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DEVELOPMENT AND VALIDATION OF A MULTIDIMENSIONAL FOOD SECURITY–NUTRITION VULNERABILITY (FOSENUVU) INSTRUMENT FOR TUBERCULOSIS PATIENTS IN DISASTER-PRONE AREAS

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ABSTRACT

Tuberculosis (TB) patients living in disaster-prone areas may experience interconnected food, nutritional, socioeconomic, and healthcare vulnerabilities that can be exacerbated by disasters. However, an instrument that comprehensively assesses food and nutrition vulnerability in this population remains limited. This study aimed to develop and validate the multidimensional Food Security-Nutrition Vulnerability (FOSENUVU) instrument for assessing food and nutrition vulnerability among TB patients living in disaster-prone areas. A methodological study was conducted through sequential instrument development and psychometric validation. Initial item development involved a literature review, healthcare worker interviews, item construction, and expert assessment. Content validity was evaluated by five experts using the Content Validity Index. The resulting 30-item instrument was administered to 300 adult pulmonary TB patients living in disaster-prone areas of Sukabumi Regency, Indonesia, selected using purposive sampling. Validity analysis was carried out in stages: content validity was assessed by five experts using the Content Validity Index (CVI), followed by item validity testing using corrected item-total correlation. Furthermore, construct validity was analysed using Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA), whilst convergent validity was assessed using Average Variance Extracted (AVE) and Composite Reliability (CR). Expert assessment demonstrated 90% agreement, supporting the content validity of the instrument. The 30-item FOSENUVU showed strong internal consistency, with Cronbach's alpha of 0.979 overall and 0.872–0.894 across six conceptual domains. EFA identified a dominant single-factor structure explaining 60.5% of the total variance, with factor loadings ranging from 0.709 to 0.825. CFA confirmed the one-factor model with excellent fit (χ^2/df=1.046, CFI=0.997, TLI=0.997, RMSEA=0.012, and SRMR=0.022). Convergent validity was supported by an AVE of 0.605 and composite reliability of 0.979. All 30 items were retained. FOSENUVU demonstrated strong content validity, internal consistency, structural validity, and convergent validity. The final 30-item instrument provides a multidimensional yet integrated measure of food and nutrition vulnerability among TB patients in disaster-prone areas.

Keywords: disaster; food insecurity; FOSENUVU; nutritional vulnerability; psychometrics; tuberculosis

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INTRODUCTION

Tuberculosis (TB) is a disease caused by the pathogen Mycobacterium tuberculosis and is a leading cause of morbidity and mortality worldwide. At the national level, the World Health Organisation (WHO) and the Indonesian Ministry of Health report that Indonesia is among the three countries with the highest tuberculosis (TB) burden in the world, with West Java being one of the regions with the highest number of cases (Christanto, 2018). This situation underscores the fact that TB remains, to this day, a public health challenge that requires a comprehensive approach, particularly through the strengthening of prevention and control measures within the community.

TB is not only linked to treatment efforts, but also to the social, economic and environmental factors that directly influence patients' lives. One such factor is meeting the dietary needs of TB patients (Wagnew et al., 2024b). This is linked to the role of adequate nutritional and energy intake

in maintaining physical condition during TB treatment. TB patients require an adequate nutritional intake to strengthen their immune system and meet their energy requirements whilst undergoing long-term therapy. Difficulties in accessing adequate food can slow down the recovery process or exacerbate the patient's clinical condition (Fâcă et al., 2025).

This food and nutritional vulnerability is exacerbated when TB patients are located in disaster-prone areas. In disaster nursing, TB patients have specific needs due to their reliance on long-term treatment, the need for adequate nutrition, and disruptions to the continuity of healthcare services during disasters (Priyatno et al., 2023; Thakur et al., 2026). However, TB management in disaster situations in Indonesia has not yet been supported by an integrated disaster nursing model capable of systematically mapping and managing food and nutritional vulnerabilities.

The National Disaster Management Agency (BNPB) has designated Sukabumi Regency as an area with a high disaster risk index, with recurring floods and landslides having a direct impact on access to food, health services and the continuity of treatment for chronic illnesses. Furthermore, data from the Central Statistics Agency (BPS) indicate that the prevalence of inadequate food consumption in Sukabumi Regency stands at around 5–6 per cent, reflecting structural food insecurity (Paruta & Nurazizah, 2026). This combination of the burden of TB, food insecurity and disaster risk underscores the background to the problem and the urgency of developing a disaster nursing model based on integrated risk assessment.

In the local context, conditions on the ground in Sukabumi Regency indicate that TB patients in disaster-prone areas often experience reduced access to food, a reliance on emergency aid that does not always meet their nutritional needs, and limited health monitoring during the recovery phase. This stems from the sub-optimal integrated screening system and the absence of risk assessment tools that integrate disaster, food and nutrition considerations into disaster nursing practice, which simultaneously presents an opportunity to develop innovations based on on-the-ground needs. Building on these issues, the development of the Food Security–Nutrition Vulnerability Model is expected to serve as a strategic solution for enhancing food and nutrition security and promoting risk-based nursing decision-making and disaster-responsive local health policies. The primary objective of this study is to develop the Food Security–Nutrition Vulnerability (FOSENUVU) Model, designed to systematically map and manage food and nutrition vulnerability.

METHOD

Research Design

This study is a methodological study aimed at evaluating the structural validity and reliability of the Food Security-Nutrition Vulnerability (FOSENUVU) instrument as a tool for assessing food and nutrition vulnerability risk among tuberculosis (TB) patients living in disaster-prone areas.

Initial Development and Content Validation of the FOSENUVU Instrument

The initial development of the Food Security-Nutrition Vulnerability (FOSENUVU) instrument was carried out prior to quantitative psychometric testing. This procedure aimed to ensure that the items tested empirically had a strong conceptual basis, were relevant to the circumstances of tuberculosis (TB) patients, and were appropriate to the characteristics of disaster-prone areas. The initial development process comprised three stages, namely (1) a literature review and interviews with healthcare workers, (2) the drafting of a set of items, and (3) an expert panel assessment to confirm content validity. This approach is consistent with previous research on the development of health instruments, which begins the construction of a scale through a literature review, stakeholder interviews, item development, and expert assessment prior to factor testing.

Stage 1. Literature review and interviews with healthcare workers

This review was supplemented by a preliminary study and interviews with healthcare workers to identify screening needs, barriers to service delivery, and the actual conditions of TB patients in

disaster-prone areas. The findings of this stage indicated that there was no existing instrument that comprehensively assessed food, nutrition and disaster-related aspects in TB patients.

The conceptual framework of the instrument was developed by integrating Delor and Hubert's theory of 'Vulnerability in Public Health' (Delor & Hubert, 2000), the Comprehensive Food Security and Vulnerability Assessment (CFSVA) framework (World Food Programme, 2009), the concept of food security, the link between TB and malnutrition, disaster nursing, and the social determinants of health. Within the FOSENUVU framework, 'Vulnerability in Public Health' views vulnerability through social trajectory, interaction and social context, whilst the CFSVA encompasses livelihoods, access to food, coping strategies, exposure to shocks, and household capacity to maintain food security.

Stage 2. Development of the item pool

The results of the theoretical review and field findings were then translated into items for the FOSENUVU instrument. The items were developed by integrating six domains, namely (1) socio-economic conditions and livelihoods, (2) access to and availability of food, (3) nutritional status and needs of TB patients, (4) exposure to disasters and shocks, (5) coping strategies and social support, and (6) access to healthcare services and the environment. This process resulted in a draft instrument comprising 30 items, with each domain consisting of five items and utilising four risk response categories: No Risk, Low Risk, Moderate Risk and High Risk, scored from 0 to 3.

Stage 3. Expert panel assessment and content validation

The draft comprising 30 items was subsequently reviewed through an expert panel, focus group discussions (FGDs), expert consultations and a review of healthcare service documents. Nutritionists assessed the suitability of the nutrition and food security indicators; disaster management practitioners and the Regional Disaster Management Agency (BPBD) assessed the relevance of the disaster risk indicators; whilst community nurses and disaster nurses assessed the clarity, practicality and suitability of the items for service practice. The Content Validity Index (CVI) was calculated using the Davis technique based on the assessment results from five experts. An item is considered to have adequate content validity if the CVI value is greater than 0.80 (Davis, 1992). The assessment results showed a level of agreement among experts of 90 per cent, indicating strong content validity.

Population and Sample

The target population for this study was tuberculosis patients living in disaster-prone areas of Sukabumi Regency. Based on the FOSENUVU study design, the study area covered sub-districts at risk of flooding and landslides, including Warungkiara, Caringin, Cibadak, Ciemas, Cikembar, Jampangtengah, Bantargadung, Simpenan and Gegerbitung. Inclusion criteria comprised patients with pulmonary TB currently undergoing intensive or continuation treatment, aged ≥18 years, and able to communicate in Indonesian. The sampling technique used in the study was purposive sampling. The dataset used for psychometric testing comprised 300 respondents with complete data on all 30 FOSENUVU items. Consequently, the ratio of respondents to items was 10:1. This number meets the general recommendation of 5 to 10 respondents per item in factor analysis, as used in previous health instrument development studies.

The FOSENUVU Instrument

The FOSENUVU Instrument comprises 30 items that are conceptually grouped into six domains, namely: socio-economic conditions and livelihoods in items 1 to 5; access to and availability of food in items 6 to 10; nutritional status and the needs of TB patients in items 11 to 15; exposure to disasters and shocks in items 16 to 20; coping strategies and social support in items 21 to 25; and access to healthcare services and the environment in items 26 to 30. The structure of these items corresponds to the FOSENUVU questionnaire used in the study. Each item was assessed using four risk levels: No Risk, Low Risk, Moderate Risk and High Risk. In data processing, these categories

were assigned scores of 0, 1, 2 and 3 respectively. The scores for all items were summed to give a total FOSENUVU score ranging from 0 to 90. A higher score indicates a higher level of food and nutrition vulnerability.

Data Analysis

The analysis began with an examination of data completeness, item score distributions, item-total correlations, and internal consistency. Data analysis was carried out using Microsoft Excel, SPSS v.29 and SmartPLS v.4. Internal reliability was assessed using Cronbach's alpha. An alpha value of ≥0.70 was used as the threshold for acceptable reliability, as has been the case in previous health instrument development studies. The suitability of the data for EFA was assessed using the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's Test of Sphericity. A high KMO value and a significant Bartlett's test result indicated that the correlation matrix met the requirements for factor analysis. This approach was also used in the instrument development studies for the PIS-HSP and NATPHCPPS.

EFA was conducted using the Principal Axis Factoring (PAF) method. The determination of the number of factors took into account eigenvalues >1, inspection of the scree plot, parallel analysis, the magnitude of factor loadings, communality, and the fit of the factors to the theoretical construct. Items were retained if they had a factor loading of at least 0.50 and adequate communality. Reference articles on health instrument development use factor loadings >0.60 to retain items and indicate that loadings >0.50 are considered adequate. The factor structure obtained from the EFA was then tested using CFA with the same 300 respondents. Model fit was evaluated using the chi-square divided by degrees of freedom (χ^2/df), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardised Root Mean Square Residual (SRMR). The model was considered to have a good fit if $\chi^2/df < 3$, CFI and TLI ≥ 0.90, and RMSEA and SRMR ≤ 0.08. CFI and TLI values ≥ 0.95 indicated an excellent model fit. These criteria are consistent with previous research on the development of health instruments. The convergent validity of the CFA model was subsequently assessed using the Average Variance Extracted (AVE) and Composite Reliability (CR). Values of AVE ≥ 0.50 and CR ≥ 0.70 were used as indicators of adequate convergent validity and construct reliability.

Research Ethics

This study has obtained ethical approval from the STIKES Sukabumi Research Ethics Committee under number 003355/KEP STIKES SUKABUMI/2026. The conduct of the research adhered to the ethical principles of research involving human subjects, including respect for respondents' autonomy, data confidentiality, the provision of adequate information regarding the aims and procedures of the research, and the right of respondents to participate voluntarily and to withdraw at any time without consequences.

RESULT

A total of 300 respondents provided complete answers to all 30 items, meaning that all the data could be included in the analysis. The total FOSENUVU score ranged from 0 to 90, with a mean of 47.23±24.58. Based on the score categories established in the FOSENUVU model, 64 respondents (21.3 per cent) were classified as low risk, 76 respondents (25.3 per cent) as moderate risk, 84 respondents (28.0 per cent) as high risk, and 76 respondents (25.3 per cent) as very high risk. Item analysis showed that the correlations between items and their respective domain scores ranged from 0.779 to 0.861. Meanwhile, the corrected item-total correlations ranged from 0.701 to 0.816. All values were well above the minimum threshold of 0.30; therefore, no items needed to be eliminated based on item-total correlations. The internal consistency of the instrument also showed very high results. The overall Cronbach's alpha for the 30 items was 0.979, whilst the alpha for the six domains ranged from 0.872 to 0.894.

Table 1.
Internal Consistency of the Conceptual Domain of FOSENUVU

Domain	Item	Mean±SD	Correlation Range	Cronbach's α
Socio-economic conditions and livelihoods	1–5	7,98±4,36	0,817–0,855	0,894
Access to and availability of food	6–10	7,87±4,30	0,779–0,849	0,878
Nutritional status and needs of TB patients	11–15	8,00±4,24	0,803–0,838	0,872
Exposure to disasters and shocks	16–20	7,51±4,31	0,817–0,846	0,883
Coping strategies and social support	21–25	7,59±4,31	0,803–0,861	0,887
Access to healthcare services and the environment	26–30	8,29±4,33	0,788–0,858	0,887
Overall FOSENUVU	1–30	47,23±24,58	0,701–0,816[1]	0,979

[1]*Corrected item-total correlation* for the entire instrument.

Exploratory Factor Analysis

The results of the correlation matrix suitability test showed a KMO value of 0.987. The Measure of Sampling Adequacy at item level ranged from 0.980 to 0.993, indicating excellent sampling adequacy. Bartlett's Test of Sphericity also yielded a significant result, namely $\chi^2(435) = 7402.67$; $p < 0.001$. Consequently, the correlation matrix exhibits sufficient inter-item relationships to conduct EFA.

Table 2.
Results of the Exploratory and Confirmatory Factor Analyses of the FOSENUVU Instrument

Item	Conseptual Domain	EFA Loading	Communalities	CFA Loading
1	D1	0,751	0,563	0,750
2	D1	0,796	0,634	0,795
3	D1	0,817	0,668	0,818
4	D1	0,814	0,663	0,814
5	D1	0,781	0,611	0,782
6	D2	0,813	0,661	0,813
7	D2	0,709	0,503	0,710
8	D2	0,778	0,606	0,778
9	D2	0,736	0,542	0,736
10	D2	0,820	0,672	0,820
11	D3	0,825	0,681	0,825
12	D3	0,721	0,520	0,721
13	D3	0,731	0,535	0,732
14	D3	0,745	0,555	0,745
15	D3	0,754	0,568	0,753
16	D4	0,766	0,587	0,767
17	D4	0,818	0,669	0,818
18	D4	0,779	0,606	0,779
19	D4	0,779	0,606	0,778
20	D4	0,771	0,595	0,772
21	D5	0,768	0,590	0,769
22	D5	0,808	0,654	0,808
23	D5	0,749	0,561	0,748
24	D5	0,765	0,586	0,765
25	D5	0,801	0,641	0,801
26	D6	0,766	0,587	0,768
27	D6	0,711	0,505	0,711
28	D6	0,809	0,655	0,809
29	D6	0,812	0,660	0,813
30	D6	0,820	0,672	0,820

Notes: D1 = socio-economic conditions and livelihoods; D2 = access to and availability of food; D3 = nutritional status and needs of TB patients; D4 = exposure to disasters and shocks; D5 = coping strategies and social support; D6 = access to healthcare services and the environment.

An examination of the eigenvalues revealed the presence of a single highly dominant factor. The first factor produced an eigenvalue of 18.546, whilst the second factor dropped to 0.661 and all subsequent factors had eigenvalues <1. The very sharp decline between the first and second factors indicated a clear 'elbow' pattern on the scree plot. The results of the parallel analysis also retained only the first factor. Using the Principal Axis Factoring method, the one-factor solution explained approximately 60.5% of the total variance. All 30 items have high factor loadings, ranging from 0.709 to 0.825, whilst communalities range from 0.503 to 0.681. No items were found with loadings <0.50 or inadequate communalities. Therefore, all 30 items were retained at the EFA stage. The findings indicate that although the 30 FOSENUVU items were conceptually organised into six domains, empirically all items showed strong convergence towards a single latent construct, namely food and nutritional vulnerability amongst TB patients in disaster-prone areas.

Confirmatory Factor Analysis

Based on the results of the EFA, a CFA was conducted to test a single-factor model comprising all 30 FOSENUVU items. No item elimination was carried out at the CFA stage as all items demonstrated adequate loadings and the initial model had achieved excellent fit.

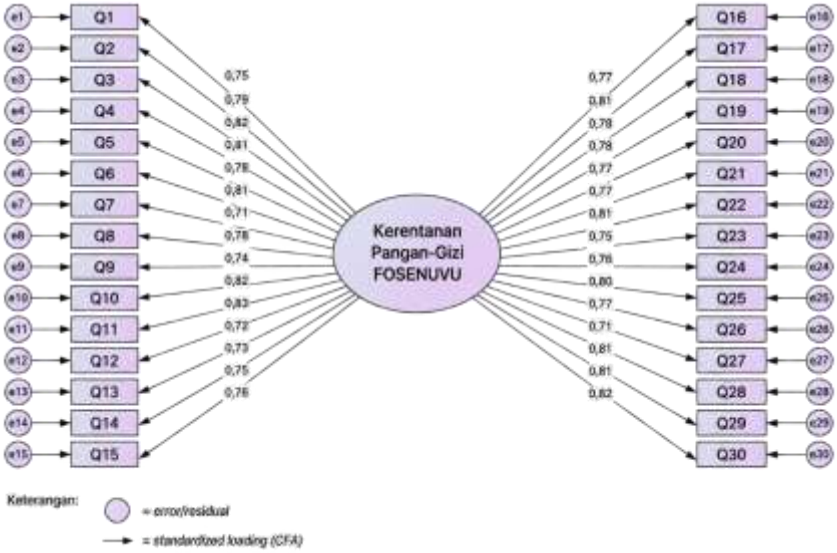

Figure 1. Single-Factor Measurement Model of the FOSENUVU Instrument Based on Confirmatory Factor Analysis (CFA)

The CFA results show a χ^2 value of 423.66 with df = 405 and p = 0.252. The χ^2/df ratio is 1.046, indicating a small discrepancy between the empirical covariance matrix and the matrix predicted by the model. Other fit indices also indicate excellent results, with CFI = 0.997, TLI = 0.997, RMSEA = 0.012 with a 90% CI of approximately 0.000–0.024, and SRMR = 0.022.

Tabel 3.
Goodness of Fit Model Confirmatory Factor Analysis FOSENUVU

Indeks	Criterion	Result	Interpretation
χ^2 (df)	p >0,05	423,66 (405); p = 0,252	Good
χ^2/df	<3,00	1,046	Very Good
CFI	≥0,90; ≥0,95 very good	0,997	Very Good
TLI	≥0,90; ≥0,95 very good	0,997	Very Good
RMSEA	≤0,08; ≤0,05 very good	0,012	Very Good
90% CI RMSEA		0,000–0,024	Very Good
SRMR	≤0,08	0,022	Very Good

All standardised factor loadings from the CFA were positive and ranged from 0.710 to 0.825. Thus, all items were above the minimum value of 0.50; indeed, all items reached or exceeded approximately 0.70. The item with the lowest loading was item 7 at 0.710, whilst the highest loading was found in item 11 at 0.825. No items required removal based on the CFA loadings.

The convergent validity of the model also showed adequate results. The Average Variance Extracted (AVE) value was 0.605, indicating that approximately 60.5 per cent of the indicators' variance is explained by the FOSENUVU vulnerability construct. The Composite Reliability (CR) value was 0.979, well above the 0.70 threshold. These results are consistent with a Cronbach's alpha of 0.979.

Table 4.
Convergent Validity and Reliability of the FOSENUVU Model

Parameter	Result	Criterion	Interpretation
Standardized loading	0,710–0,825	≥0,50	Meets requirements
AVE	0,605	≥0,50	Meets requirements
Composite Reliability	0,979	≥0,70	Very Good
Cronbach's alpha	0,979	≥0,70	Very Good

Overall, the CFA provided strong support for the one-factor structure of the FOSENUVU, comprising 30 items. All items retained at the EFA stage were also retained in the CFA. Thus, the number of items in the EFA results was 30, and the number of items in the CFA results also remained at 30. Based on the sequence of instrument development, content validation, EFA and CFA, 30 final FOSENUVU items were obtained, all of which were retained. These thirty items represent six assessment domains, namely socio-economic conditions and livelihoods; access to and availability of food; nutritional status and the needs of TB patients; exposure to disasters and shocks; coping strategies and social support; and access to healthcare services and the environment. Each domain comprises five items, meaning that the final instrument retains the 30-item structure as in the initial design. The structure of the final items is presented in Table 5.

Table 5.
Final Items of the FOSENUVU Instrument

No	Domain/Statement
	Socio-economic Conditions and Livelihood
1	My head of household's main job provides sufficient income to meet the family's needs.
2	My household income has fallen since the patient contracted TB.
3	My household income has fallen as a result of a disaster.
4	Most of my income is spent on food.
5	My household relies on social assistance or support from family.
	Access to and Availability of Food
6	My household has struggled to obtain food over the past month.
7	I (a TB patient) eat less than three times a day.
8	I eat meat or other animal-based protein less than three times a week.
9	I do not eat fruit and vegetables regularly.
10	My household's food supplies often run out before the next income arrives.
	Nutritional Status and Needs of TB Patients
11	My appetite has decreased due to TB.
12	I have lost weight over the last 3 months.
13	I often skip meals because of my TB symptoms.
14	I am unable to follow the recommended high-protein diet.
15	My BMI is <18.5 kg/m² or my upper arm circumference is low.
	Disaster Exposure and Shock
16	My household has been affected by flooding in the last 12 months.
17	My household has been affected by a landslide in the last 12 months.
18	Food prices rose significantly following the disaster.
19	The disaster led to a loss of employment or income.
20	The disaster disrupted access to healthcare facilities.
	Coping Strategies and Social Support
21	I have reduced the size of my meals.
22	I have reduced the frequency of my meals.
23	I borrow money to buy food.
24	I sell assets to buy food or pay for medical treatment.
25	I have no family or community support when facing difficulties.
	Access to Healthcare and the Environment
26	I find it difficult to reach TB healthcare facilities.
27	I do not have adequate transport to reach healthcare services.

28	Access to clean water is limited.
29	Home sanitation is inadequate.
30	TB follow-up visits have been disrupted due to environmental factors or disasters.

DISCUSSION

This study shows that FOSENUVU has robust psychometric characteristics for measuring food and nutritional vulnerability among TB patients in disaster-prone areas. Of the 300 respondents, 28.0% fell into the high-risk category and 25.3% into the very high-risk category, meaning that more than half of the respondents (53.3%) were in the two highest vulnerability categories. These findings indicate that food and nutritional vulnerability are critical conditions among TB patients that can be influenced by socioeconomic status and the ability to meet their needs during treatment. The WHO emphasizes that TB patients and their families may face the burden of both medical and non-medical costs, loss of income, transportation costs, and expenditures on food and nutritional needs; therefore, social protection is a vital component of TB control (World Health Organization, 2025a). Other evidence also suggests that nutritional support can play a role in improving adherence to TB treatment; therefore, meeting food and nutritional needs must be viewed as part of the support necessary for successful treatment (Wagnew et al., 2024a). Thus, the variations in vulnerability levels identified through FOSENUVU underscore the importance of measurements capable of capturing food and nutrition conditions alongside the accompanying social and economic factors.

The internal consistency of the FOSENUVU also yielded strong results, with corrected item-total correlations ranging from 0.701 to 0.816 and an overall Cronbach's alpha of 0.979, while the values for the six domains ranged from 0.872 to 0.894. These results indicate that the FOSENUVU items are strongly interrelated in representing the construct being measured, while the six domains consistently contribute to the instrument as a whole. This consistency is important because the factors contributing to TB patients' vulnerability are not isolated; economic constraints can affect access to food, while food and nutritional needs can add to the household burden, and loss of income and transportation costs can further limit patients' ability to access health care. These conditions align with a WHO report indicating that the costs of transportation, food, accommodation, nutritional supplements, and loss of income are part of the burden faced by TB-affected households, and that food assistance, financial aid, and support for maintaining treatment are essential components of social protection for TB patients (World Health Organization, 2025a). In instrument development, internal consistency is a key component for demonstrating that the items collectively represent the intended construct (Boateng et al., 2018). Based on these results, the high internal consistency of the FOSENUVU indicates that all six domains are empirically related in describing food and nutritional vulnerability among TB patients.

The EFA results further revealed a single dominant factor with an eigenvalue of 18.546, explaining 60.5% of the variance, with all items exhibiting factor loadings ranging from 0.709 to 0.825. Although the FOSENUVU is conceptually organized into six domains, these findings indicate that all domains show strong convergence toward a single, broader latent construct. This structure was subsequently confirmed through CFA, which demonstrated excellent model fit, with all 30 items retained and standardized factor loadings ranging from 0.710 to 0.825. This pattern indicates that socioeconomic conditions, food access, nutritional status, exposure to disasters, coping strategies and social support, as well as access to health services and the environment, can be understood as interrelated dimensions that collectively shape a state of food and nutritional vulnerability. The EFA approach, followed by CFA, is a crucial part of testing the latent structure of an instrument because it allows the structure identified exploratorily to be confirmed against empirical data (Boateng et al., 2018). Substantively, the interrelationships among these dimensions are also consistent with the WHO's approach, which identifies food support, material support, transportation, income protection, and access to services as interrelated components in reducing the vulnerability of TB patients. Thus, the results of the EFA and CFA provide strong empirical support for the use of FOSENUVU as a 30-item instrument to measure a single main construct—food and nutrition

vulnerability among TB patients in disaster-prone areas—as represented by six interrelated domains.

Domain 1. Socioeconomic Conditions and Livelihoods

The socioeconomic and livelihood domain indicates that the ability of TB patients' households to meet their food needs is inextricably linked to their economic conditions, sources of livelihood, and ability to maintain an income. Employment and income are critical components of economic access to food, as the availability of food at the household level does not automatically guarantee that families can obtain sufficient and nutritious food; access to food is also influenced by income, expenditures, prices, and the ability to obtain food through the market (Food and Agriculture Organization of the United Nation, 2008). For TB patients, economic vulnerability becomes even more critical because the disease can lead to loss of income and various costs for households, while the WHO identifies poverty, loss of income, and limited social protection as key determinants in TB control (World Health Organization, 2025a). These conditions underscore the relevance of the FOSENUVU items that assess the adequacy of the head of household's income, the decline in income after a family member contracts TB, the proportion of income spent on food, and dependence on social assistance as indicators of household socioeconomic vulnerability. In disaster-prone areas, this vulnerability can be exacerbated because disasters can damage productive assets, disrupt livelihoods, reduce income, drive up food prices, and hinder physical and economic access to markets (Food and Agriculture Organization of the United Nations, 2023). Thus, the inclusion of income loss due to disasters in the Socioeconomic and Livelihoods Domain provides a more specific context for the vulnerability of TB patients and broadens the assessment of food security from merely current economic conditions to households' ability to maintain food resources when facing illness and disasters (Food and Agriculture Organization of the United Nations, 2023).

Domain 2. Food Access and Availability

The domain of food access and availability emphasizes that food insecurity among TB patients is not only related to the presence or absence of food at home, but also to the ability to consistently obtain food and meet the need for sufficient and varied meals. The concept of food security broadly encompasses food availability, access, utilization, and stability; thus, a household can be said to have food security if it has both physical and economic access to sufficient, safe, nutritious, and sustainably available food (Committee on World Food Security, 2014). In line with this framework, Domain 2 of FOSENUVU covers difficulties in obtaining food, eating fewer than three meals a day, low consumption of animal-based protein, irregular consumption of vegetables and fruits, and food supplies running out before the next intake. The relevance of this domain is particularly strong for TB patients because malnutrition and TB have a bidirectional relationship, while adequate nutrient intake is a critical component of maintaining health and ensuring successful TB treatment (World Health Organization, 2013). The WHO also recommends nutritional assessments and counseling for people with tuberculosis and emphasizes the importance of food interventions for food-insecure households (World Health Organization, 2025b). In disaster situations, this access can be further disrupted due to infrastructure damage, market disruptions, loss of livelihoods, and reduced household food stocks, which can ultimately affect the diversity of foods consumed (Food and Agriculture Organization of the United Nations, 2005). Therefore, the Food Access and Availability Domain is a critical component of FOSENUVU because it captures manifestations of food insecurity at the household level as well as aspects of dietary quality relevant to the nutritional needs of TB patients.

Domain 3. Nutritional Status and Needs of TB Patients

Domain 3, concerning the nutritional status and needs of TB patients, describes the biological conditions related to patients' vulnerability to malnutrition. The aspects assessed include decreased appetite, weight loss, the habit of skipping meals, the ability to meet protein requirements, and anthropometric status as measured by BMI or mid-upper arm circumference (MUAC). A decreased appetite and the habit of skipping meals can lead to insufficient energy and nutrient intake, while

weight loss may indicate changes in nutritional status during the course of TB. Protein requirements are also a concern because they play a role in maintaining body mass and supporting immune function. These conditions can further be observed through low BMI or LILA as anthropometric indicators. Li et al. (2023) demonstrated that malnutrition is a significant problem among patients with pulmonary TB, with a prevalence reaching 48.0%. Assessing the nutritional status of TB patients must also consider multiple indicators, as relying on a single indicator such as BMI does not fully capture the overall picture of malnutrition (Ter Beek et al., 2021). Therefore, the various indicators within Domain 3 complement one another in providing a more comprehensive picture of TB patients' dietary intake and nutritional status.

Domain 4. Exposure to Disasters and Shock

Domain 4, regarding disaster exposure and shocks, describes external conditions that can affect the food security of households with tuberculosis patients. This domain includes experiences of flooding and landslides, rising food prices following a disaster, loss of employment or income, and disruptions to access to health facilities. Floods and landslides can hinder access to food and economic activities, while rising food prices can further limit households' ability to obtain adequate food. These impacts can be exacerbated when disasters lead to job or income loss, as purchasing power to meet food and health needs decreases. Furthermore, disruptions to access to healthcare facilities can hinder TB patients from receiving care and continuing their treatment. (FAO et al. (2023) explains that disasters can disrupt food systems and people's livelihoods, thereby affecting households' ability to obtain food during and after a disaster. The WHO (2025) also emphasizes that food insecurity and limited access to health services can increase the vulnerability of individuals with TB. Therefore, Domain 4 not only describes households' exposure to disaster events but also captures their impact on food, income, and access to health services factors that can exacerbate the vulnerability of TB patients.

Domain 5. Coping Strategies and Social Support

Coping strategies and social support are important aspects in understanding the ability of TB patients and their families to cope with economic pressures, food needs, and medical treatment. TB patients may experience a decline in their ability to work and in their income, while food needs and medical expenses must still be met. These circumstances prompt patients to use coping strategies such as asking family for help, seeking emotional support, borrowing money, obtaining food assistance, or relying on community support. Coping strategies are important because they can help patients maintain access to food and continue their treatment when household resources are limited (Kilima et al., 2024). Social support also helps patients maintain their psychological well-being and their ability to cope with their illness. Support from family, friends, healthcare providers, and the community can take the form of emotional support, information, financial assistance, or material aid. Social support within the FOSENUVU framework serves as a resource that patients can utilize to address food insecurity, economic pressures, and medical care (Wang et al., 2024). In the context of FOSENUVU, this domain is important because coping skills and social support can determine the extent to which patients are able to maintain food security and nutrition while facing stress due to TB. Patients with strong social support tend to have more resources to access food, cover transportation costs, and receive treatment support. This domain is particularly important given its broad scope, ranging from the ability to seek help, family support, emotional support, food or financial assistance, community support, and the ability to maintain food security while undergoing TB treatment (Carwile et al., 2025).

Domain 6. Access to Health Care and the Environment

Access to health care and environmental conditions are key factors in the vulnerability of TB patients, as successful treatment requires sustained access to health care facilities, medications, examinations, information, and health care workers. This access can be affected by distance to health facilities, transportation costs, economic conditions, service availability, and living conditions. When patients face barriers to reaching health care facilities, their treatment needs may

be disrupted (Lestari et al., 2025). The environment can also exacerbate these barriers, particularly in disaster-prone areas where disasters can disrupt transportation, damage health facilities, hinder the distribution of medicines and food, and cause population displacement. The WHO emphasizes that population displacement, food and water insecurity, and disruptions to health systems are factors that can increase vulnerability to TB (WHO, 2024). This domain in FOSENUVU is intended to describe a patient's ability to maintain access to health care services and a supportive environment while undergoing TB treatment, both under normal conditions and during disruptions or disasters. Indicators may include distance and travel time to health facilities, transportation costs, medication availability, continuity of care, access to information and screenings, road or transportation conditions, disaster risks, relocation, and access to water and sanitation.

CONCLUSION

This study developed and validated the Food Security–Nutrition Vulnerability (FOSENUVU) instrument for tuberculosis patients living in disaster-prone areas. The final instrument consists of 30 items covering six interrelated domains: socioeconomic conditions and livelihoods, food access and availability, nutritional status and needs, exposure to disasters and shocks, coping strategies and social support, and access to healthcare services and the environment. The FOSENUVU demonstrated excellent internal consistency (Cronbach's $\alpha = 0.979$), strong item-total correlations (0.701–0.816), and adequate construct validity. EFA identified a single dominant factor explaining 60.5% of the variance, while CFA demonstrated excellent model fit with all 30 items retained. Therefore, FOSENUVU can be considered a reliable and valid instrument for assessing food and nutritional vulnerability among TB patients in disaster-prone areas and may support risk-based nursing assessment and intervention planning.

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