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Associations between food-related behaviours, nutrient intake and nutritional status through Structural Equation Model (SEM) among clients undergoing Community-Based Treatment and Rehabilitation (CBTaR): A cross-sectional study in Kelantan, Malaysia

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ABSTRACT

Objective To examine the associations between food-related behaviours and nutrient intake on nutritional status among clients undergoing Community-Based Treatment and Rehabilitation (CBTaR) in Kelantan, Malaysia.

Design Cross-sectional analytical study.

Setting Seven CBTaR centres (n=7) across the state of Kelantan, Malaysia.

Participants A total of 393 adult clients (aged 18 years and above) enrolled in CBTaR programmes between June and December 2022 were selected through stratified random sampling.

Primary and secondary outcome measures The primary outcome was nutritional status, assessed using body mass index. Secondary outcomes included nutrient intake (macronutrients and micronutrients) and food-related behaviours (emotional eating, external eating, restrained eating and food addiction), measured through Bahasa Malaysia validated questionnaires and 24-hour dietary recalls. All variables were introduced into the structural equation modelling to examine the associations among these variables and their association with nutritional status.

Results The results revealed that food-related behaviour was significantly associated with the nutrient intake (β=–0.524, p≤0.001). Additionally, the drug use profile significantly determined the food-related behaviour (β=–0.129, p=0.006) and nutritional status (β=–0.134, p=0.007). Nutrient intake was found to be a significant predictor of nutritional status (β=–0.213, p≤0.001). Sociodemographic and drug use profiles were significantly correlated with nutritional outcomes through behavioural and dietary associations. Importance-performance map analysis identified nutrient intake as the most impactful variable, highlighting the need for urgent intervention (R^2=0.272).

Conclusions This study highlights that nutrient intake is a significant predictor associated with food-related behaviours on nutritional status among individuals with substance use disorder. Integrating nutrition counselling and behavioural interventions into CBTaR services may improve recovery and long-term health outcomes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study was a cross-sectional study design, which may not present a causal relationship.
⇒ The study used validated Malay-language instruments for data collection to ensure quality.
⇒ Although the study identifies certain determinants that were associated with nutritional status, there may be other unmeasured confounding variables that could affect the outcomes.
⇒ Self-reported dietary intake data may introduce recall bias.
⇒ The research was conducted in seven Community-Based Treatment and Rehabilitation centres across Kelantan, Malaysia, providing diverse insights from different regions.

INTRODUCTION

Substance use disorders (SUDs) continue to present complex health challenges, not only in terms of addiction recovery but also regarding long-term nutritional outcomes and behavioural health. Nutritional status among individuals with a history of substance abuse is frequently compromised, manifesting as undernutrition, micronutrient deficiencies or metabolic imbalances due to altered appetite regulation, poor food choices and disordered eating behaviours during and after drug use.[1] Based on the recent systematic reviews and meta-analyses studies, the relationship between nutrition, dietary behaviours and SUDs is evident. Individuals with SUDs often exhibit poor dietary patterns, such as irregular meal consumption and a preference for high-fat and high-sugar foods, contributing to nutritional deficiencies and weight fluctuations. These behaviours are associated with metabolic issues, such as obesity or undernutrition, and can hinder recovery outcomes.[2–4]

In Malaysia, the Community-Based Treatment and Rehabilitation (CBTaR) programme has been introduced to support the recovery and reintegration of individuals affected by drug use through psychosocial, behavioural and occupational interventions.[5] Both states, Kedah and Kelantan, have been identified as frequent hotspots for drug use and have been categorised as high-risk areas for drug abuse. Their proximity to the Thailand border was related to the easy access to the supply and distribution of the drugs, making them particularly vulnerable.[6] Kelantan, in particular, is located in northeastern Peninsular Malaysia, near the Thai border, and close relationships between the communities with an unrestricted transit are always considered a major support to Kelantan's drug epidemic.[7] However, little attention has been given to nutrition-focused approaches within this recovery framework among SUD clients.[8] A growing body of evidence now recognises that recovery from substance use must address underlying behavioural determinants of health—including dietary behaviours and nutrient adequacy—to achieve holistic rehabilitation outcomes.[2 9]

Individuals with SUDs often exhibit specific maladaptive eating patterns, including emotional eating, sugary foods and refined carbohydrates, weight gain, binge eating, foods that are high in cholesterol and sodium, or FA-like symptoms, especially during early recovery phases. It is due to the withdrawal from substances which may shift the compulsive behaviours towards food.[10 11] These food-related behaviours can severely disrupt dietary balance, leading to excessive intake of sugars, carbohydrates or fats, and resulting in poor nutrient profiles.[11 12] At the same time, nutritional adequacy plays a crucial role in maintaining mental health stability, achieving energy balance, enhancing immune function and promoting physical recovery. For instance, deficiencies in protein or specific micronutrients may exacerbate fatigue, mood instability or impair neurochemical recovery, which are all relevant to relapse risk.[13 14]

While various international studies used structural equation modelling (SEM) to analyse behavioural and dietary associations with health outcomes, such approaches remain limited in Malaysia, particularly within vulnerable populations such as CBTaR clients. SEM assists in modelling the predictors of independent variables on the dependent variable. Additionally, when using traditional regression methods analysis, predicted power does not emerge, and it is considered a non-parametric analysis, meaning that tests for normality or homogeneity are not required. It can be applied to small sample sizes and exhibits strong predictive power.[15] SEM enables the simultaneous modelling, making it a robust statistical tool for evaluating factors such as sociodemographic characteristics, drug use history, food-related behaviours and nutrient intake that interact to determine nutritional status.[16 17] Therefore, this study aims to apply an SEM approach to examine the associations between food-related behaviours and nutrient intake on nutritional status among clients undergoing CBTaR in Kelantan, Malaysia. Understanding these associations is crucial for designing nutrition-sensitive interventions that can be effectively integrated into rehabilitation programmes, particularly in Malaysia, to promote long-term recovery and health resilience.

MATERIALS AND METHODS

Study design and participants

A cross-sectional study was conducted between August and December 2024 at seven National Anti-Drugs Agency (NADA) centres located in Kota Bharu, Bachok, Tumpat, Pasir Mas, Pasir Puteh, Tanah Merah and Machang within the state of Kelantan, Malaysia. Although a cross-sectional design was effective for gathering data at a single point in time, it limited the ability to determine causality or establish temporal relationships between variables. A total of 393 participants were recruited. Site selection for this study focused on districts situated along the northern border of Peninsular Malaysia and areas near the coast. This northern border, which is adjacent to the Golden Triangle region, has long been recognised as a hotspot for organised crime and illicit drug trafficking. Given Kelantan's geographical proximity to this region, the state has encountered significant issues with the distribution and consumption of illicit drugs, particularly Amphetamine-Type Stimulants and other synthetic substances.[18]

The inclusion criteria for this study were male and female clients aged 18–59 years who enrolled in CBTaR, had attended the programme in the selected districts for at least 1 month following their registration with NADA, were proficient in Bahasa Malaysia and in good health at the time of data collection. Participants were excluded if they did not provide consent prior to data collection, were detained by authorities or were female participants who were pregnant. To determine the sample size, G-power software was employed. The sample size was calculated for each variable related to the determinants of malnutrition using power and sample size estimation. The largest estimated sample size was 393, determined using the single proportion formula. The reference population proportion (p) was set at 0.64,[19] corresponding to a Z-score of 1.96 and a precision (d) of 0.05. An additional 10% was included, as commonly practised in similar studies, to account for potential non-response or participant dropout.[20] Therefore, the total required sample size was 393. Written informed consent was obtained from all participants prior to data collection.

Data collection procedures

The study used stratified random sampling to select 393 participants, ensuring representation of individuals enrolled in CBTaR programmes across seven NADA centres in Kelantan. The 10 NADA district offices operating CBTaR were initially stratified by geographical region, considering factors such as proximity to the northern border with Thailand and coastal areas. Only 7 out of 10 districts fell within the defined strata. Participants were recruited from seven centres located in Kota Bharu, Tumpat, Pasir Mas, Bachok, Pasir Puteh, Tanah Merah and Machang. Clients were selected using proportional simple random sampling from official NADA client lists of those registered between 2023 and 2024 who met the study's inclusion and exclusion criteria.

To facilitate recruitment and prevent bias selection, NADA officers, acting as gatekeepers due to the court-ordered supervision of clients, assisted in identifying eligible participants and coordinating interviews. Prior to data collection, the study protocol and permissions were discussed with the head officers of each district to ensure cooperation. However, due to the dynamic nature of the community-based rehabilitation setting, several clients initially selected became unavailable shortly before data collection (eg, newly detained, transferred or intoxicated). To address this, the field substitution method was applied, whereby non-responding participants were replaced with other clients who fulfilled the predefined inclusion and exclusion criteria.[21] In this study, the replacement was carried out randomly by selecting the next number on the random sequence list, ensuring that the process remained consistent with the principles of random sampling. This procedure was carried out collaboratively between the researcher and the gatekeepers to ensure transparency and adherence to the planned sample structure. A 100% response rate was achieved, with no missing data. To address potential non-response bias, participants who missed their initial interviews were contacted and rescheduled. This approach ensured the completeness of the data. However, the sampling frame was limited to individuals under court supervision, which may introduce selection bias, as those not under supervision were excluded from the study.

To measure dietary intake, food-related behaviours and other variables, the study relied on self-reported data through interviews and questionnaires. This method introduces the potential for recall bias, as participants might inaccurately report their food intake and behaviours. To mitigate this, validated tools, such as the Malay Yale Food Addiction Scale (YFAS) and the 24-hour dietary recall (24hDR) method, were used. Validated Malay-language questionnaires were used to collect data on sociodemographic characteristics, drug use profile and food-related behaviours, including nutrient intake, diet quality, food addiction (FA), sugar craving, emotional eating, restrained eating and external eating. Data collection was carried out through face-to-face interviews conducted by trained nutritionists using these validated questionnaires, which included the YFAS 2.0, the Malaysian Sugar Craving Assessment Tool (MySCAT) and Malay Dutch Eating Behaviour Questionnaires (DEBQ).[22–25] After finishing the interview session, the participant underwent an anthropometric assessment to identify their nutritional status. All the administered questionnaires were presented in online supplemental table 1.

Drug use profile

Information on drug use profile collected in this study included age at initiation of drug use, duration of drug use, types of drugs, duration of incarceration for rehabilitation, most recently used drug, smoking status, duration of smoking, presence of chronic diseases and concurrent treatment with other drug therapies while enrolled in CBTaR under NADA. These items were incorporated into the validated questionnaire and aligned with NADA's administrative procedures.[8]

Food-related behaviour assessment

The assessment of food-related behaviours covered nutrient intake, diet quality, FA, sugar cravings and eating behaviours, including emotional eating, restrained eating and external eating. Daily nutrient intake was evaluated using the 24hDR method on two non-consecutive days, consisting of 1 weekday and 1 weekend day.[26] During the 24-hour recall interviews, participants provided detailed consumption and accurate information regarding the quantities, preparation methods, commercial brands, sauces, dressings, condiments, liquids, multivitamins, food supplements and beverages.[27] In estimating portion sizes, a household measurement tools catalogue published by the Institute for Public Health Malaysia (2020) was used.[28] All dietary data were entered and analysed using Nutritionist Pro software (Axxya Systems LLC, Stafford, Texas, USA) to calculate participants' daily total caloric intake as well as their intake of key macronutrients and micronutrients.[29] The participants' dietary intake data were then compared with the 2017 Recommended Nutrient Intakes for Malaysia.[30]

Diet quality in this study was assessed across three main domains: nutrient adequacy, food variety and diversity, and moderation of foods, food groups and nutrients. The Malaysia Healthy Eating Index (MHEI) was used to analyse participants' diet quality. Scoring for each MHEI component followed the recommended serving sizes and nutrient intake guidelines outlined in the Malaysia Dietary Guidelines 2020.[31] Scores from each component were summed to calculate a composite percentage score, which categorised participants' diet quality as poor (<51%), moderate/needs improvement (51%–80%) or good (>80%).[32] FA status was assessed using the YFAS to identify eating patterns consistent with addictive behaviours. The Malay version of the YFAS 2.0, translated and validated by Swarna Nantha and colleagues, was used in this study.[25] The YFAS 2.0 measures 11 FA indicators and one clinical impairment criterion, with classifications of mild FA (meeting 2–3 criteria), moderate FA (meeting 4–5 criteria) and severe FA (meeting 6 or more criteria). Sugar craving status was assessed using the MySCAT.[23] This questionnaire was developed to reflect commonly consumed sugar-containing foods and beverages preferred by Malaysians. Responses were recorded on a 5-point Likert scale, and participants' sugar craving status was determined based on their total score. Scores between 0 and 44 indicated no sugar craving, while scores of 45 and above indicated the presence of sugar craving.

Eating behaviour status was evaluated across three domains: emotional eating, restrained eating and external eating, using the DEBQ, which was validated in Malay.[24] Emotional eating refers to consuming food in response to negative emotions or stress as a coping strategy, restrained eating involves dietary restriction due to concerns about body weight, and external eating refers to eating in response to external cues such as the visual appeal or palatability of food.[22] The Malay version of DEBQ consists of 30 items, with 13 items assessing emotional eating, and each of the external and restrained eating consists of 8 and 9 items, respectively. A higher average score within any of these domains indicated a greater tendency towards that specific eating behaviour.

Anthropometric measurements

Participants' height was measured using a SECA 213 stadiometer (Germany). During the measurement, participants were asked to stand barefoot in a relaxed position, with their shoulders at ease, eyes looking straight ahead, arms hanging naturally at their sides, and heels and knees together. Body weight was measured in kg using a SECA 872 digital weighing scale (Germany), which had a maximum capacity of 200 kg. Participants wore light clothing during the measurement.[33] The body mass index (BMI) was calculated by dividing the weight in kilograms by the height in metres squared (kg/m²). Nutritional status was assessed using the BMI cut-off points recommended by WHO (2004), which consider the increased health risks associated with lower BMI thresholds among Asian populations.[34] The BMI classification used in this study included: underweight (<18.5 kg/m²), normal (18.5–22.9 kg/m²), overweight (23.0–27.4 kg/m²), pre-obesity (27.5–32.4 kg/m²), obesity class I (32.5–37.4 kg/m²) and obesity class II (≥37.5 kg/m²).

Statistical analysis

Data analysis was conducted using IBM SPSS (V.30.0). Descriptive statistics were first applied to summarise sociodemographic characteristics and drug use profiles. Data with a normal distribution were presented as means and SD, while categorical variables were reported as frequencies and percentages. χ^2 tests were used to compare the frequency distribution of categorical variables related to metabolic risk factors, and comparisons between two or more than two groups based on factor scores were conducted using Student's t-test or one-way Analysis of Variance (ANOVA) test.

SEM was used to empirically determine the association between sociodemographic characteristics, drug use profile and food-related behaviours (including nutrient intake, diet quality, FA, sugar craving, emotional eating, restrained eating and external eating) among clients undergoing CBTaR. SEM was employed because it enables the simultaneous estimation of multiple interrelated relationships among latent constructs. Constructs such as food-related behaviours and nutrient intake are multidimensional and partly latent, measured through several validated instruments (eg, YFAS 2.0, DEBQ and MySCAT), making SEM more appropriate than conventional regression approaches. The partial least squares-structural equation modelling (PLS-SEM) method was adopted due to its advantages for exploratory and predictive research, its robustness in handling non-normally distributed data and its applicability to small sample sizes and complex models.[15] Although the present study employed a cross-sectional design, SEM remains valuable for evaluating the theoretical structure and strength of hypothesised associations among variables rather than establishing causality.

The conceptual model illustrating the correlations among dependent and independent variables is presented in figure 1. The conceptual model included: (1) sociodemographic factors, drug use profile and food-related behaviours are associated with nutrient intake; (2) drug use profile and sociodemographic factors are associated with food-related behaviours; (3) nutrient intake is associated with nutritional status and (4) food-related behaviours are associated with nutritional status. Multigroup analysis (MGA) was conducted to investigate potential differences in the model's associations across subgroups defined by sociodemographic factors, specifically age group, employment status and education level. The inclusion of multiple subgroups based on demographic factors was driven by prior research indicating that age, employment status and education level could determine the relationship between food-related behaviours, nutrient intake and nutritional status, particularly in vulnerable populations such as those undergoing rehabilitation for substance use.[1–3] Correction for multiple testing was performed using the Bonferroni correction.[35] Corrected p value for association analysis was ≤0.006 (three independent variables (food-related behaviours, nutrient intake and drug use profiles)*three sociodemographic factors (age group, employment status and education level)=9 tests). Data were also presented, along with the SEM analysis results, which included the path coefficient, R^2, R^2 adjusted, f^2 (effect size) and an importance-performance map analysis (IPMA). All statistical tests were two-tailed, with a significance level set at $p<0.05$.

RESULTS

Characteristics of participants

In table 1, of the 393 participants, 17.8% were underweight, 37.9% had normal BMI and 44.3% were overweight

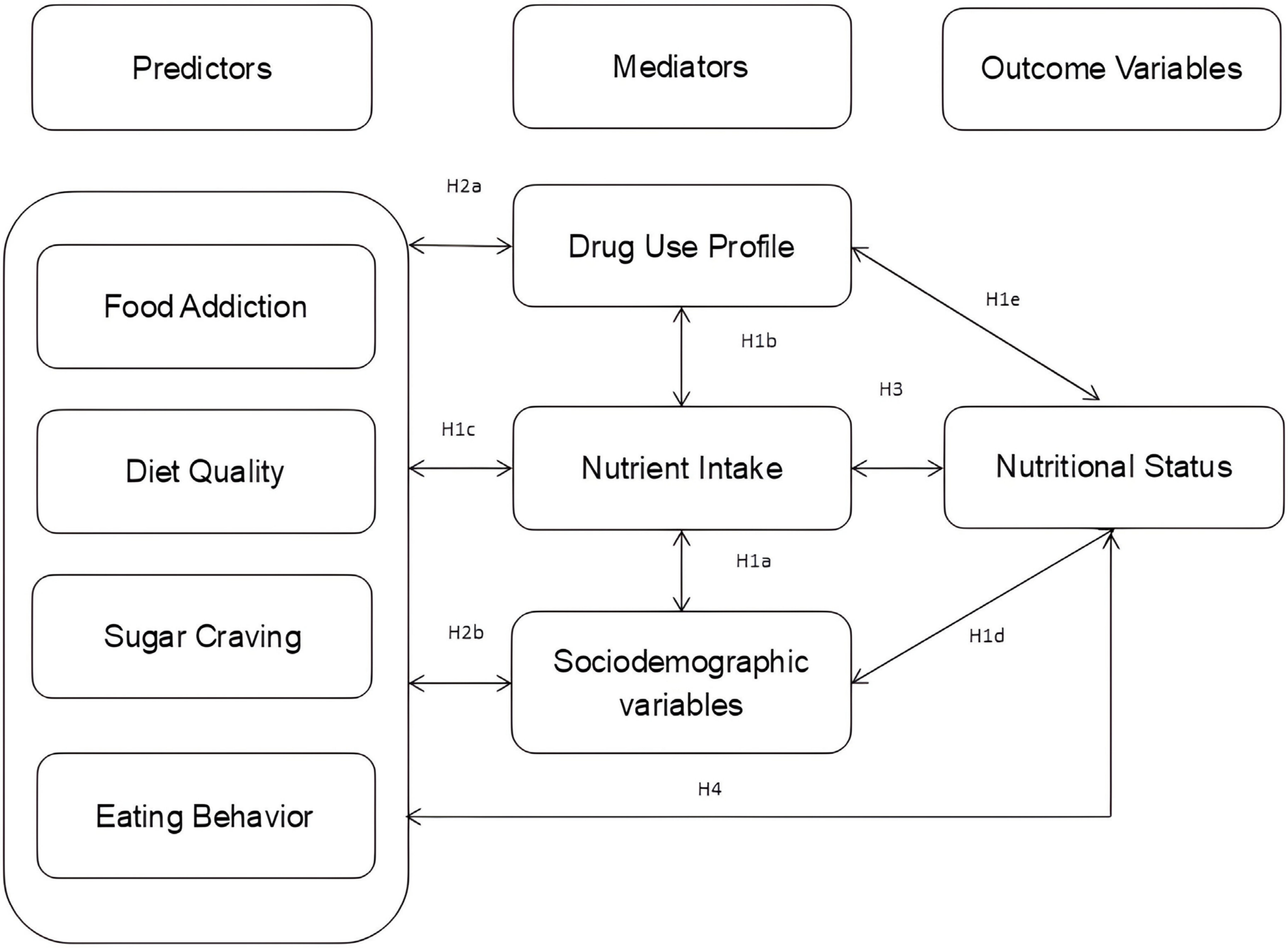

Figure 1 Schematic illustration of the model used to examine the associations of the present study. Hypothesis 1a (H1a): sociodemographic factors were associated with altered nutrient intake in CBTaR addiction recovery. Hypothesis 1b (H1b): drug use profile was associated with altered nutrient intake. Hypothesis 1c (H1c): food-related behaviours were associated with altered nutrient intake. Hypothesis 1d (H1d): sociodemographic factors were associated with nutritional status. Hypothesis 1e (H1e): drug use profile was associated with nutritional status. Hypothesis 2a (H2a): drug use profile was associated with altered food-related behaviours. Hypothesis 2b (H2b): sociodemographic factors were associated with altered food-related behaviours. Hypothesis 3 (H3): nutrient intake factors were associated with nutritional status. Hypothesis 4 (H4): food-related behaviours were associated with nutritional status in CBTaR addiction recovery. CBTaR, Community-Based Treatment and Rehabilitation.

or obese. Age was significantly associated with nutritional status ($p \leq 0.001$), with overweight-obese participants predominantly aged ≥30 years (77.6%) compared with the underweight group (45.7%). Gender was also significantly associated ($p=0.021$), where females were more represented in the overweight-obese group (5.7%) compared with underweight (1.4%). Other variables, including race ($p=0.604$), marital status ($p=0.159$), education level ($p=0.386$), employment status ($p=0.419$) and socioeconomic status ($p=0.139$), were not significantly associated with nutritional status. Age and gender were significantly associated with nutritional status among clients undergoing CBTaR, with higher age and female gender more prevalent in the overweight-obese category ($p<0.05$).

Food-related behaviour status

Table 2 found that sugar craving was significantly associated with nutritional status ($p=0.025$), with the underweight group reporting higher sugar cravings (45.7%) compared with overweight-obese (29.9%). Eating behaviour status also showed a significant association ($p=0.004$), where restrained eating was more prevalent among overweight-obese participants (17.2%) compared with underweight (4.3%). FA ($p=0.291$) and diet quality ($p=0.193$) were not significantly associated with nutritional status. Sugar cravings and restrained eating behaviours were significantly associated with nutritional status, indicating their potential role in dietary patterns among clients undergoing CBTaR ($p<0.05$).

Nutrient intake status

Table 3 showed that carbohydrate intake (g) differed significantly across nutritional status groups ($p=0.021$), with underweight participants having higher intake (246.6±89.1 g) compared with overweight-obese (217.3±77.7 g). Sugar intake was also significantly

Table 1 Sociodemographic characteristics according to nutritional status (n=393)

Sociodemographic characteristics	Total, n (%)	Nutritional status: Underweight (%)	Normal (%)	Overweight-obese (%)	P value*
		17.8	37.9	44.3	
Age, years	34.5±8.8				≤0.001
≥30 years	270 (68.7)	45.7	69.1	77.6	
<30 years	123 (31.3)	54.3	30.9	22.4	
Gender					0.021
Male	381 (96.9)	98.6	99.3	94.3	
Female	12 (3.1)	1.4	0.7	5.7	
Races					0.604
Malay	384 (97.7)	98.6	98.0	97.1	
Chinese	8 (2.0)	1.4	1.3	2.9	
Others	1 (0.3)	0	0.7	0	
Marital status					0.159
Single/divorced	274 (69.7)	78.6	69.8	66.1	
Married	119 (30.3)	21.4	30.2	33.9	
Education level					0.386
Primary	21 (5.3)	8.6	2.7	6.3	
Lower secondary (form 1–3)	128 (32.6)	34.3	34.2	30.5	
Upper secondary (form 4–5)	188 (47.8)	45.7	45.6	50.6	
Higher education	56 (14.2)	11.4	17.4	12.6	
Employment status					0.419
Yes	352 (89.6)	85.7	89.3	91.4	
No	41 (10.4)	14.3	10.7	8.6	
Monthly income† status					0.139
B40 (<3060 RM)	361 (91.9)	97.1	93.3	88.5	
M40 (3060–6469 RM)	26 (6.6)	2.9	6.0	8.6	
T20 (≥6470 RM)	6 (1.5)	0	0.7	2.9	

B40=The bottom 40% of income earners (<RM5150); 1US$=Ringgit Malaysia (RM) 4.21.
*Significant at p<0.05 for χ^2 tests and t-test.
†Household income category based on Household Income Survey Report 2022 (Department of Statistics Malaysia, 2023).

different (p=0.005) between underweight and overweight-obese groups, with underweight participants consuming a higher amount of sugar intake (77.8±42.2 g) than overweight-obese participants (68.5±43.7 g). Vitamin A (p=0.017) and Vitamin C (p=0.044) intake differed significantly, with higher Vitamin A intake among underweight participants and higher Vitamin C intake among those with normal BMI. Other macronutrient distributions, energy intake (p=0.050) and micronutrient intakes showed no significant differences across groups. Carbohydrate, sugar, Vitamin A and Vitamin C intakes were significantly associated with nutritional status, highlighting differences in specific nutrient consumption patterns among clients in CBTaR programmes (p<0.05).

SEM analysis

The validity and reliability of the formative constructs were evaluated in accordance with recommended PLS-SEM procedures.[36] Multicollinearity assessment showed that all formative indicators had acceptable variance inflation factor (VIF) values (<5), indicating no critical collinearity issues (see online supplemental table S1). Bootstrapped outer weights were examined to assess indicator relevance, and most indicators demonstrated significant contributions to their respective constructs, supporting convergent validity (see online supplemental table S2). Discriminant validity was further confirmed through Heterotrait-Monotrait Ratio of Correlations values that were below the recommended thresholds (see online supplemental table S3). Thus, these results indicate that the formative measurement model met the validity and reliability criteria required for PLS-SEM.

Before analysing structural relationships, collinearity must be assessed using VIF to ensure unbiased regression results. Hair *et al*[36] recommended a VIF <3, and in this

Table 2 Food-related behaviour status according to nutritional status

Food-related behaviour variables	Total, n (%)	Nutritional status			P value*
		Underweight (%)	Normal (%)	Overweight-obese (%)	
Food addiction					
No food addiction	390 (99.2)	45.7	50.3	43.7	0.291
Severe food addiction	3 (0.8)	54.3	49.7	54.6	
Diet quality					
Poor	234 (67.9)	68.6	55.7	59.2	0.193
Moderate	159 (32.1)	31.4	44.3	40.8	
Good	0 (0)				
Sugar craving					
No sugar craving	267 (67.9)	54.3	71.8	70.1	0.025
Having a sugar craving	126 (32.1)	45.7	28.2	29.9	
Eating behaviour status					
Restrained eating	42 (10.7)	4.3	6.0	17.2	0.004
Emotional eating	9 (2.3)	2.9	3.4	1.1	
External eating	342 (87.0)	92.9	90.6	81.6	

*Significant at p<0.05 for χ^2 tests.

study, VIF values ranged from 1.000 to 1.155, indicating no collinearity issues (see online supplemental table S4). In addition, the evaluation of the structural model was based on R^2, f^2, Q^2 and the path coefficient.[36] The R^2 value indicates that food-related behaviour can only be explained by 1.7% through the drug use profile, nutrient intake is explained by 27.2% through the combination of eating behaviour and drug profile, while nutritional status is only explained by 5.6% through the three predictors in the model. After adjustment, the adjusted R^2 values for food-related behaviour, nutrient intake and nutritional status were 0.014, 0.269 and 0.049, respectively. Referring to the criteria of PLS-SEM, these values indicate that the model's explanatory power for food-related behaviour and nutritional status is weak, while for nutrient intake, it falls into the moderate category.[36 37] The Q^2 values, ranging from 0.003 to 0.250, indicated the predictive relevance of the exogenous constructs for the endogenous constructs, as a Q^2 value >0 signifies predictive relevance.[36] These findings suggested that the model has a fairly good predictive ability for nutrient intake; however, other factors outside the model are likely more dominant in influencing eating behaviour and nutritional status.

The effect size (f^2) analysis showed that eating behaviour had a strong association with nutrient intake (f^2=0.372), while its association with nutritional status was almost negligible (f^2=0.002). The drug use profile showed a small association with eating behaviour (f^2=0.017) and nutritional status (f^2=0.019), as well as a very small association with nutrient intake (f^2=0.001). Meanwhile, nutrient intake had a small association with nutritional status (f^2=0.035). Based on the criteria of PLS-SEM, these findings indicated that the most substantial pathway in the model was the association of eating behaviour with nutrient intake, whereas other relationships tended to be weak (see online supplemental table S5).[36 37] Thus, nutritional status is more likely to be associated through the mechanisms of nutrient intake and external factors beyond the model.

Model fit was assessed using the standardised root mean square residual (SRMR), normed fit index (NFI) and discrepancy measures (d_ULS and d_G) as recommended for PLS-SEM. The results indicated good model fit with SRMR=0.037 and NFI=0.943, both within the recommended thresholds (SRMR<0.08; NFI>0.90). The discrepancy measures (d_ULS=0.832; d_G=0.149) and the minimal difference between the saturated and estimated models further confirmed satisfactory fit (see online supplemental table S6). These findings demonstrate that the proposed structural model adequately represents the observed data.[15 38]

Association analysis results (table 4) revealed that nutrient intake had the strongest and most significant negative association with food-related behaviour (β=−0.524, p≤0.001) and nutritional status (β=−0.213, p≤0.001), indicating that poorer nutrient intake is associated with severe problematic eating behaviours and lower nutritional status. The drug use profile was also found to have a significant association on both food-related behaviour (β=−0.129, p=0.006) and nutritional status (β=−0.134, p=0.007), suggesting that drug use patterns and history determine nutritional vulnerability. Conversely, the relationship between food-related behaviour and nutritional status was not statistically significant (β=−0.048, p=0.253), nor was it associated with drug use profile on nutrient intake (β=0.025, p=0.278). These findings underscore the role of nutrient intake as a key mediating factor linking eating behaviour, drug use and nutritional status.

MGA by age group

To minimise the risk of Type I errors arising from multiple comparisons across the multigroup analyses

Table 3 Nutrient intake according to nutritional status

Nutrient intake variables†	Total, n (%)	Nutritional status			P value*
		Underweight (%)	Normal (%)	Overweight-obese (%)	
% CH					
<50%	170 (43.3)	37.1	38.3	50.0	0.096
50%–65%	209 (53.2)	58.6	56.4	48.3	
>65%	14 (3.6)	4.3	5.4	1.7	
% Protein					
≤20%	338 (86.0)	88.6	86.6	84.5	0.684
>20%	55 (14.0)	11.4	13.4	15.5	
% Fat					
>30%	208 (52.9)	45.7	47.0	60.9	0.052
20%–30%	168 (42.7)	51.4	47.0	35.6	
<20%	17 (4.3)	2.9	6.0	3.4	
Energy, kcal	1730.0±569.4	1880.4±655.4	1692±567.4	1701±526.2	0.050
Carbohydrate, g	222.2±81.2	246.6±89.1	216.4±79.1	217.3±77.7	0.021
Protein, g	71.1±22.5	69.4±25.1	69.3±20.4	73.2±23.0	0.244
Fat, g	61.2±25.6	58.8±27.0	60.4±24.7	62.9±25.9	0.488
Sugar, g	66.4±43.0	77.8±42.2	58.5±41.2	68.5±43.7	0.005
Salt, g	7.0±3.4	7.4±3.6	6.9±3.4	6.9±3.3	0.612
Fibre, g	3.6±3.3	3.4±2.9	3.5±3.3	3.7±3.5	0.844
Calcium, mg	391.3±192.5	390.6±196.9	390.1±184.3	392.5±199.3	0.993
Magnesium, mg	125.0±56.9	127.6±67.9	117.7±49.1	130.2±57.8	0.132
Selenium, mg	46.0±27.0	47.2±26.3	43.2±26.5	47.9±27.5	0.275
Zinc, mg	5.7±3.1	5.6±2.7	5.3±3.2	6.1±3.3	0.093
Fe, mg	12.1±5.4	12.0±5.7	11.8±5.5	12.4±5.2	0.642
Sodium, mg	2803.0±1348.6	2966.8±1469.8	2782.2±1368.6	2755.0±1281.9	0.526
Potassium, mg	1426.5±533.5	1341.8±579.4	1420.9±510.5	1465.4±532.5	0.259
Vitamin A, mg	696.8±621.1	854.8±778.2	722.5±689.7	611.2±455.4	0.017
Vitamin C, mg	56.1±58.7	51.2±50.8	65.5±72.6	49.9±46.2	0.044
Vitamin D, mg	1.00±1.2	0.7±1.2	0.7±1.2	0.8±1.3	0.476
Vitamin E, mg	3.0±7.3	2.3±1.6	2.9±4.7	3.2±10.0	0.681
Vitamin B1, mg	1.0±0.3	0.6±0.3	0.7±0.3	0.7±0.3	0.672
Vitamin B2, mg	1.1±0.5	1.1±0.5	1.2±0.5	1.1±0.4	0.310
Vitamin B3, mg	13.2±6.2	13.6±7.2	13.3±6.1	13.0±5.8	0.735
Vitamin B6, mg	1.2±1.4	1.1±0.7	1.2±1.3	1.2±1.6	0.794
Vitamin B9, mg	101.6±71.4	94.1±68.4	96.1±52.0	109.3±85.3	0.160

Data presented as mean±SD or n (%). % macronutrient intake was a percentage of the total daily calories.
*Significant at p<0.05 for Analysis of Variance (ANOVA) test.
†Nutrient intake is based on the Malaysia Recommended Nutrient Intake (RNI).
CH, carbohydrate.

(tables 5–7), a Bonferroni correction was applied. Table 5 displayed the results of the MGA based on age group. In individuals aged ≥30 years, the association between drug use profile and nutritional status (β=−0.159, p=0.003) was statistically significant, indicating that drug use history has a tangible impact on nutritional status in older adults. In contrast, these associations were not significant among participants under 30 years of age (p>0.1). The association between food-related behaviour and nutrient intake was significant in both age groups (p≤0.001). The association between nutrient intake and nutritional status was significant in the ≥30 years age group (p=0.001). The association between food-related behaviour and nutritional status was not significant in either group. These findings suggest that the association of drug use history with nutrient intake on nutritional outcomes is more pronounced among adults, highlighting the need for

Table 4 The association results between variables

Association	β	Mean (SD)	Effect size (f^2)	95% CI	P value
Food-related behaviour→Nutritional status	−0.048	−0.045 (0.067)	0.002	−0.162 to 0.078	0.253
Food-related behaviour→Nutrient intake	−0.524	−0.516 (0.034)	0.372	−0.582 to −0.470	≤0.001
Drug use profile→Food-related behaviour	−0.129	−0.107 (0.043)	0.017	−0.207 to −0.042	0.006
Drug use profile→Nutrient intake	0.025	0.044 (0.051)	0.001	−0.095 to 0.046	0.278
Drug use profile→Nutritional status	−0.134	−0.132 (0.050)	0.019	−0.221 to −0.042	0.007
Nutrient intake→Nutritional status	−0.213	−0.215 (0.056)	0.035	−0.304 to −0.114	≤0.001
	R^2	R^2 adjusted	Q^2	IPMA*	IPMA†
Food-related behaviour	0.017	0.014	0.003	0.064	39.107
Nutrient intake	0.272	0.269	0.250	−0.213	60.232
Nutritional status	0.056	0.049	0.034	–	–
Drug use profile	–	–	–	−0.137	41.115

*Construct total effects (importance).
†Construct performances for nutritional status.
IPMA, importance-performance map analysis.

age-specific interventions in rehabilitation and nutritional recovery programmes.

MGA by employment status

In table 6, the MGA based on employment status revealed differences in the strength and significance of model associations between unemployed and employed individuals. The association between drug use profile, food-related behaviour and nutrient intake was not significant among both age groups (p≥0.006). Similar results were also found for the association between food-related behaviour and nutritional status. Drug use profile and nutritional status were significantly associated only in the employed group (β=−0.143, p=0.002), suggesting that drug use experiences have determined the nutritional status among those who are actively working. Additionally, the association between food-related behaviour and nutrient intake was significant in both groups (p≤0.001 and p≤0.001, respectively). Meanwhile, nutrient intake and nutritional status were significantly associated only in the employed group (β=−0.186, p=0.001), suggesting that nutrient intake has a significant association with nutritional status among those who are actively working. These findings demonstrated that employment status determined drug use profile and nutrient intake on eating behaviour and nutritional status. Therefore, rehabilitation strategies and nutrition interventions should be tailored to consider individuals' employment conditions.

MGA by education level

In table 7, the MGA based on educational level revealed notable differences in the strength and significance of model pathways across groups. The path from food-related behaviour to nutritional status was not significant across groups (p≥0.006). Similar results were also found that the association between drug use profile, food-related behaviour, nutrient intake and nutritional status was not significant across groups (p≥0.006). Meanwhile, the association between food-related behaviour and nutrient intake was significant across all educational groups, with the strongest association observed in the high school group (β=−0.546, p≤0.001). The association between nutrient intake and nutritional status was significant only in the high school, indicating that the association of nutrient intake on nutritional status is less evident among higher-educated individuals. These findings highlight that the educational levels were associated with the model, reinforcing the need for tailored nutritional and

Table 5 Multigroup analysis by age group

Association	β (<30 years)	β (≥30 years)	P value (<30 years)	P value (≥30 years)
Food-related behaviour→Nutritional status	−0.096	≤0.001	0.215	0.500
Food-related behaviour→Nutrient intake	−0.474	−0.529	**≤0.001***	**≤0.001***
Drug use profile→Food-related behaviour	−0.094	−0.110	0.202	0.037
Drug use profile→Nutrient intake	−0.077	0.049	0.188	0.203
Drug use profile→Nutritional status	−0.092	−0.159	0.160	**0.003***
Nutrient intake→Nutritional status	−0.196	−0.207	0.023	**0.001***

*Significant p value ≤0.006 after multiple testing with Bonferroni correction.

Table 6 Multigroup analysis by employment status

Association	β (No)	β (Yes)	P value (No)	P value (Yes)
Food-related behaviour→Nutritional status	−0.137	−0.013	0.315	0.434
Food-related behaviour→Nutrient intake	−0.586	−0.517	**≤0.001**	**≤0.001**
Drug use profile→Food-related behaviour	−0.336	−0.081	0.150	0.021
Drug use profile→Nutrient intake	−0.141	0.056	0.018	0.134
Drug use profile→Nutritional status	−0.084	−0.143	0.303	**0.002***
Nutrient intake→Nutritional status	−0.345	−0.186	0.032	**0.001***

*Significant p value ≤0.006 after multiple testing with Bonferroni correction.

rehabilitation interventions that account for participants' educational backgrounds.

Importance-performance map analysis

The results of the IPMA showed that nutrient intake had the strongest association on nutritional status, with an importance value of −0.213 and the highest performance of 60.232, followed by the drug use profile with an importance of −0.137 and performance of 41.115, while food-related behaviour had a relatively small association with an importance of 0.064 and the lowest performance of 39.107 (table 4). These findings suggest that nutritional status is more closely determined by the quality of nutrient intake than by other constructs, indicating that improving dietary patterns should be the primary priority strategy. The drug use profile was also negatively associated despite having moderate performance, highlighting the need for careful monitoring of drug therapy to avoid potential impacts on nutritional status. Meanwhile, food-related behaviour, which has a small association but low performance, remains an important area to address as a potential target for long-term intervention.

DISCUSSION

The model used in this study accounts for only 5.6% of the variance in nutritional status, as indicated by the R^2 value for nutritional status. This relatively low percentage of explained variance suggests that numerous other factors—beyond those measured in the study—are likely associated with nutritional status. The variables included in the model, such as food-related behaviours, nutrient intake and drug use profiles, were associated with nutritional status, but these associations do not imply causation. The study design, being cross-sectional, limits the ability to draw causal conclusions and consider the possibility of reverse causation. The model's explanatory power is limited because other clinical, environmental and psychosocial factors, such as stress, physical activity and socioeconomic conditions, were not incorporated into the study analysis. These factors might play a significant role in shaping nutritional outcomes, but were not addressed in the current model. From a clinical application perspective, this suggests that while food-related behaviours and nutrient intake are associated with nutritional status, interventions aimed at improving nutritional status should take a broader, holistic approach. It would be essential to consider additional factors, such as mental health support, social environment and lifestyle changes, in interventions for individuals in CBTaR programmes.[39]

The conceptual framework hypothesised that individuals in recovery may adopt maladaptive eating behaviours as substitutes for psychoactive substances, in particular for

Table 7 Multigroup analysis by education level

Association	β (High school)	β (Middle school)	β (University)	P value (High school)	P value (Middle school)	P value (University)
Food-related behaviour→Nutritional status	−0.120	−0.043	0.328	0.143	0.373	0.045
Food-related behaviour→Nutrient intake	−0.546	−0.504	−0.399	**≤0.001***	**≤0.001***	**0.003***
Drug use profile→Food-related behaviour	−0.009	−0.174	−0.105	0.447	0.022	0.257
Drug use profile→Nutrient intake	0.103	−0.011	0.093	0.071	0.451	0.256
Drug use profile→Nutritional status	−0.170	−0.151	−0.180	0.018	0.037	0.077
Nutrient intake→Nutritional status	−0.265	−0.205	−0.064	**0.001***	0.015	0.314

*Significant p value ≤0.006 after multiple testing with Bonferroni correction.

sugar and carbohydrate intakes, which in turn affect their nutritional well-being.[40] This study revealed that sociodemographic characteristics, such as age, employment status and educational attainment, were significantly associated with nutritional status among CBTaR clients in Kelantan. Younger adults (18–30 years) and unemployed individuals were more likely to be undernourished, consistent with prior research showing that economic instability and limited nutrition literacy exacerbate nutritional vulnerabilities in populations with SUDs.[41–43] These findings highlight the need for integrative rehabilitation approaches that combine drug cessation programmes with vocational training and health education to reduce socioeconomic barriers to recovery.[35]

Food-related behaviours also played an important role among clients with abnormal nutritional status who demonstrated higher levels of FA and emotional eating, suggesting that recovery from substance use may trigger maladaptive compensatory eating patterns.[14 44] This aligned with the neurobiological theory that dysregulated dopaminergic pathways in SUD resemble mechanisms observed in FA. Emotional dysregulation, commonly reported in addiction recovery, may further lead to emotional eating as a coping strategy during withdrawal and stress.[45] Studies among individuals in addiction recovery programmes in Malaysia reported similar findings, where emotional instability determined binge eating and inconsistent food intake.[46 47] Such behaviours can undermine dietary balance and lead to weight fluctuations, reinforcing the bidirectional link between addiction and disordered eating.

Clients with malnutrition had significantly lower intakes of energy, protein and essential micronutrients, including calcium, vitamin C and iron.[2] These deficiencies may impair physiological recovery, immune function and mental health resilience—all of which are essential for sustaining abstinence.[1 48] The role of nutrient intake as a strong predictor or risk factor in the SEM model supports its centrality in determining nutritional status. Protein energy malnutrition, common among individuals with substance dependence, can hinder liver function, muscle regeneration and cognitive stability.[49] Micronutrient deficiencies may contribute to fatigue, depression and weakened immunity.[11] A narrative review study by Mahboub *et al*[10] similarly reported inadequate intake of iron and vitamin C among male drug rehabilitation residents.[10] The centrality of nutrient intake in the model underscores its role not only in physiological recovery but also in shaping eating behavioursas inadequate intake was associated with a greater risk of maladaptive dietary patterns. These findings highlight the importance of structured dietary interventions within rehabilitation centres.[44 50] Tailoring CBTaR programmes to include nutrition-focused modules may enhance treatment efficacy by addressing the biological and behavioural aspects of recovery. Integrating nutritionists into multidisciplinary teams and providing practical food literacy workshops could address these gaps and lead to more sustainable actions.

Drug use profile—including age of first use, number and type of substances and duration of use—was significantly associated with both food-related behaviours and nutritional status, supporting earlier findings that substance use disrupts appetite regulation, taste perception and metabolism.[51 52] However, its association with dietary quality seemed to be a secondary determinant, likely determined by behavioural factors. Notably, MGA showed more potent effects of drug use on nutritional outcomes among clients aged ≥30 years and those employed, possibly reflecting cumulative physiological burden and lifestyle stressors. These subgroup differences highlighted the need for tailored nutrition strategies that consider demographic vulnerabilities and cumulative exposure to substances.[2 53]

Contrary to the initial results, food-related behaviours did not exert an association with nutritional status across the whole sample. This suggests that in clinical populations with SUD, the physiological consequences of drug use may outweigh the behavioural determinants of nutrition.[40] This is further reinforced by the minimal effect size and low importance value in the IPMA results. Thus, behavioural modifications alone may be insufficient to restore and improve nutritional status without concurrent improvements in nutrient intake and medical care.[54] Interestingly, this association was significant only among higher-educated clients, suggesting a moderating role of cognitive and food literacy in translating behaviours into anthropometric outcomes.[55] This suggests the presence of cognitive associations, where individuals with higher education may translate behavioural patterns more correlated to physical health outcomes. Although the explained variance in nutritional status was modest, the SEM still provided novel insights into the interplay between sociodemographics, drug use, dietary behaviours and nutrient intake.[15 16]

The limitations of the present study are, as follows: (1) the cross-sectional design precluding causal inference; (2) the poor explanatory power of the model; (3) potential selection bias from the CBTaR setting; (4) self-report bias in dietary data; (5) residual confounding from unmeasured variables and (6) limited generalisability beyond Malaysian CBTaR clients in the State of Kelantan. Future studies should incorporate additional determinants such as mental health, stress, physical activity and food environment, and adopt longitudinal designs to strengthen causal inference and inform targeted interventions. Additionally, providing individualised behavioural recommendations should be considered, as all intervention research demonstrates their effectiveness. This suggests that additional variables, such as mental health status, stress level, physical activity, gut microbiota and food environment, may need to be considered to enhance the model's explanatory power. Future research should employ longitudinal or experimental designs to track behavioural and nutritional shifts over time. Integrating qualitative interviews may also help uncover nuanced motivations and barriers related to food choices during addiction recovery.

CONCLUSION

This study demonstrated that nutrient intake showed the strongest association with nutritional status among adults in CBTaR programmes in Malaysia. While younger age, unemployment and lower education were associated with poorer nutritional outcomes, inadequate energy and micronutrient intake—particularly calcium, vitamin C and iron—emerged as the most critical determinant. FA and emotional eating are further associated with poor diet quality, although their association with nutritional status was limited. These findings underscore the importance of implementing future health promotion recommendations in SUD treatment centres in Kelantan, integrating nutrition counselling, food literacy education and behavioural support into rehabilitation programmes to enhance recovery outcomes and long-term health. Future studies should adopt longitudinal designs capable of examining temporal relationships and potential causal mechanisms.

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