking and high BMI significantly worsen periodontal conditions.

A key observation in this study was that overweight workers who consumed tobacco faced heightened risks of oral health deterioration, likely due to a combination of systemic inflammation from obesity and tissue damage caused by tobacco [24]. This finding aligns with research emphasizing the need for integrated interventions addressing both tobacco cessation and weight management [25].

While some studies, such as in the U.S., did not identify a significant BMI-smoking interaction, cultural and occupational differences may explain these inconsistencies [26,27]. Nonetheless, the synergistic impact of lifestyle factors on oral health, as reported by Al-Karadsheh *et al.* [26], aligns closely with the results of the study.

This study highlights the urgent need for comprehensive health interventions tailored to construction workers that address BMI management, tobacco cessation, improved nutrition and enhanced oral hygiene practices. Effective workplace policies, accessible dental care services and structured educational programs are essential in mitigating these identified health risks [20,28]. By addressing these multifactorial risks through targeted public health strategies, policymakers can improve the oral and overall well-being of this vulnerable population.

CONCLUSION

This study explores the intricate relationships between Body Mass Index (BMI), tobacco consumption and oral health status among construction workers in Chennai using neural network analysis to uncover complex, non-linear correlations. The findings emphasize that abnormal BMI-both underweight and obesity-combined with tobacco consumption significantly contribute to poor oral health outcomes. Construction workers with abnormal BMI values, particularly underweight individuals facing nutritional deficiencies and obese individuals experiencing systemic inflammation, demonstrated heightened vulnerability to periodontal disease, tooth loss and compromised oral health.

The study further identifies that workers who consumed tobacco-particularly those combining heavy tobacco use with abnormal BMI-were at the greatest risk of developing severe oral health issues such as periodontal disease, oral mucosal lesions and elevated DMFT scores. The neural network model's predictive accuracy of 87% highlights the model's strength in identifying these multi-dimensional interactions more effectively than traditional statistical approaches. The model's ability to capture hidden risk patterns underscores the potential of machine learning in public health research, particularly for complex, multifactorial health determinants.

This study highlights the urgent need for integrated health interventions targeting tobacco cessation, BMI management, improved nutrition and enhanced oral hygiene practices. Such strategies are vital to improving the overall well-being of vulnerable occupational groups such as construction workers.

Future Scope

While this study offers critical insights, several limitations warrant further research. The study's focus on predominantly male workers limits its applicability to female construction workers, who may face unique health risks. Additionally, the reliance on self-reported tobacco use data may introduce reporting bias. Future research should adopt longitudinal study designs to track oral health trends over time and explore broader lifestyle factors, including alcohol consumption, dietary patterns and occupational stress. Expanding research to incorporate biomarkers for tobacco exposure and investigating the influence of workplace conditions would provide a more comprehensive understanding of risk factors. Future studies should also explore alternative machine learning models, such as decision trees or random forests, to validate and compare predictive performance. Integrating these approaches could enhance risk prediction accuracy and contribute to improved intervention strategies tailored for vulnerable occupational populations.

In conclusion, this study underscores the significant oral health burden faced by Chennai's construction workers, driven by BMI abnormalities and tobacco use. By leveraging neural network analysis, this research advances public health strategies by emphasizing the importance of multi-faceted, data-driven interventions. These insights offer policymakers and healthcare professionals a valuable framework for designing targeted oral health programs that can enhance workforce well-being and productivity.

Ethical Considerations

This study was conducted in accordance with ethical guidelines outlined by the Scientific Review Board of Saveetha University. Ethical clearance was obtained before initiating the study. All participants were provided with detailed oral and written information about the study objectives, methods and potential benefits. Written informed consent was obtained from each participant prior to data collection. Participant confidentiality and anonymity were strictly maintained throughout the research process. Data was securely stored and access was limited to authorized personnel only. Any participants requiring dental treatment were referred to Saveetha Dental College for appropriate care.

Conflict of Interest

The authors declare no conflict of interest related to this research. The study was conducted independently without any influence from funding agencies, industry bodies, or other external organizations.

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