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DEVELOPMENT AND VALIDATION OF A CULTURE-SPECIFIC FOOD FREQUENCY QUESTIONNAIRE AMONG PULMONARY TUBERCULOSIS PATIENTS IN SABAH, MALAYSIA

Khalid Mokti[1*], Zaleha Md Isa[2]

Abstract

Accurate dietary assessment among populations with infectious diseases remains a challenge, particularly in culturally diverse and low-resource settings. This study aimed to develop and validate a region-specific Food Frequency Questionnaire (FFQ) to assess nutrient intake among patients with pulmonary tuberculosis (PTB) in Kota Kinabalu, Sabah, Malaysia. A semi-quantitative FFQ comprising 62 food items grouped into 13 categories was developed based on three-day 24-hour dietary recalls (24HR) from 41 newly diagnosed adult PTB patients. The FFQ was validated by comparing nutrient intake estimates with the mean values obtained from 24-hour recalls using Pearson correlation, energy-adjusted correlation, cross-classification, and intra-class correlation coefficient (ICC) analysis. Reproducibility was assessed by administering the FFQ twice, with a three- to five-week interval between administrations. Unadjusted Pearson correlation coefficients between the FFQ and 24HR ranged from 0.39 (carotene) to 0.90 (energy), with a mean of 0.66 ± 0.17. Energy-adjusted correlations ranged from 0.23 (niacin) to 0.76 (vitamin B1), averaging 0.55 ± 0.16. The proportion of participants classified into the same nutrient intake quartile ranged from 27% to 61%, while the proportion of extreme misclassification ranged from 5% to 24%. ICCs for reproducibility between FFQ1 and FFQ2 were high, ranging from 0.79 (vitamin C) to 0.99 (protein). We validated an FFQ specifically designed for Malaysian patients with pulmonary tuberculosis, providing a culturally relevant and reproducible dietary assessment tool. The FFQ showed strong correlation with reference recalls (mean Pearson r = 0.66), and excellent reproducibility (ICC range 0.79–0.99). It is particularly suited for epidemiological research examining the association between nutrition and TB treatment outcomes, and can inform future nutritional surveillance and targeted interventions in TB control programs.

Keywords: Food Frequency Questionnaire (FFQ), Pulmonary Tuberculosis, Nutritional Assessment, Validation Study, Dietary Intake

*Correspondence Email: khalid.mokti@ums.edu.my

[1]*Department of Public Health Medicine, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Jalan UMS, Kota Kinabalu 88400, Sabah, Malaysia.*

[2]*Department of Public Health Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia, Jalan Yaacob Latif, Bandar Tun Razak 56000 Cheras, Kuala Lumpur, Malaysia.*

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INTRODUCTION

Tuberculosis (TB) remains a significant public health concern, with over 10.6 million new cases and 1.6 million deaths globally in 2021 alone, surpassing HIV/AIDS in infectious disease mortality burden (World Health Organization, 2025). Pulmonary TB (PTB), the most common form, disproportionately affects low- and middle-income countries, including Malaysia. Nutritional status plays a crucial role in TB progression and recovery, with undernutrition both a risk factor for disease activation and a consequence of active infection. Malnourished TB patients face delayed sputum conversion, reduced treatment efficacy, and higher relapse and mortality rates (Bhargava et al., 2013).

This bidirectional relationship creates a vicious cycle: undernutrition impairs host immunity, increasing susceptibility to TB, while TB induces nutrient depletion through anorexia, malabsorption, and metabolic alterations (Cegielski J & McMurray D., 2004). Recognizing this, the World Health Organization's End TB Strategy emphasizes addressing social determinants, including nutrition as a pillar of integrated, patient-centred TB care (Uplekar et al., 2015).

Assessing dietary intake among PTB patients is, therefore, not only clinically relevant but essential for effective public health intervention. However, accurately assessing dietary intake in low-resource and culturally diverse populations remains a methodological challenge. Among the available tools, Food Frequency Questionnaires (FFQs) are widely favoured for epidemiological research due to their low cost and ability to capture habitual intake over time (Aoun et al., 2019). Yet FFQs must be population-specific to yield valid results, particularly in disease contexts where clinical symptoms and socioeconomic factors influence food intake patterns.

Undernutrition is strongly linked to delayed sputum conversion and poor treatment outcomes among PTB patients (Bhargava et al., 2013; Ma et al., 2022). Validated PTB-specific FFQs have been reported in Georgia (Frediani et al., 2013), Ethiopia (Regassa et al., 2021), and Peru (Rodriguez et al., 2017), yet none are available for South-East Asia. Our study, therefore, fills this critical gap by developing and validating a culturally tailored FFQ for Sabah. This is a critical gap, especially in regions like Sabah, where TB incidence is among the highest in the country and where local diets diverge significantly from peninsular norms.

This study aims to address that gap by developing and validating a culturally specific semi-quantitative FFQ to assess habitual macronutrient and micronutrient intake among adult PTB patients in Kota Kinabalu, Sabah. Specifically, the objectives were to: (1) construct the FFQ based on commonly consumed foods identified through 24-hour dietary recalls; (2) evaluate its relative validity against three-day 24HRs using correlation and classification techniques; and (3) assess its reproducibility over a three- to five-week interval. The validated tool is expected to contribute to clinical management, nutritional surveillance, and policy planning within TB control programs in Malaysia.

METHODS

Study Design and Setting

This cross-sectional validation study was conducted from May to July 2019 in outpatient tuberculosis (TB) treatment centres across Kota Kinabalu, Sabah, Malaysia. The primary objective was to develop and validate a culturally appropriate Food Frequency Questionnaire (FFQ) to assess habitual dietary intake among adults newly diagnosed with pulmonary tuberculosis (PTB). The study was embedded within a larger investigation to evaluate the relationship between nutritional intake and delayed sputum smear conversion in PTB patients. As illustrated in Figure 1, the study proceeded in two phases: the development phase used three 24-hour recalls from 41 participants to identify and group 131 foods into 13 categories before refining them to a 62-item FFQ, and the validation phase compared FFQ results with mean recall data and repeated the FFQ to assess reproducibility.

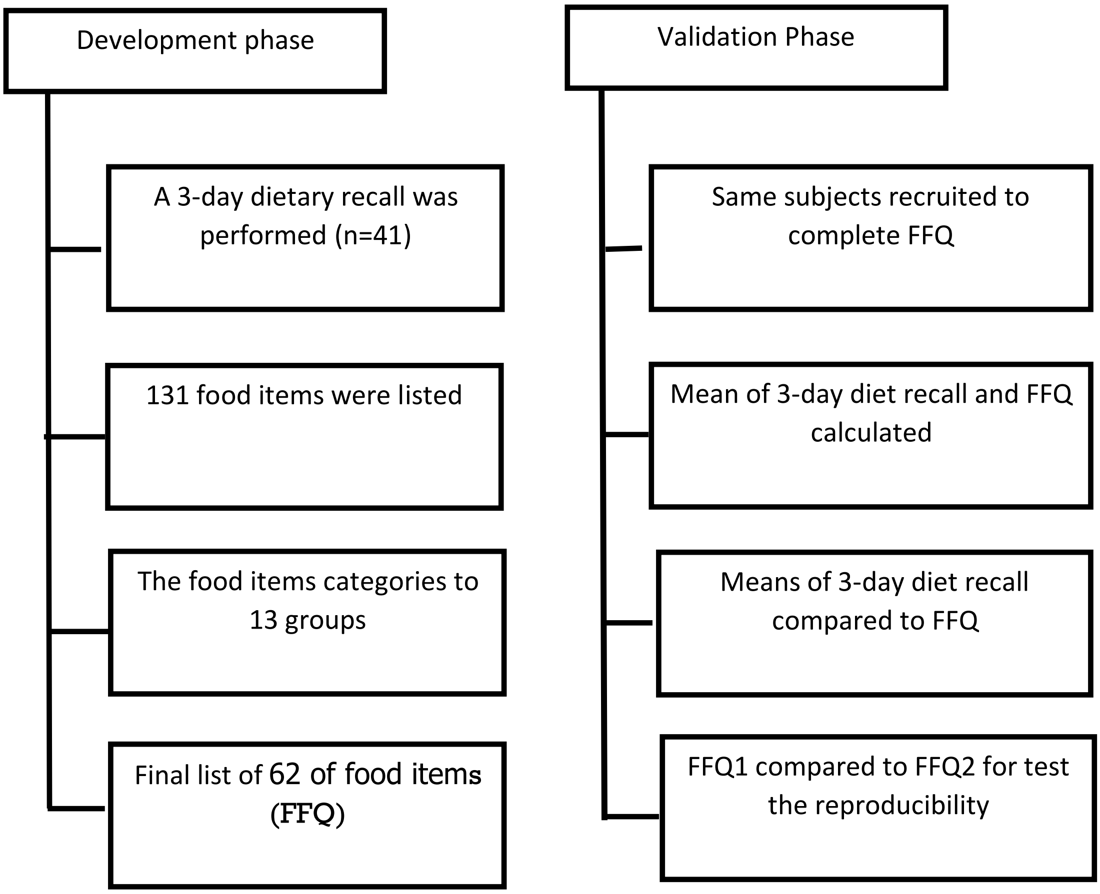

Figure 1: Flow chart to depict the development and validation phase of the FFQ.

Study Population and Sampling

Participants were recruited via purposive sampling because newly diagnosed PTB patients must begin treatment within two weeks of diagnosis. Random sampling would have missed rapidly hospitalized individuals or lost to follow-up. The inclusion criteria required patients to be Malaysian adults aged between 18 and 65, newly diagnosed with PTB and initiated on treatment within two weeks, receiving outpatient care at TB treatment centres, and willing to provide informed consent and complete dietary assessments. Exclusion criteria included pregnancy or lactation, institutionalization or incarceration, and any comorbid condition likely to affect dietary intake or nutrient metabolism, such as recent cancer (within five years), liver cirrhosis, seizure disorders, nephrolithiasis, organ transplant history, or current use of corticosteroids or immunosuppressive agents.

From the 42 patients approached, one participant was excluded due to loss to follow-up, resulting in a final analytical sample of 41 participants. Although modest, this exceeds the ≥30 participants recommended for dietary validation studies (Cade et al., 2002; Zhang et al., 2021). This sample size was deemed adequate for dietary validation studies, aligning with methodological recommendations that a minimum of 30 participants is sufficient to detect moderate correlations with 80% power and $\alpha = 0.05$ (Cade et al., 2002; Willett W., 2012).

Development of the Food Frequency Questionnaire (FFQ)

The FFQ was developed based on detailed dietary information obtained from three non-consecutive 24-hour dietary recalls (24HRs) collected from each participant, comprising two weekdays and one weekend day to capture intra-individual variation. Trained dietitians conducted face-to-face interviews using food models and standardized household utensils (e.g., cups, tablespoons, plates) to improve portion size estimation. The 24HRs data yielded a list of 131 distinct food items, categorized into 13 major food groups, including cereals and cereal products, meats, vegetables, fruits, beverages, and condiments. Food items consumed by ≥10 % of participants were retained. Rarely eaten items with similar nutrient profiles (e.g., sago, tapioca) were aggregated under a single representative item. Nutrient similarity was verified with the Malaysian Food-Composition database, yielding a final list of 62 items. A condensed list of 62 food items was selected based on frequency and cultural relevance to the local dietary patterns of PTB patients in Kota Kinabalu. The finalized FFQ was interviewer-administered and included information on intake frequency (daily, weekly, monthly), portion size, and cooking methods. The instrument was available in both Malay and English and included local food items and everyday dishes reflective of the region's dietary culture (see Table 1).

Table 1: Food groups and total food items in the initial of FFQ

Category of food	Number of food items
Cereals and cereals product	7
Fast food	1
Meat and meat products	3
Fish and seafood	6
Egg	2
Nuts and nuts products	1
Milk and dairy products	2
Bread spread	2
Vegetables	9
Fruits	10
Drinks	7
Confection	5
Seasoning	7
Total number of the food item	**62**

Reference Method: 24-Hour Dietary Recalls

The 24HRs served as the reference method for validating the FFQ, following recommendations for dietary validation studies to improve the reliability of habitual intake assessment. The same 41 participants who completed the development recalls also provided the validation recalls to maintain consistency. We acknowledge that such overlap may slightly inflate correlation coefficients. The first recall was conducted in person during a clinic visit, while the second and third recalls were obtained during subsequent visits or via telephone. Participants were guided to recall all food and beverages consumed in the preceding 24 hours, including preparation details, meal timing, and portion sizes. Food models and probing techniques were employed to reduce recall bias and underreporting. The average intake from the three 24HRs was used to estimate each participant's habitual nutrient intake.

Reproducibility Assessment

To assess the reproducibility of the FFQ, the same instrument was administered to all participants a second time after a three- to five-week interval. This interval was chosen to minimize respondent recall of previous answers while allowing for normal dietary variation. Only clinically stable participants (weight change < 2 kg and no change in TB stage) were re-tested. The same trained interviewer conducted both FFQ administrations (FFQ1 and FFQ2) to reduce inter-interviewer variability. This timing is supported by previous reproducibility studies on FFQ, which recommend a 3–6-week window when the recall period spans the past month.

Nutrient Analysis

Nutrient intake from the FFQ and the 24HRs was analysed using DIET 4, a nutrient analysis software developed explicitly for Malaysian foods. The software utilizes the Malaysian Food Composition Database curated by the Institute for Medical Research, which includes nutrient profiles for locally consumed foods. Mixed dishes were deconstructed into core ingredients using a Sabah recipe database. Household measures were converted to grams with standard conversion tables. For foods available in fried and soup variants, weighted nutrient profiles were calculated according to reported frequency. Nutrient outputs included daily intake estimates of total energy, macronutrients (carbohydrates, proteins, fats), and selected micronutrients, including calcium, phosphorus, iron, carotene, retinol equivalents (RE), vitamins B1, B2, niacin, and vitamin C. All data were double-entered and verified for accuracy. Range checks and consistency screening were applied to minimize data entry errors. Data were anonymized and stored in a secure, password-protected database accessible only to authorized research personnel.

Statistical Analysis

All statistical analyses were performed using SPSS version 27. Pearson correlation coefficients were calculated to assess relative validity using the residual method to compare nutrient intakes estimated from the FFQ with those from the reference 24HRs, both before and after energy adjustment. Cross-classification analysis was performed by categorizing participants into quartiles based on nutrient intake levels from each technique, determining the percentage of individuals classified into the same, adjacent, or extreme quartiles. Agreement between methods was further assessed with Bland-Altman plots for energy and each nutrient, yielding mean bias and 95 % limits of agreement. Reproducibility was assessed using intra-class correlation coefficients (ICC) between FFQ1 and FFQ2, employing a two-way mixed-effects model with absolute agreement. ICC values were interpreted as follows: values less than 0.50 indicated poor reliability, 0.50 to 0.75 indicated moderate reliability, 0.75 to 0.90 indicated good reliability, and values greater than 0.90 indicated excellent reliability (Koo T.K. & Li M.Y., 2016). A two-sided p-value of less than 0.05 was considered statistically significant for all analyses.

RESULTS

A total of 41 participants completed the study and were included in the final analysis. The mean age of the participants was 37.2 years (SD = 13.7), with a slightly higher proportion of females (53.7%) than males (46.3%). Indigenous groups predominated, Bajau (22.0 %), Dusun (13.0 %), and Murut (6.5 %), while 24.4 % were non-native residents. Most respondents had completed at least secondary education (61.0%) and were employed (70.7%). Full sociodemographic characteristics are presented in Table 2. Baseline clinical characteristics, including BMI (18.9 ± 2.2 kg/m²), sputum smear grade, and weeks since treatment initiation, are summarised in Table 2.

Table 2: Sociodemographic and clinical data of participants

Characteristic	Frequency(n=41)	Percentage (%)
Age (years)	**Mean (SD):** 37.2 (13.7)	
Gender		
Male	19	46.3
Female	22	53.7
Ethnicity		
Muslim native	17	41.5
Non-Muslim native	10	24.4
Non-native	10	24.4
Non-Malaysia	4	9.8
Education		
Illiterate	4	9.8
Primary	9	22.0
Secondary	25	61.0
Tertiary	3	7.0
Employment		
Employed	29	70.7
Unemployed	12	29.3
Marital Status		
Married	28	68.3
Single/Divorced/Widow	13	31.7
Body-mass index, BMI (kg m⁻²)	**Mean (SD):** 18.9 (2.2)	
Underweight (<18.5 kg m⁻²)	24	58.5
Normal (18.5–24.9 kg m⁻²)	17	41.5
Overweight/Obese	-	-
Sputum-smear grade, n (%)		
1 +	12	29.3
2 +	16	39.0
3 +	13	31.7
Weeks since treatment initiation	**Mean (SD):** 1.4 (0.6)	

Nutrient Intake Estimations: FFQ vs. 24HR

Nutrient intake data derived from the first FFQ administration (FFQ1) and the average of three 24-hour recalls (24HR) are summarized in Table 3. Across all nutrients, FFQ estimates were significantly higher than 24HR for energy (mean difference = 169 kcal, $p = 0.002$) and vitamin C (mean difference = 33.9 mg, $p < 0.001$) (Table 3). The mean daily energy intake estimated by the FFQ was 2009.4 ± 366.4 kcal, compared to 1840.2 ± 340.0 kcal from the 24HR, representing a relative overestimation of 9.2%. Macronutrient intake showed a similar pattern, with overestimations of 4.1% for protein, 10.5% for carbohydrates, and 10.0% for fat.

Table 3: Validation study: mean daily intake of the nutrient, relative difference, Pearson correlation coefficient, and cross-classification to compare FFQ1 and 24 HR in PTB patients (n=41).

Nutrients	Mean±SD		Relative Difference (%)	Pearson (r)	
	FFQ1	24HR		**Un-adjusted**	**Energy-Adjusted**
Energy	2009.36±366.4	1840.22±340.03	9.19	0.90**	-
Protein	85.45±23.54	82.1±25.87	4.08	0.84**	0.60**
Fat	58.92±11.4	44.5±11.96	9.96	0.70**	0.49**
Carbohydrate	307.18±61.22	277.90±54.38	10.54	0.85**	0.57**
Calcium	377.17±121.01	303.31±116.16	19.58	0.61**	0.59**
Phosphorus	1203.22±322.61	1160.82±339.04	3.65	0.80**	0.41**
Iron	14.89±4.61	11.04±4.45	34.87	0.62**	0.61**
Retinol	717.68±235.47	634.59±221.77	13.09	0.67**	0.65**
Carotene	793.98±403.14	789.77±477.69	0.53	0.39*	0.37*
RE	849.92±260.71	766.27±233.72	10.92	0.68**	0.65**
B1	0.72±0.17	0.58±0.28	19.35	0.73**	0.69**
B2	1.25 ±0.41	0.97±0.41	23.97	0.63**	0.63**
Niacin	13.05±3.41	10.61±3.31	23.00	0.39*	0.23
Vitamin C	68.35±26.8	34.49±17.56	98.17	0.40*	0.34*

FFQ1, food frequency questionnaire during first administration; 24 HR, dietary recall; RE, retinol equivalents; SD, standard deviation

‡ Relative difference = [(FFQ1 – 24 HR)/ 24 HR] *100

* $P<0.05$; ** $P<0.01$

Among micronutrients, iron, vitamin B2, and vitamin C exhibited the most significant relative differences between the FFQ and 24HR, with vitamin C intake nearly doubling in the FFQ estimates (98.2% difference). The slightest discrepancy was observed for carotene (0.5%). Despite these differences, the FFQ provided reasonable estimates for most nutrients compared to the reference method.

Validity Assessment

The unadjusted Pearson correlation coefficients between the FFQ and 24HR ranged from 0.39 for carotene to 0.90 for energy intake, with an overall mean correlation of 0.66 ± 0.17. These correlations indicate moderate to strong agreement between the two methods for most nutrients. Following energy adjustment using the residual method, correlations remained statistically significant for most nutrients, except niacin and vitamin C. The energy-adjusted correlation coefficients ranged from 0.23 (niacin) to 0.76 (vitamin B1), with a mean of 0.55 ± 0.16. These results support the relative validity of the FFQ for assessing energy and nutrient intake in this population.

Bland-Altman plots were used to assess agreement between FFQ and 24HR estimates for energy and individual nutrients (Figure 2). The plots showed a small positive mean bias for most nutrients, indicating slight overestimation by the FFQ. The 95% limits of agreement were narrow for energy, protein, and carbohydrates, but wider for vitamin C and niacin, reflecting higher variability in micronutrient estimation.

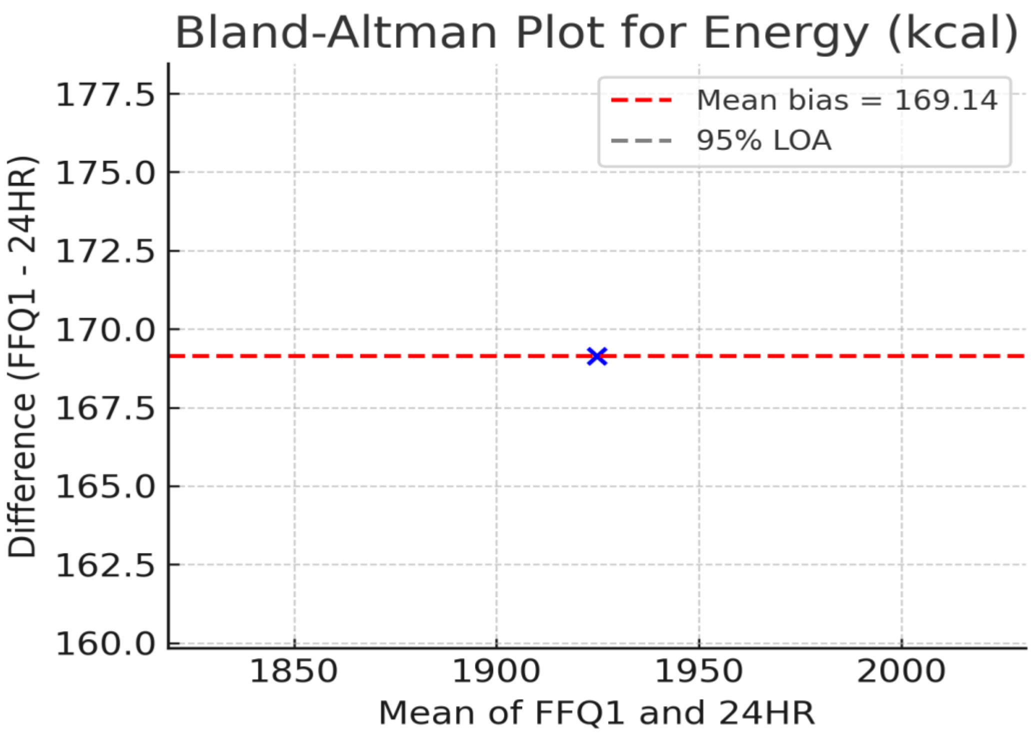

Figure 2: Bland-Altman Plot Showing Agreement Between FFQ1 and 24HR for Energy Intake (kcal)

Cross-Classification Analysis

The agreement between FFQ and 24HR estimates was further evaluated using quartile classification (Table 4). The percentage of participants classified into the same intake quartile by both methods ranged from 27% (carotene) to 61% (energy), with a median of 45.4%. Adjacent quartile agreement ranged from 34% to 56%, while extreme misclassification into opposite quartiles occurred in 5% to 24% of cases. The highest rates of extreme misclassification were observed for vitamin C (24%), carotene (17%), and calcium and iron (14% each). These findings indicate that the FFQ demonstrates acceptable ability to rank participants according to nutrient intake, though caution is warranted for certain micronutrients.

Table 4: Cross-classification of quartiles by 62 food items listed FFQ and three 24-hour dietary recalls (24 HR) in PTB patients.

Nutrients	FFQ/ 24 HR		
	% in the same quartile‡	% in adjacent quartiles§	% in extreme quartiles††
Energy	61	34	5
Protein	56	39	5
Fat	46	44	10
Carbohydrate	49	44	7
Calcium	49	37	14
Phosphorus	46	44	10
Iron	49	37	14
Retinol	32	54	14
Carotene	27	56	17
RE	39	49	12
B1	49	41	10
B2	56	34	10
Niacin	37	49	14
Vitamin C	39	37	24

‡The two methods categorized nutrient intake into the same quartile
§The two methods categorized nutrient intake into adjacent quartiles (difference within two quartiles)
††The two methods categorized nutrient intake into extreme quartiles (difference within more than two quartiles)

Reproducibility of the FFQ

The reproducibility of the FFQ was evaluated by comparing nutrient intake data from FFQ1 and FFQ2, collected three to five weeks apart (Table 5). Intra-class correlation coefficients (ICCs) ranged from 0.786 (vitamin C) to 0.986 (protein), indicating good to excellent test-retest reliability across all nutrients. Most nutrients demonstrated ICC values above 0.90, including energy, protein, carbohydrate, calcium, phosphorus, retinol, and several B vitamins, reflecting excellent reproducibility. These results affirm the stability of the FFQ in capturing habitual dietary intake over time.

Table 5: Reproducibility study: mean daily nutrient intake, relative difference, Spearman correlation coefficient, and cross-classification for comparing FFQ1 and FFQ2 in PTB patients (n=41).

Nutrient	FFQ 1 Mean ± SD	FFQ2 Mean ± SD	ICC (95% CI)
Energy	2009.36 ± 366.42	2109.03 ± 365.18	0.963 (0.730-0.988) **
Protein	85.45 ± 23.54	89.54 ± 23.24	0.986 (0.857-0.996) **
Fat	58.92 ± 11.40	52.95 ± 11.98	0.936 (0.641-0.978) **
Carbohydrate	307.18 ± 61.22	318.97 ± 59.24	0.963 (0.897-0.984) **
Calcium	377.17 ± 121.01	396.26 ± 119.20	0.974 (0.930-0.988) **
Phosphorus	1203.22 ± 322.61	1262.95 ± 4.34	0.985 (0.812-0.996) **
Iron	14.89 ± 4.61	16.57 ± 4.34	0.845 (0.632-0.927) **
Retinol	717.68 ± 235.47	774.64 ± 225.56	0.945 (0.840-0.976) **
Carotene	793.98 ± 403.14	933.79 ± 543.43	0.635 (0.326-0.803) *
RE	849.92 ± 260.71	930.17 ± 245.44	0.905 (0.742-0.957) **
B1	0.72 ± 0.17	0.74 ± 0.17	0.965 (0.930-0.982) **
B2	1.25 ± 0.41	1.32 ± 0.40	0.979 (0.923-0.986) **
Niacin	13.05 ± 3.41	13.85 ± 3.25	0.957 (0.845-0.983) **
Vitamin C	68.35 ± 26.8	75.11 ± 31.37	0.786 (0.601-0.886) **

‡FFQ1, food frequency questionnaire during first administration; FFQ2, food frequency questionnaire during second administration; RE, retinol equivalents
*p>0.001, **p>0.0001

DISCUSSION

We developed a culturally specific semi-quantitative FFQ for PTB patients in Kota Kinabalu and showed moderate-to-strong validity (Pearson r = 0.39–0.90, energy-adjusted r = 0.23–0.76) and excellent reproducibility (ICC = 0.79–0.99). These findings align well with recent validation results in similar contexts. For example, Md Ali et al. (2020) reported unadjusted correlations of 0.35–0.47 in Malaysian haemodialysis patients, reinforcing the reliability of culturally adapted FFQs within clinical populations (Md Ali et al., 2020). Similarly, Regassa et al. (2021) validated a culturally adapted FFQ in Southern Ethiopia and reported crude food-group correlations ranging from 0.12 to 0.78, and de-attenuated correlations from 0.24 to 1.00, demonstrating good performance in ranking dietary intake. (Regassa et al., 2021).

The high reproducibility of our instrument (protein ICC up to 0.99) exceeds benchmarks from other disease-specific FFQ validations, such as those in Peru, where Cronbach's alpha ranged from 0.65 to 0.85 (Wennberg et al., 2024). This supports our choice of a 3–5-week re-test interval, consistent with methods used in recent FFQ validations to capture habitual intake while minimizing recall bias.

Our observation of overestimating certain micronutrients (e.g., vitamin C, niacin) is not unexpected. This trend is documented in multiple FFQ validations and is attributed to the high intra-individual variability of such nutrients (Frediani et al., 2013). Despite this, the FFQ reliably ranks individuals, with 45.4% correctly classified into the same intake quartile and ≤24% extreme misclassification, making it a valuable tool for epidemiological studies assessing dietary risk factors.

The FFQ addresses a gap in Malaysia, where most validated dietary tools target non-communicable diseases rather than PTB (Hong et al., 2010). As a result, this instrument can support improved nutritional monitoring within the TB care continuum, which is an objective in Malaysia's National Strategic Plan to End TB (2021–2030) (Arinah et al., 2016) and aligns directly with the WHO's global strategy, emphasizing integrated, patient-centered TB care, which includes addressing nutritional vulnerability.

The high prevalence (33–88%) and prognostic significance of malnutrition among PTB patients, linked to increased mortality and delayed treatment response, underscores the necessity for tailored dietary assessment tools in this population (Ma et al., 2022). Indeed, recent cohort data from Ethiopia showed that undernutrition in PTB patients contributed substantially to unsuccessful treatment outcomes (Population Attributable Fraction ~20%) (Wagnew et al., 2024). Reviews have also documented that nearly 48% of TB patients in diverse contexts present with nutritional deficits, thereby reinforcing the imperative to integrate nutrition into TB care, both clinically and in policy.

Clinically, the FFQ can help identify patients who need nutritional support. It could be used by clinicians and dietitians to proactively identify PTB patients at nutritional risk, enabling referrals for dietary counselling or supplementation. It also provides a practical dietary outcome measure for future randomized trials evaluating nutritional interventions aimed at optimizing sputum conversion rates, immune recovery, or medication bioavailability.

Adapting the FFQ to a mobile-health platform would broaden access. The Norwegian DIGIKOST-FFQ and similar web-based FFQs have demonstrated validity and reproducibility comparable to paper-based formats (Henriksen et al., 2022). The WHO's End TB Strategy identifies digital tools as foundational to future TB care (Falzon et al., 2016). Implementation toolkits have begun supporting mobile adoption in national TB programs. Implementing a validated digital food frequency questionnaire (FFQ) for PTB populations could enable remote dietary monitoring, especially in rural Sabah and during public health emergencies.

Key strengths include the use of three non-consecutive 24-hour recalls, culturally specific food items, standardized interviewing, and rigorous validation. At the same time, limitations include a sample size that, while consistent with validation guidelines, could be expanded in multi-centre studies to increase generalizability. Future research could also incorporate objective dietary biomarkers (e.g., serum retinol or vitamin C) and test the FFQ's external validity in other high-risk populations like HIV-infected TB patients or individuals from diverse indigenous backgrounds.

CONCLUSION

This study presents the first validated Food Frequency Questionnaire (FFQ) tailored explicitly for pulmonary tuberculosis (PTB) patients in Malaysia. Developed using culturally relevant food items and rigorously validated against three-day 24-hour dietary recalls, the FFQ demonstrated strong relative validity and excellent reproducibility. It provides a reliable and practical tool for assessing habitual intake of both macronutrients and micronutrients among PTB populations in Kota Kinabalu.

Beyond its research value, the FFQ offers clinical utility in identifying patients at nutritional risk and supporting targeted dietary interventions. Its application can enhance both epidemiological surveillance and patient-cantered care, contributing to Malaysia's National Strategic Plan to End TB and aligning with the World Health Organization's 2030 End TB Strategy. Future efforts should focus on expanding the tool to broader populations, integrating objective biomarkers, and adapting it into a digital or mHealth format to facilitate scalable and contactless administration, especially in remote or resource-limited settings.

Conflict of interest statement

The authors state that the study was conducted independently of any commercial or financial associations that could lead to a future interest conflict being misinterpreted.

Acknowledgment

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Ethical Considerations

The Medical Research and Ethics Committee granted ethical approval for this study (MREC) of the Ministry of Health Malaysia (Ref: KKM/NIHSEC/P19-443(11)) and registered in the National Medical Research Register (NMRR-18-3698-40627). Written informed consent was obtained from all participants prior to data collection.(Md Ali et al., 2020)

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