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Nutritional status of older adults in India: An exploration of the role of oral health and food insecurity factors

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ABSTRACT

Background: In this study, we attempted to generate insights into the determinants of nutritional status among older adults in India by exploring the role of factors including oral health, food insecurity, socioeconomic, demographic and health-related variables. The study also examined the moderating role of tooth loss with the association between chewing ability and nutritional status.

Methods: The data was obtained from Longitudinal Ageing Study India (LASI) – Wave 1 (2017-18). The sample consisted of 27,411 older adults (Male = 13, 232; Female = 14, 179) aged 60 years and above. In addition to descriptive and bivariate analysis, we employed multinominal logistic regression analysis.

Result: There was a significant association between the ability to chew solid food and tooth loss in the nutritional status of older adults. It was further revealed that tooth loss acted as a moderator (aRRR = 1.50, 95 % CI: 1.08–2.08) between the chewing ability and the risk of being underweight. The weight loss due to food insecurity increased the relative risk ratio of being underweight (aRRR = 1.58, 95 % CI: 1.25–2.00). Further evidence showed that self-rated health (SRH), Instrumental Activities of Daily Living (IADL), morbidity status and socioeconomic factors had a significant role in determining the nutritional status among older adults.

Conclusion: Chewing ability, tooth loss, and food insecurity determine nutritional status among older adults. It is suggested to care for oral and general physical health as these factors increase the risk of nutritional deficits. Also, policy measures should be strengthened to address the specific health and food security needs of older adults from vulnerable socioeconomic circumstances.

1. Introduction

Nutrition has a crucial role in the process of ageing. Good nutrition plays a significant role in a healthier life, and the nutritional intake in the earlier years influences the later years of life [1]. A recent study proposed a theoretical model for assessing the bidirectional association between nutritional and functional status, and it comprises four domains: food and nutrition, physical functioning and capacity, health and somatic disorders, and cognitive, affective and sensory function [2]. This model established that the components of all four domains were associated with inadequate nutritional status [2]. At the global level, there has been a rise in

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malnutrition among older adults [3]. Literature also showed that undernutrition and overweight or obesity reportedly increase morbidity and mortality risk [4]. Older adults generally tend to change their food preferences, patterns, and nutritional intake, and physical, emotional, and psychological aspects also witness alterations [1]. A study reported that as people age, they experience decreased average Body Mass Index (BMI) [5]. Remarkably, nutritional factors can slow ageing with lifestyle factors such as following a nutritious diet, physical activity, and avoiding unhealthy behaviour such as smoking [6].

Further, evidence suggests that nutritional status is influenced by oral health factors [7]. A well-established literature exists on the relationship between oral health and nutritional outcome [8]. Ageing adults face multiple issues with oral health due to the loss of natural teeth, which significantly impacts their diet pattern as they prefer food that is comfortable to chew, along with reduced intake of vegetables and fruits, which leads to nutritional disturbances [8–11]. A review study suggested that tooth loss during ageing inhibits individuals from consuming fruits and vegetables, leading to nutritional imbalance [10]. Further, a study discussed the importance of enhancing oral health among older adults to reduce the risk of nutritional deficiencies [12]. Even the saliva undergoes chemical changes with ageing as it becomes thicker, leading to dry mouth (xerostomia), especially due to medications [13]. This will also lead to trouble with chewing and low nutrient intake [14]. In addition, a study reported that more than 50 % of Lebanese older adults aged 70 years and above required dental care and were on the verge of nutritional deficit [12]. Studies also reported that masticatory performance was low among obese individuals compared to their counterparts [15], and further, individuals with lower masticatory performance had lower BMI [16].

Food security is important for understanding nutritional status, as earlier studies established the association between food insecurity and malnutrition [17,18]. Food insecurity is also an important risk factor for older adults and makes them vulnerable to chronic diseases [19]. A study identified the association between food insecurity and nutrition status-malnutrition and overweight, suggesting the burden of food security on nutritional status [17]. Another study found a positive correlation between food insecurity with weight and nutritional risk but no association with BMI categories [20]. Further, it was established that income directly impacted health through nutrition, which is generally overlooked [21,22].

It is evident from the literature that various socioeconomic and demographic factors determine nutritional status, including age, gender, marital status, number of individuals in the household, income and savings and socioeconomic status [23,24]. Also, mental health and educational status significantly affect nutritional status [7]. Studies established that health risk behaviours such as smoking and alcohol consumption were significantly associated with the risk of nutritional problems [25]. There is a significant gender difference in weight among Indian adults, and females were more prone to be overweight or underweight than males due to health risk-related behaviours [5]. A study reported that economic vulnerability, residency, diagnosis with chronic diseases and depression were the major risk factors for malnutrition among eastern Ethiopian older adults [26]. In addition, a study among hospitalized adult patients who reported poor self-rated health and reduced food intake had a high mortality risk [27]. Literature supports the association between health-related variables and nutritional status. A study identified chronic pain and earlier hospitalization as predictors of malnutrition among older adults [22].

Nutritional deficits are one of the critical issues among older adults in India, as about 45 % faced food insecurity, and approximately half were malnourished [18,28]. Another study found the prevalence of malnutrition among older adults to be 18.29 %, the risk at

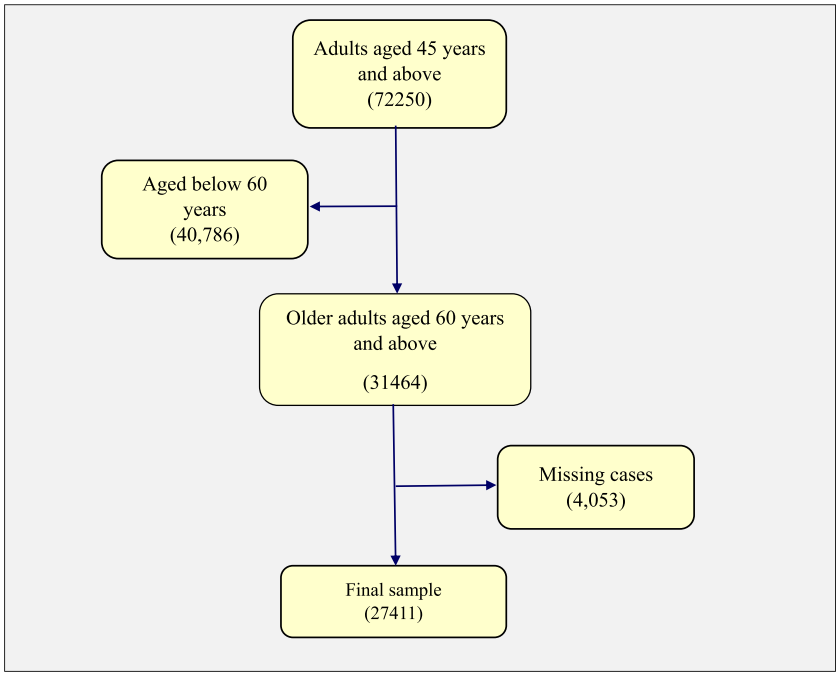

Fig. 1. Sample selection criteria.

48.17 % and a higher prevalence among females [29]. There is a dire need to understand the nutritional trajectory in the ageing process. This is specifically crucial with the projection of an increasingly ageing population globally and in developing countries like India in the near future [30]. It becomes important to get an insight into the determinants of nutritional status among older adults in India as socio-cultural, economic and health-related factors may play a significant role in nutritional status. In this context, the current study aims to understand the determinants of nutritional status among older adults in India. In this study, we have considered multifaceted variables, including oral health, food security, health-related variables, health behaviour factors, and socioeconomic and demographic variables. Further, we explored the moderating role of tooth loss between the association of the ability to chew solid food and nutritional status.

2. Methods

2.1. Data and sample

The present study utilized secondary data from the first wave of the Longitudinal Ageing Study in India (LASI) collected between April 2017 and December 2018. The survey collected information on socioeconomic, health, and psycho-social aspects of adults aged 45 years and above. This is one of the credible ongoing longitudinal databases related to the ageing population in India and is a nationally representative survey and is harmonized with the Health and Retirement Study (HRS). The survey covered all the Indian states and Union Territories (except Sikkim) in the first wave, with a sample size of 72,250 ageing adults. The LASI was supported and funded by the Ministry of Health and Family Welfare, Government of India, the National Institute of Aging and the United Nations Population Fund-India, along with the International Institute for Population Sciences (IIPS), Mumbai, the University of Southern California (USC) and Harvard T H Chan School of Public Health (HSPH), few other institutions provided technical support for the execution of the study at India [31]. The survey used three- and four-stage sampling designs in rural and urban areas, respectively. For the current study, 31464 older adults aged 60 years and above were considered. After dropping missing cases, a total of 27411 (Male = 13,232, Female = 14,179) older adults were included in the study. A summary of the sample selection criterion is presented in Fig. 1.

2.2. Measures

2.2.1. Outcome variable

Nutritional status: Body Mass Index (BMI) was considered to assess the nutritional status of older adults [32]. It was calculated using the standard BMI formula (weight of the individual in kg/square of height in meters). Based on BMI score, the participants were grouped into WHO standards; those samples with less than 18.5 kg/m^2 were categorized as "underweight", 18.5–24.9 kg/m^2 as "normal weight", and 25.0–29.9 kg/m^2 as "overweight" and above 30 kg/m^2 as "obese" [5].

2.2.2. Predictor variables

A well-established literature exists on the relationship between oral health and nutritional outcome [8]. A review study suggested that tooth loss during ageing inhibits individuals from consuming fruits and vegetables, leading to nutritional imbalance [10]. Further, a study discussed the importance of enhancing oral health among older adults to reduce the risk of nutritional deficiencies [12].

Oral health: We have included three major indicators to assess the study population's health: chewing ability, tooth loss, and other oral health problems.

1. **Chewing Ability:** It was assessed using the question, 'How well can you chew solid food like chapati, guava, apple and nuts?' with response patterns of very well, pretty well, fairly well, not well and not at all. Further, the adults were categorized in terms of 'yes' based on the ability to chew solid food if they responded very well, pretty well and fairly well and 'no' ability to chew if their response was not well or not at all.
2. **Tooth Loss:** The response to the question 'Have you lost some or all of the natural teeth?' was categorized into 'yes' if the responses were some or all the teeth lost and 'no' if no teeth were lost.
3. **Other Oral Health Problems**: This was understood through their response to the question, 'In the last 12 months, have you ever been diagnosed with or suffered from any oral problems' like painful teeth, ulcer lasting more than two weeks, bleeding gums, swelling gums and loose teeth, dental cavity, soreness or cracks in the corner of the mouth and any other problem. Based on this response, the participants were categorized as 'yes', indicating they suffered from any problem and 'no', indicating no problem.

Food Security: [19]. The study measured the participants' food security using four indicators collected to assess hunger and food availability. It consists of i) whether the participant ever reduced the size of the meals or skipped meals in the last 12 months as there was not enough food, ii) was hungry but did not eat in the last 12 months as there was not enough food, iii) ever did not eat for a whole day as there was no enough food, and iv) lost weight in the last 12 months as there was no enough food in the household. Each indicator was dichotomized as "yes" or "no".

Health-related Variables: The health-related variables included in the study consist of Self-Rated Health (SRH) status, Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL) and Morbidity status. SRH was assessed based on self-reported information and was categorized as "good" (which includes fair, good and very good) and "poor" (by combining poor and very poor). The ADL was assessed based on difficulties in performing basic activities, including dressing, walking, bathing, eating, getting out of bed and using the toilet. The IADL was measured based on difficulties in performing seven activities: shopping, making a

telephone call, cooking, doing work around the house/gardening, taking medications, managing money and movement. ADL and IADL were classified as "low" if the difficulty was reported in performing at least one of the respective activities. Morbidity status was assessed based on nine conditions, including hypertension, diabetes, cancer, chronic lung diseases, chronic heart diseases, stroke, arthritis, any neurological or psychiatric issues and high cholesterol. Morbidity status was categorized into "none", "single", and "multimorbidity".

Health Behaviour Factors: Three indicators were considered to account for the health behaviour factors. It consists of alcohol consumption, ever smoker and engagement in physical activity. As established earlier, these health risk behaviours are considered important determinants of nutrition status[33]. All three responses were categorized as binary indicators as "yes"' and "no".

Socioeconomic and Demographics Variables: The current study considered different variables to account for these factors. The variables consist of age (60–69 years, 70–79 years and 80 years and above), gender, educational attainment (no schooling, 1–5 years, 6–10 years and more than 10 years), social class (Scheduled Tribe [SC], Scheduled Caste [ST], Other Backward Class [OBC] and

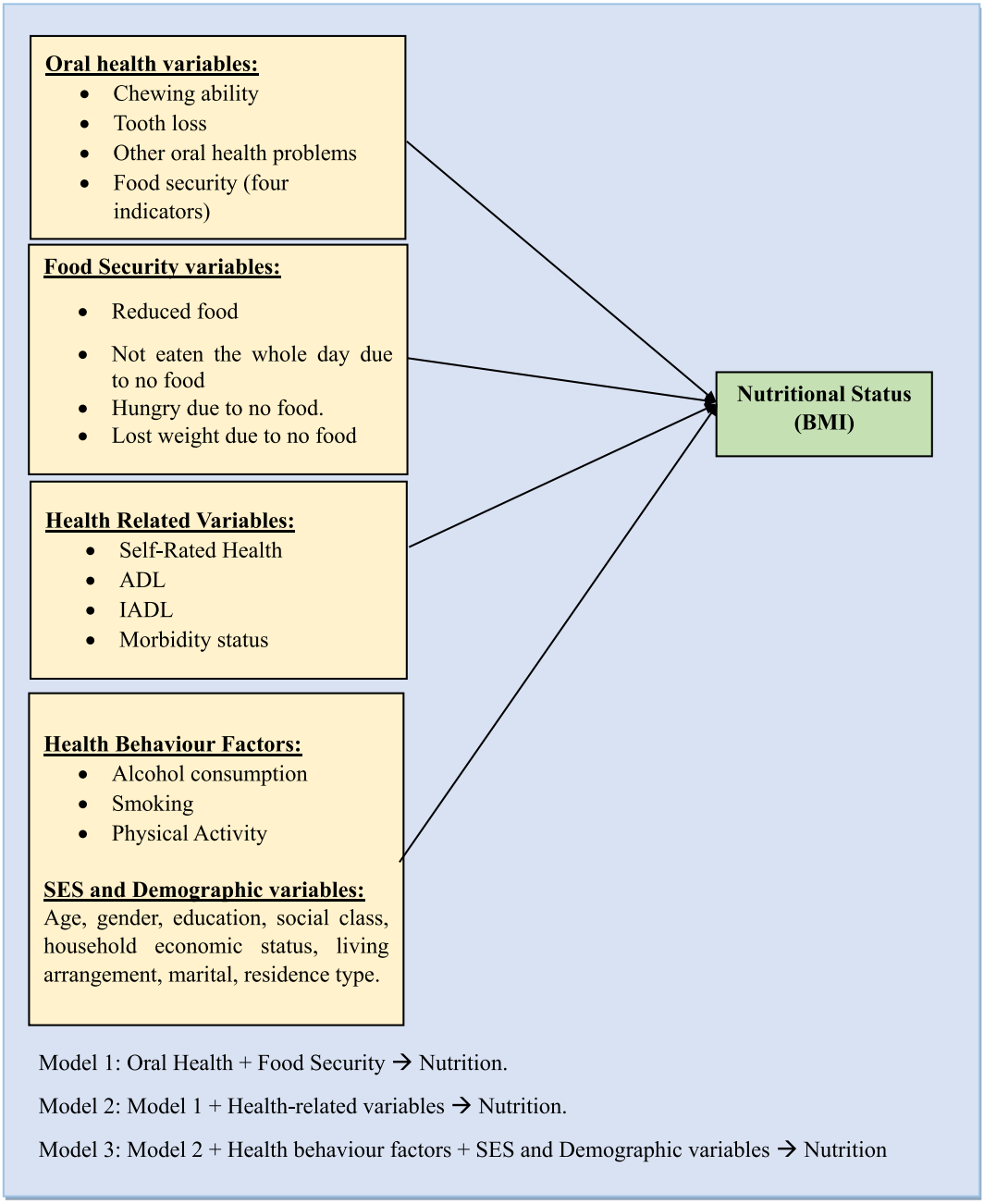

Fig. 2. Summary of the conceptual framework of the multinomial regression models.

others), SC and ST are socially and economically disadvantaged groups in India and are constitutionally protected with special privileges. The OBC belong to other castes that are socially and economically vulnerable. The household economic status is classified as poorest, poorer, middle class, richer, and richest. In addition, living arrangement (living alone, living with spouse and others, living with others), marital status (in a union and not in a union) and residence type (urban or rural) were considered. The household economic status was given in the LASI dataset and was measured based on standardized household expenditure on selected food and non-food items.

2.2.3. Statistical analysis

We employed descriptive and bivariate analysis for the statistical analysis to understand the sample and background characteristics. Specifically, we employed chi-square statistics for bivariate analysis. Further, multinomial regression analysis was conducted to get an insight into the risk ratio of being underweight and overweight compared to normal nutritional status across the variables. Specifically, the study employed four multinomial regression models. Model 1 (unadjusted model) aimed to explore the association between oral health and food security factors with nutritional status. In Model 2 (unadjusted model), we added health-related factors and variables included in Model 1. In Model 3 (adjusted model), we considered health behaviour factors, socioeconomic status, and demographics. Additionally, in Model 4, the role of tooth loss as a moderator was explored. A summary of the conceptual framework of these models is represented in Figs. 2 and 3. The multinomial regression results are presented using Relative Risk Ratios (RRR) with a 95 % significance level. In the current study, RRR was used to identify the likelihood of the risk of being underweight, overweight and obese among the participants. The statistical analysis was implemented using STATA version 14.2.

3. Results

The nutritional status of participants is presented in Fig. 4. It was found that more than half of the study sample had a normal weight. 26.95 %, 16.31 %, and 5.45 % had reported being underweight, overweight, and obese, respectively. The characteristics of the samples are presented in Table 1. Among the older adults included in the study, more than 66 % could chew solid food well, and about 11 % of older adults had tooth loss. It is important to note that more than half of the adults reported having other oral health problems (51.44 %). Less than 10 % of the study participants reduced food intake, did not eat the whole day, were hungry, and lost weight due to insufficient food. Health-related factors indicated that about a quarter of the study participants reported poor health status. Regarding disability status, 21.94 % and 46.84 % reported low ADL and IADL statuses, respectively. 29.27 % and 23.30 % reported single and multimorbid conditions, respectively.

The study participants consisted of older adults aged 60–69 years (59.99 %), followed by 70–79 years (29.27 %), and 80 years and above (10.29 %). The sample consisted of more females (52.29 %) than males (47.71 %). Notably, 56.53 % had no formal education, and only 7.75 % had attained education of 10 years and more. Further, about 45.22 % of participants belonged to other backward caste (OBC), with least proportion of participants from scheduled tribe (8.51 %). In terms of household economic status, 21.80 % from poorer background with lower proportion from richest background (16.47). It was found that 5.80 % of participants lived alone, whereas 62.10 % lived with spouses and others. 63.17 % of participants were in a marital union. Nearly three-fourths of the study participants were from rural areas. Based on health risk behaviour, it was found that 14.74 % and 41.03 % of participants were ever-consumed alcohol and ever-smokers, respectively. It was found that 32.45 % of participants engaged in some form of physical activity.

A bivariate analysis was conducted with nutritional status with baseline characteristics to extract preliminary results further. The result is presented in Table 2. The evidence indicated that participants unable to chew solid food had a significantly higher prevalence of underweight than those who could chew solid food (34.91 % Vs 23.00 %; $p = .00$). On the contrary, a higher prevalence of overweight (18.31 % Vs 12.28 %; $p = .00$) and obesity (6.76 % Vs 2.83 %; $p = .00$) conditions was observed among participants with the ability to chew solid food compared to those who reported no ability to chew solid food. The prevalence of underweight was significantly higher among individuals with tooth loss compared to those who reported no tooth loss (31.47 % Vs 26.39 %; $p = .00$). It was found that individuals with food insecurity in terms of the four selected indicators (i.e., reduced food, did not eat food the whole day, was hungry and lost weight due to no food) had a significantly higher prevalence of underweight than their counterparts. On the

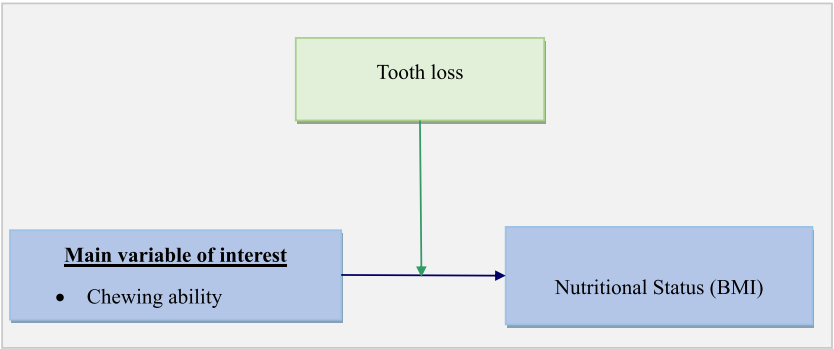

Fig. 3. Conceptual framework of moderation analysis.

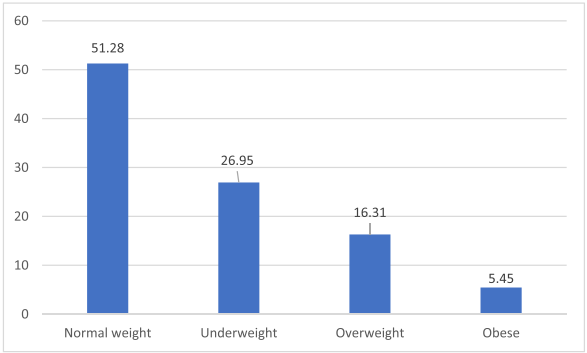

Fig. 4. Nutritional status of older adults in India (weighted percentage).

other side, as expected, older adults with food security in all four indicators had a significantly higher prevalence of overweight and obesity in comparison to older adults with food insecurity. It was observed that older adults with poor self-rated health, low ADL and IADL status had a significantly higher prevalence of underweight than their counterparts. The results showed that in comparison to participants with no morbid conditions, those participants with multimorbid conditions had a significantly lower prevalence of underweight (14.13 % Vs 34.79 %, p = .00) and a higher prevalence of overweight (26.20 % Vs 10.21 %, p = .00) and obesity (12.42 % Vs 1.84 %, p = .00).

In terms of socioeconomic and demographic variables, it was found that individuals aged above 80 years were males. In contrast, the prevalence of overweight and obesity was significantly lower among them. In addition, the prevalence of underweight was higher among older adults from the ST social background. Similarly, it was found that the prevalence of underweight was higher among participants from the poorest and poorer household economic status. It was noticed that participants living alone or with others had a higher prevalence of underweight (30.86 % and 30.40 %, respectively), whereas it was lower among those living with their spouse and others (24.80 %). Similarly, it was found that underweight was significantly higher among those who were not in a marital union compared to those who were in a marital union (30.78 % Vs 24.72 %; p = .00). Based on rural and urban residence status, it was observed that the prevalence of underweight was significantly higher among rural participants (32.49 % Vs 12.45 %; p = .00) and the prevalence of overweight (26.65 % Vs 12.36 %; p = .00) and obesity (11.82 % Vs 3.02 %; p = .00) was higher among urban older adults. Based on health-related factors, individuals who ever consumed alcohol (32.19 % Vs 26.05 %; p = .00) and smokers (34.72 % Vs 21.55 %; p = .00) had a significantly higher prevalence of being underweight. The prevalence of underweight was higher among those who engaged in physical activity (27.35 % Vs 26.76 %; p = .00), whereas overweight and obesity were lower among them.

The results of multinominal regression of underweight and overweight by background characteristics are presented in Table 3. In Model 1 (unadjusted model), participants with the inability to chew solid food had a higher relative risk ratio of being underweight (uRRR = 1.59, 95 % CI: 1.43–1.75), a lower relative risk ratio of being overweight (uRRR = 0.70, 95 % CI: 0.62–0.80) and obese (uRRR = 0.41, 95 % CI: 0.30–0.56) compared to older adults who were able to chew solid food well. Similar results were obtained in Model 2 (unadjusted model), Model 3 (fully adjusted model), and in adjusted model with interaction. It was observed that participants who reported oral health problems had a lower relative risk ratio of being underweight (aRRR = 0.94, 95 % CI: 0.72–1.23) in all the models. Consistent with unadjusted models, it was found that those who reported that they lost weight due to no food availability had a higher relative risk ratio of being underweight in the fully adjusted model (aRRR = 1.58, 99 % CI: 1.25–2.00) compared to participants who did not lose weight due to no food availability. Consistent with unadjusted models, participants who reported that they lost weight due to no food availability had a lower relative risk ratio of being overweight (aRRR = 0.66, 95 % CI: 0.48–0.92) compared to older adults who did not lose weight due to no food availability.

The interaction model indicated that the combined effect of the inability to chew solid food and tooth loss showed a statistically significant higher relative risk ratio of being underweight (aRRR = 1.50, 95 % CI: 1.08–2.08). It was also observed that the combined effect of the inability to chew solid food and tooth loss showed no statistically significant effect on overweight and obesity.

Based on model 4, health-related factors, it was observed that older adults who reported poor SRH had a higher relative risk ratio of being underweight (aRRR = 1.23, 95 % CI: 1.08–1.39) and a lower relative risk of being overweight (aRRR = 0.84, 95 % CI: 0.72–0.96). Based on disability status, it was found that participants with low IADL status had a higher relative risk ratio of being underweight than participants with high IADL status (aRRR = 1.14, 95 % CI: 1.02–1.27). The results indicated that in comparison with older adults with no morbid condition, those participants with the single and multimorbid condition had a lower relative risk ratio of being underweight (aRRR = 0.77, 95 % CI: 0.69–0.86), and (aRRR = 0.50, 95 % CI: 0.43–0.58), respectively, whereas they had a higher relative risk ratio of being overweight (aRRR = 1.70, 95 % CI: 1.47–1.97, and aRRR = 2.48, 95 % CI: 2.13–2.87), respectively and obesity (aRRR = 2.74, 95 % CI: 1.03–3.69) and (aRRR = 5.30, 95 % CI: 4.08–6.89), respectively.

It was found that in comparison with participants aged 60–69 years, participants aged 70–79 years and 80 years and above had a significantly lower relative risk ratio of being overweight (aRRR = 0.68, 95 % CI: 0.59–0.79) and (aRRR = 0.69, 95 % CI: 0.49–0.99), respectively. It was also found that participants aged 80 years and older had a higher relative risk ratio of being underweight than participants aged 60–69 years. It was found that male participants had a lower relative risk ratio of being overweight and obese than female older adults (aRRR = 0.63, 95 % CI: 0.53–0.75) and (aRRR = 0.26, 95 % CI: 0.19–0.35). Based on educational attainment, it was

Table 1
Descriptive characteristics of the study variables.

Variables	Frequency	Weighted percentage
Ability to chew solid food		
Well	18634	66.86
Not Well	8777	33.14
Loss of tooth		
No	24429	88.98
Yes	2982	11.02
Other oral health problems		
No	13121	48.56
Yes	14290	51.44
Reduced food due to no food		
No	25946	93.69
Yes	1465	6.31
Not eaten the whole day due to no food		
No	26551	95.89
Yes	860	4.11
Hungry due to no food		
No	26218	94.45
Yes	1193	5.55
Lost weight due to no food		
No	26167	94.28
Yes	1244	5.72
Self-Rated Health		
Good	21269	76.43
Poor	6142	23.57
ADL		
High	22067	78.06
Low	5344	21.94
IADL		
High	15666	53.16
Low	11745	46.84
Morbidity		
None	12670	47.43
Single	8050	29.27
Multimorbidity	6691	23.30
Age		
60–69 years	16885	59.99
70–79 years	7865	29.27
80 years and above	2661	10.29
Gender		
Male	13232	47.71
Female	14179	52.29
Education		
No Schooling	14607	56.63
1–5 years	5185	17.86
6–10 years	5375	17.76
Above 10 years	2244	7.75
Social class		
Scheduled Tribe (ST)	4496	8.51
Scheduled Caste (SC)	4535	19.27
Other Backward Class (OBC)	10488	45.22
Others	7892	17.01
Household economic status		
Poorest	5560	21.76
Poorer	5667	21.80
Middle	5645	20.87
Richer	5401	19.10
Richest	5138	16.47
Living arrangement		
Alone	1442	5.80
With spouse and others	17386	62.10
With others	8583	32.09
Marital status		
In a union	17724	63.17
Not in a union	9687	36.83
Residence type		
Urban	9103	27.65
Rural	18308	72.35
Ever consume alcohol		

(*continued on next page*)

Table 1 (*continued*)

Variables	Frequency	Weighted percentage
None	22674	85.26
Yes	4737	14.74
Ever smoker		
None	16568	58.97
Yes	10843	41.03
Physical activity		
None	18721	67.55
Yes	8690	32.45
Sample	**27411**	**100**

indicated that the relative risk ratio of being underweight decreased with a higher level of education. In contrast, the relative risk ratio of overweight and obese increased with higher education.

Similarly, the results indicated that the odds of relative risk for being underweight were lower among older adults from higher social class and economic status backgrounds than those from lower social and economic statuses. On the other hand, it was revealed that the odds of relative risk for being overweight and obese were higher among participants from higher social class and economic status backgrounds than those from lower social and economic statuses. The results showed that older adults who lived with a spouse and others had a higher relative risk ratio of being obese in comparison with those who lived alone, whereas those who were not in a marital union had a higher relative risk ratio of being underweight. It was further revealed that rural participants had a higher relative risk ratio of being underweight (aRRR = 1.87, 95 % CI: 1.62–2.16), whereas they had a lower relative risk ratio of being overweight and obese in comparison with urban participants (aRRR = 0.59, 95 % CI: 0.51–0.68) and (aRRR = 0.42, 95 % 0.31–0.57).

Based on the health risk behaviour factors, smoking significantly affects nutritional status. The results showed that compared to non-smokers, ever smokers had a higher relative risk ratio of being underweight (aRRR = 1.48, 95 % CI: 1.33–1.64) and had a lower relative risk of being overweight (aRRR = 0.75, 95 % CI: 0.65–0.86). As expected, those who engaged in physical activity have a lower relative risk ratio of being overweight than those who did not engage in vigorous physical activity.

4. Discussion

In this study, we attempted to understand the determinants of nutritional status among older adults and especially sought to dissect the role of oral health and food security. The study results showed that individuals unable to chew solid food had a higher risk of underweight and a lower risk of overweight, which is consistent with the literature. A study among Japanese older adults concluded that chewing ability was relatively associated with nutritional status and preferred food intake, further pointing to undernutrition among older adults [34]. In addition, similar results were noticed among older adults above 65 years in Korea, indicating that undernutrition resulted from the inability to chew food and poor diet quality [35]. As individuals age, the issues with oral health increase in terms of chewing and masticatory efficiency, leading to poor quality food choices that are low in overall nutritional level except for carbohydrates [34]. In contrast, a study among the older population of Sri Lanka revealed an association between tooth loss and underweight but not overweight [36]. However, a study by Nakamura et al. pointed out that a smaller number of teeth and food intake was related to underweight and obesity among older adults [37].

The study presented a contradicting result regarding older adults' other oral health problems, indicating that those with oral health problems had a low risk of underweight compared to their counterparts. This could be due to the different methods used for assessing oral health in the present study, as it was assessed in terms of problems and illnesses associated with teeth and gums. Weight loss evident in the present study's results due to food security is consistent with literature indicating a strong association between food insecurity and underweight [17,18].

The study results revealed a significant moderating role of tooth loss between the association of the ability to chew solid food and nutritional status. The earlier studies reported the impact of tooth loss on the healthy eating index among older adults, especially individuals with severe loss who are less likely to meet the criteria than their counterparts [38]. As indicated earlier, tooth loss is significantly associated with food choices in later life. Further, similar to the contrasting evidence in our study results, though was not statistically significant, a study interestingly noted that individuals with more tooth loss were prone to being overweight, and this was highly significant among females compared to males and also pointed out at the association of tooth with underweight and overweight [39]. However, the mechanism behind tooth loss and nutritional status is unclear. In this context, the present study brings out the moderating role of tooth loss, where the evidence indicated that tooth loss played a moderating role between the ability to chew solid food and underweight.

Self-rated health was a significant determinant of nutritional status, as individuals with poor self-rated health had a greater risk of underweight and a lower risk of being overweight and obese. Similarly, a study among Swedish older adults concluded that self-perceived health and symptoms of depression lead to a greater risk of malnutrition [40]. Further, a study from India using data from WHO's study on Global AGEing and adult health (SAGE) reported that 29.6 % of adults reporting poor self-rated health were underweighted compared to 16.4 % and 20.1 % of normal weight and overweight cases, respectively [53]. Our study results showed that disability had a significant effect on undernutrition. An earlier study indicated that physical functioning and disability were associated with undernutrition [41]. There is also a possibility of the bidirectional relationship between disability and nutritional status, where future studies can ponder its mechanism. The study evidence indicated that older adults with morbid conditions had a

Table 2
Bivariate analysis of nutritional status with baseline characteristics.

Variables	Weighted percentage of underweight	P value	Weighted percentage of normal weight	P value	Weighted percentage of overweight	P value	Weighted percentage of obesity	P value
Ability to chew solid food								
Well	23.00	.00	51.93	.00	18.31	.00	6.76	.00
Not Well	34.91		49.99		12.28		2.83	
Loss of tooth								
No	26.39	.00	51.38	0.22	16.63	.00	5.60	.04
Yes	31.47		50.47		13.77		4.29	
Other oral health problems								
No	28.09	.00	50.93	0.12	16.31	.00	4.67	0.18
Yes	25.88		51.61		16.31		6.20	
Reduce Food								
No	26.17	.00	51.51	.00	16.65	.00	5.67	.00
Yes	38.58		47.93		11.24		2.24	
Not eaten the whole day due to no food								
No	26.29	.00	51.61	.00	16.49	.00	5.61	.00
Yes	42.49		43.52		12.21		1.78	
Hungry due to no food								
No	26.17	.00	51.57	.00	16.61	.00	5.65	.00
Yes	40.18		46.44		11.20		2.18	
Lost weight due to no food								
No	25.89	.00	51.66	.00	16.77	.00	5.68	.00
Yes	44.37		45.06		8.83		1.75	
Self-Rated Health								
Good	25.65	.00	51.87	.00	16.82	0.91	5.67	.00
Poor	31.16		49.39		14.68		4.77	
ADL								
High	25.99	.00	52.34	.00	16.48	0.60	5.19	.00
Low	30.38		47.51		15.72		6.39	
IADL								
High	23.84	.00	53.44	.00	17.61	.00	5.11	0.27
Low	30.48		48.84		14.83		5.84	
Morbidity								
None	34.79	.00	53.17	.00	10.21	.00	1.84	.00
Single	24.47		51.43		18.33		5.77	
Multimorbidity	14.13		47.26		26.20		12.42	
Age								
60–69 years	23.81	.00	51.27	0.14	18.61	.00	6.31	.00
70–79 years	28.86		53.06		13.38		4.71	
80 years and above	39.75		46.21		11.41		2.63	
Gender								
Male	28.32	.00	54.10	.00	14.83	.00	2.75	.00
Female	25.70		48.71		17,66		7.92	
Education								
No Schooling	33.52	.00	51.06	0.07	11.91	.00	3.50	.00
1–5 years	24.60		52.30		17.72		5.39	
6–10 years	16.57		51.52		22.31		9.60	
Above 10 years	8.12		49.99		31.49		10.40	
Social class								
Scheduled Tribe (ST)	38.66	.00	51.50	.00	8.80	.00	1.03	.00
Scheduled Caste (SC)	34.07		50.78		12.28		2.87	
Other Backward Class (OBC)	26.50		50.96		16.58		5.95	
Others	18.93		52.11		21.10		7.86	
Household economic status								
Poorest	35.54	.00	50.63	0.10	10.75	.00	3.09	.00
Poorer	31.71		50.52		13.38		4.66	
Middle	27.11		51.08		17.63		4.19	
Richer	21.18		53.21		19,34		6.28	
Richest	15.82		51.54		22.36		10.28	
Living arrangement								
Alone	30.86	.00	49.55	.00	15.66	.00	3.94	.04
With spouse and others	24.80		52.51		17.32		5.36	
With others	30.40		49.22		14.48		5.91	
Marital status								

(*continued on next page*)

Table 3
Results of multinominal regression of underweight and overweight by background characteristics.

Variables	Model 1			Model 2			Model 3			Model 4 [interaction model]		
	Underweight uRRR (CI)	Overweight uRRR (CI)	Obesity uRRR (CI)	Underweight uRRR (CI)	Overweight uRRR (CI)	Obesity uRRR (CI)	Underweight aRRR (CI)	Overweight aRRR (CI)	Obesity uRRR (CI)	Underweight aRRR (CI)	Overweight aRRR (CI)	Obesity uRRR (CI)
Ability to chew solid food (Ref: Well)												
Not Well	1.59* (1.43–1.75)	0.70* (0.62–0.80)	0.41* (0.30–0.56)	1.46* (1.32–1.62)	0.72* (0.64–0.83)	0.41* (0.31–0.55)	1.34* (1.21–1.49)	0.80* (0.70–0.92)	0.47* (0.37–0.61)	1.29* (1.15–1.45)	0.77* (0.67–0.88)	0.44* (0.33–0.59)
Loss of tooth (Ref: No)												
Yes	0.96 (0.83–1.11)	0.98 (0.77–1.25)	1.19 (0.88–1.62)	0.96 (0.83–1.11)	0.94 (0.74–1.20)	1.10 (0.80–1.50)	0.95 (0.82–1.11)	0.95 (0.76–1.18)	1.14 (0.81–1.59)	0.71* (0.54–0.94)	0.75* (0.60–0.98)	0.90 (0.55–1.46)
Interaction effect												
Not well to chew solid food # lost tooth|										1.50* (1.08–2.08)	1.49 (0.89–2.28)	1.60 (0.84–3.06)
Other oral health problems (Ref: No)												
Yes	0.85* (0.77–0.94)	1.02 (0.90–1.16)	1.43 (1.00–2.04)	0.87* (0.79–0.96)	0.94 (0.83–1.07)	1.19 (0.88–1.63)	0.88* (0.80–0.97)	0.94 (0.83–1.07)	1.17 (0.91–1.50)	0.89* (0.80–0.98)	0.95 (0.84–1.08)	1.18 (0.92–1.52)
Reduced Food (Ref: No)												
Yes	1.01 (0.79–1.29)	0.84 (0.63–1.11)	0.67 (0.40–1.40)	0.97 (0.73–1.27)	0.86 (0.65–1.15)	0.68 (0.41–1.13)	0.94 (0.72–1.23)	0.91 (0.68–1.21)	0.78 (0.45–1.36)	0.94 (0.72–1.23)	0.91 (0.68–1.21)	0.78 (0.45–1.36)
Not eaten the whole day due to no food (Ref: No)												
Yes	1.28 (0.93–1.78)	1.38 (0.82–2.29)	0.75 (0.40–1.42)	1.29 (0.91–1.83)	1.36 (0.80–2.31)	0.72 (0.38–1.39)	1.21 (0.87–1.71)	1.52 (0.88–2.61)	0.87 (0.43–1.73)	1.22 (0.87–1.70)	1.52 (0.87–2.61)	0.87 (0.44–1.74)
Hungry due to no food (Ref: No)												
Yes	1.12 (0.85–1.49)	0.86 (0.59–1.26)	0.78 (0.46–1.32)	1.09 (0.81–1.47)	0.86 (0.58–1.27)	0.77 (0.45–1.32)	1.02 (0.75–1.37)	0.93 (0.63–1.38)	0.87 (0.50–1.52)	1.02 (0.75–1.37)	0.93 (0.63–1.38)	0.87 (0.50–1.52)
Lost weight due to no food (Ref: No)												
Yes	1.63* (1.28–2.06)	0.63* (0.46–0.86)	0.50 (0.24–1.05)	1.62* (1.27–2.07)	0.63* (0.46–0.87)	0.50 (0.24–1.04)	1.58* (1.25–2.00)	0.66* (0.48–0.92)	0.56 (0.25–1.23)	1.58* (1.25–2.00)	0.67* (0.48–0.92)	0.56 (0.25–1.23)
Self-Rated Health (Ref: Good)												
Poor				1.29* (1.15–1.46)	0.78* (0.67–0.90)	0.63* (0.45–0.89)	1.23* (1.08–1.39)	0.83* (0.72–0.96)	0.70* (0.53–0.94)	1.23* (1.08–1.39)	0.84* (0.72–0.96)	0.70 (0.52–0.94)
ADL (Ref: High)												
Low				1.09 (0.96–1.25)	1.07 (0.90–1.28)	1.21 (0.75–1.95)	1.06 (0.93–1.21)	1.11 (0.94–1.31)	1.34 (0.94–1.91)	1.06 (0.93–1.21)	1.10 (0.94–1.31)	1.34 (0.94–1.91)
IADL (Ref: High)												
Low				1.34* (1.20–1.49)	0.88 (0.76–1.00)	1.13 (0.70–1.80)	1.14* (1.03–1.28)	1.02 (0.89–1.17)	1.21 (0.88–1.66)	1.14* (1.02–1.27)	1.02 (0.89–1.17)	1.21 (0.88–1.66)
Morbidity (Ref: None)												
Single				0.68* (0.61–0.77)	1.92* (1.65–2.25)	3.29* (2.46–4.41)	0.77* (0.69–0.86)	1.70* (1.47–1.97)	2.74* (2.03–3.69)	0.77* (0.69–0.86)	1.70* (1.47–1.97)	2.74* (1.03–3.69)
Multimorbidity				0.39* (0.34–0.46)	3.18* (2.73–3.69)	8.12* (5.51–11.96)	0.50* (0.43–0.58)	2.47* (2.13–2.87)	5.30* (4.08–6.89)	0.50* (0.43–0.58)	2.48* (2.13–2.87)	5.31* (4.09–6.90)
Age (Ref:60–69 years)												
70–79 years							1.09 (0.98–1.22)	0.68* (0.59–0.79)	0.62* (0.43–0.90)	1.09 (0.98–1.22)	0.68* (0.59–0.79)	0.62* (0.43–0.90)
80 years and above							1.57* (1.30–1.89)	0.69* (0.49–0.99)	0.43* (0.18–1.00)	1.57* (1.29–1.89)	0.69* (0.49–0.98)	0.43* (0.18–1.00)
Gender (Ref: Female)												

(*continued on next page*)

Table 3 (*continued*)

Variables	Model 1			Model 2			Model 3			Model 4 [interaction model]		
	Underweight uRRR (CI)	Overweight uRRR (CI)	Obesity uRRR (CI)	Underweight uRRR (CI)	Overweight uRRR (CI)	Obesity uRRR (CI)	Underweight aRRR (CI)	Overweight aRRR (CI)	Obesity uRRR (CI)	Underweight aRRR (CI)	Overweight aRRR (CI)	Obesity uRRR (CI)
Male							1.12 (0.98–1.27)	0.63* (0.53–0.74)	0.26* (0.19–0.35	1.11 (0.98–1.27)	0.63* (0.53–0.75)	0.26* (0.19–0.35)
Education (Ref: No schooling)												
1–5 years							0.80* (0.70–0.92)	1.37* (1.16–1.64)	1.39 (0.98–1.98)	0.80* (0.70–0.92)	1.38* (1.16–1.64)	1.39 (0.98–1.98)
6–10 years							0.68* (0.58–0.80)	1.57* (1.30–1.90)	2.29* (1.48–3.57)	0.68* (0.58–0.81)	1.57* (1.30–1.91)	2.29* (1.48–3.56)
Above 10 years							0.49* (0.38–0.63)	1.87* (1.45–2.41)	2.40* (1.63–3.51)	0.49* (0.38–0.63)	1.86* (1.45–2.39)	2.39* (1.63–3.51)
Social class (Ref: Scheduled Tribe (ST))												
Scheduled Caste (SC)							0.91 (0.76–1.08)	1.42 (0.96–2.10)	3.11* (1.35–7.19)	0.91 (0.76–1.08)	1.42 (0.96–2.10)	3.13* (1.35–7.24)
Other Backward Class (OBC)							0.83* (0.71–0.98)	1.58* (1.08–2.31)	4.50* (2.12–9.60)	0.83* (0.71–0.98)	1.58* (1.08–2.31)	4.52* (2.12–9.65)
Others							0.68* (0.57–0.81)	1.64* (1.11–2.42)	4.49* (2.19–9.23)	0.68* (0.57–0.81)	1.65* (1.12–2.43)	4.53* (2.20–9.32)
Household economic status (Ref: Poorest)												
Poorer							0.96 (0.83–1.10)	1.18 (0.98–1.43)	1.38 (0.89–2.12)	0.96 (0.83–1.10)	1.19 (0.98–1.43)	1.38 (0.89–2.12)
Middle							0.84* (0.73–0.98)	1.47* (1.19–1.81)	1.11 (0.81–1.51)	0.84* (0.73–0.98)	1.46* (1.19–1.81)	1.11 (0.81–1.51)
Richer							0.63* (0.54–0.74)	1.50* (1.22–1.85)	1.54* (1.07–2.21)	0.63* (0.54–0.74)	1.50* (1.22–1.85)	1.54* (1.07–2.20)
Richest							0.52* (0.47–0.65)	1.60* (1.31–1.94)	2.10* (1.35–3.26)	0.55* (0.47–0.66)	1.60* (1.31–1.94)	2.10* (1.35–3.26)
Living arrangement (Ref: Alone)												
With spouse and others							1.59 (0.97–2.60)	1.47 (0.88–2.46)	2.47* (1.01–6.25)	1.58* (1.01–2.58)	1.47 (0.88–2.46)	2.47* (0.98–6.23)
With others							1.01 (0.81–1.25)	0.91 (0.67–1.24)	1.27 (0.75–2.15)	1.01 (0.81–1.25)	0.91 (0.67–1.23)	1.27 (0.75–2.14)
Marital status (Ref: In a union)												
Not in a union							1.91* (1.21–3.00)	1.39 (0.89–2.20)	1.59 (0.73–3.48)	1.89* (1.20–2.97)	1.40 (0.89–2.19)	1.59 (0.72–3.48)
Residence type (Ref: Urban)												
Rural							1.87* (1.62–2.16)	0.59* (0.51–0.68)	0.42* (0.31–0.57)	1.87* (1.62–2.16)	0.59* (0.51–0.68)	0.42* (0.31–0.57)
Ever consume alcohol (Ref: None)												
Yes							0.99 (0.86–1.13)	1.06 (0.89–1.26)	0.80 (0.53–1.22)	0.99 (0.86–1.13)	1.06 (0.89–1.26)	0.80 (0.53–1.22)
Ever smoker (Ref: None)												
Yes							1.48* (1.33–1.65)	0.75* (0.65–0.86)	0.74 (0.52–1.06)	1.48* (1.33–1.64)	0.75* (0.65–0.86)	0.74 (0.52–1.06)
Physical activity (Ref: None)												
Yes							0.98 (0.88–1.09)	1.03 (0.88–1.21)	0.74* (0.55–99)	0.98 (0.88–1.09)	1.03 (0.88–1.20)	0.74* (0.55–0.99)

uRRR: unadjusted Relative Risk Ratio, aRRR: adjusted Relative Risk Ratio; CI: Confidence Interval; *p < .05; #Interaction model.

Table 2 (*continued*)

Variables	Weighted percentage of underweight	P value	Weighted percentage of normal weight	P value	Weighted percentage of overweight	P value	Weighted percentage of obesity	P value
In a union	24.72	.00	52.68	.00	17.27	.00	5.34	0.69
Not in a union	30.78		48.89		14.67		5.65	
Residence type								
Urban	12.45	.00	49.07	.00	26.65	.00	11.82	.00
Rural	32.49		52.13		12.36		3.02	
Ever consume alcohol								
None	26.05	.00	51.00	.04	16.89	.00	6.06	.00
Yes	32.19		52.89		12.97		1.95	
Ever smoker								
None	21.55	.00	51.25	.00	19.73	.00	7.48	.00
Yes	34.72		51.33		11.40		2.55	
Physical activity								
None	26.76	.00	50.29	.00	16.52	.00	6.44	.00
Yes	27.35		53.35		15.88		3.41	
Sample Size	**6374**		**14394**		**6050**		**1583**	

higher risk of overweight and obesity than older adults with no morbid condition. This could be because of the diseases considered for assessing morbidity status in this study. The morbidity status was measured using chronic conditions, mainly a representation of disease of affluence.

Socioeconomic and demographic factors such as age, gender, years of education, social class, household economic status, living arrangement, marital status, residence status and smoking habits significantly determine nutritional status among older adults. As supported by literature [25,42], the present study suggests that an increase in age leads to variations in nutritional status, especially creating a higher risk of malnourishment and underweight. Also, females are more prone to be overweight and obese than males. Interestingly, older adults with formal education had a lower risk of underweight and a higher risk of overweight and obesity when compared to older adults with no schooling. Earlier studies have elucidated the role of education in nutritional status [7,43]. In the present study, it is remarkable that the higher prevalence and risk of overweight among educated is due to their socioeconomic status and overweight being one of the diseases of affluence. In the same line, as found in the present study, individuals with higher economic status and social class generally tend to have a high risk of being overweight and obese compared to older adults from lower socio-economic classes [44,45].

Regarding living arrangements, individuals living with spouses and others had a higher risk of overweight than adults living alone. Similarly, a study among US adults aged above 55 years pointed out the difference in the quality of diet in terms of living arrangement; men who lived alone had poor quality of diet compared to those who lived with their spouse [46]. Marital status was a significant determinant of nutritional status as individuals living alone have to make efforts to prepare food, leading to less interest in them and poor dietary diversity [47].

It is remarkable to note the high risk of undernutrition among older adults in rural areas and overweight and obesity among adults in urban residences. This may majorly pertain to differences in socioeconomic status in the two settings, and overweight being one of the diseases of affluence [48], especially among older adults in urban areas. In support of this result, a study among older adults in Taiwan indicated the difference between nutritional status among urban and rural resident adults [49]. There exist a few contrasting pieces of evidence as well. Studies showed that obesity is higher among rural adults than urban residents [50,51]. Further, the present study showed that older adults with a smoking habit had a higher risk of malnutrition, possibly because they might have disrupted food intake, leading to being underweight [52]. The study has many strengths as it includes a sample from large-scale data, especially with more older adults from rural backgrounds. Further, the study considered a unique combination of variables and tried to understand the moderating role of tooth loss between the ability to chew and nutritional status among older adults in India.

5. Limitations

This study has certain limitations. Firstly, the study is cross-sectional. Therefore, the cause-and-effect association between the study variables cannot be established. Future studies may try to understand the underlying mechanisms behind oral health, food security, tooth loss and its effect on nutritional status, as the same sample will be followed in the future waves of LASI. Secondly, the study included a few variables understood through older adults' self-reported information. Even though these responses are reliable, they may not be free from reporting biases.

6. Conclusion

As a developing country with an increasing population of older adults, it becomes essential to understand the dynamics of healthy ageing in India. Contextually, the current study aimed to understand the determinants of nutritional status by exploring the role of oral health and food security. The study further examined the role of tooth loss as a potential moderator between chewing ability and nutritional outcome. The study evidenced that tooth loss moderated the ability to chew solid food and nutritional status. In addition,

oral health problems, poor self-rated health, multimorbidity, increase in age, being female, lower years of education, low social class and household economic status, living spouse and others, not in a union, rural residency and smoking habit were significant determinants of poor nutritional status among older adults. The study implies better access to denture procedures in primary and secondary healthcare facilities and sensitization programs to enhance awareness of the importance of nutritional needs in old age. In addition, the public distribution system needs to be strengthened, especially in rural areas, to establish food security, specifically for older adults from vulnerable socioeconomic circumstances.

Further, the insights from the study are meaningful for countries with similar socioeconomic contexts like India, especially resource-poor settings. Because diminishing nutritional status among older adults is a global public health concern, it becomes essential to address the scenario globally, starting with health education programs and interventions for older adults, providing dental care at primary healthcare facilities, and changes at the policy level to promote a nutritious diet among older adults.

Data availability statement

The data used for this study is available through the following website. https://www.iipsindia.ac.in/content/lasi-wave-i.

Additional information

No additional information is available for this paper.

Ethical approval and consent to participate

The data used for this study is freely available in the public domain. Hence, no ethical approval is required.

Consent for publication

Not applicable.

Availability of data and materials

The data used for this study is available through the following website. https://www.iipsindia.ac.in/content/lasi-wave-i.

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CRediT authorship contribution statement

P. Padma Sri Lekha: Writing – original draft. **C.V. Irshad:** Formal analysis, Data curation, Conceptualization. **E.P. Abdul Azeez:** Writing – review & editing, Supervision, Methodology. **S. Irudaya Rajan:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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