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# Effect of food insecurity on hazardous alcohol consumption and psychological well-being among people with tuberculosis in Kampala, Uganda

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ABSTRACT

*Rationale:* Food insecurity (FI), hazardous alcohol consumption (HAC), and poor mental health are common among people with tuberculosis (TB), yet empirical evidence on their interrelationships remains limited.
*Objective:* We evaluated the effect of FI on HAC and psychological well-being among people with pulmonary TB in Kampala, Uganda.
*Methods:* We collected data across five TB clinics and constructed a quasi-experimental design. FI was the exposure, measured using the FI Experience Scale (FIES). FIES scores range between 0 and 8, and individuals were classified as food insecure if they scored $\geq$ 4. The primary outcome was HAC, assessed using the Alcohol Use Disorders Identification Test (AUDIT) tool. Participants with AUDIT scores $\geq$ 16, indicating high-risk drinking or possible alcohol dependence, were categorized as having HAC. The secondary outcome was psychological well-being measured using the World Health Organization's Five Well-Being Index, with a total score of <15 indicating poor psychological well-being. We used doubly robust estimation to report causal risk ratios (RR) and 95 % confidence intervals (CI).
*Results:* Of 818 participants, 475 (58.1 %) were from food-insecure households, 153 (18.7 %) had HAC, and 316 (38.6 %) had poor psychological well-being. FI was independently associated with HAC (RR 1.43, 95 % CI: 1.21–1.69), but not poor psychological well-being (RR 1.06, 95 % CI: 0.81–1.37).
*Conclusion:* FI is associated with a higher likelihood of HAC but not psychological well-being among people with TB in Kampala, Uganda. Given their high prevalence, there is a need to address food insecurity, HAC, and poor psychological well-being within TB control programs.

## 1. Introduction

Food insecurity encompasses a lack of availability or access to food of sufficient quality and quantity [1], and is increasingly recognized as a social determinant of health [2]. Food insecurity is prevalent among people with tuberculosis (TB) [3], and studies have linked it to a higher risk of infectious and non-infectious diseases. Food insecurity is associated with an increased likelihood of TB disease [4], diabetes mellitus [5], and major depression [6]. A systematic review showed that a strong bidirectional relationship exists between food insecurity and TB. Food insecurity increases vulnerability to TB by weakening the immune system through undernutrition, which raises the risk of TB infection and disease progression. It also contributes to poor treatment adherence and worse TB treatment outcomes. In turn, TB exacerbates food insecurity by reducing income and increasing healthcare costs [1].

Food insecurity has also been linked to mental health outcomes. It has been associated with a nearly five-fold increase in the odds of depression among people with TB [7]. In Botswana, a cross-sectional study found that food-insecure newly diagnosed individuals with TB were more likely to experience depression and anxiety compared to their food-secure counterparts [8]. Yet poor mental health is a known risk factor for TB disease [9], suggesting a potential syndemic interaction between food insecurity, mental health, and TB. In addition to mental health outcomes, food insecurity may be associated with psychological

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well-being, but data on this subject are limited. For instance, food insecurity may contribute to maladaptive coping behaviours such as harmful alcohol use among people with TB, and existing evidence suggests a possible connection [10]. In Ethiopia, food insecurity was shown to be associated with substance use—alcohol and drug use—among people with TB [11]. In general, very few studies have examined this relationship. Yet these studies did not directly assess the causal relationship between food insecurity and harmful alcohol consumption.

Although there is limited evidence to link food insecurity and harmful alcohol use, the plausibility of the association may be through mechanisms of stress and maladaptive coping. We hypothesize that unreliable access to food may lead to psychological strain, triggering alcohol abuse to mask emotional distress. Over time, the alcohol use may escalate to harmful consumption, complicating TB care and recovery. This gap in evidence constrains the development of holistic interventions that address both the clinical and psychosocial needs of people with TB.

To address the gap, we evaluated the effect of food insecurity on both hazardous alcohol consumption and psychological well-being among people with drug-susceptible pulmonary TB across five health facilities in Kampala, Uganda. The findings will inform integrated models for TB care that incorporate routine screening for alcohol use disorder and targeted interventions for food insecurity and mental health, particularly in resource-limited, high-TB-burden settings such as Uganda.

## 2. Methods

### 2.1. Data source

We analyzed data from a cross-sectional study that investigated the prevalence of malnutrition and its associated factors across five public health facilities in Kampala, the capital city of Uganda [12]. The sites have been described in past studies [13,14] and provide TB care per the national guidelines. From these sites, 818 (99.5 % response rate) individuals with drug-susceptible pulmonary TB were enrolled in the cross-sectional study. The sample size was powered to detect a 10 % absolute difference in malnutrition prevalence between people with TB who smoke and those who do not, assuming a 53.6 % prevalence among smokers, 80 % power, and a two-sided alpha of 0.05 using a Chi-square test. The participants had either a clinically diagnosed or bacteriologically confirmed pulmonary TB, and were treated with the standard six-month anti-TB regimen: rifampicin (R), isoniazid (H), pyrazinamide (Z), and ethambutol (E) for two months and then rifampicin and isoniazid for four months (2RHZE/4RH).

Data collected included a range of factors: personal factors such as age, sex, marital status, educational level, employment status, and socioeconomic status (SES); clinical factors such as TB treatment history, human immunodeficiency virus (HIV) serostatus, anti-TB regimen, body mass index (BMI); psychosocial factors like psychological well-being and TB-related stigma; behavioral factors, namely smoking, alcohol consumption, household violence; and dietary factors such as dietary diversity, feeding problems, and food insecurity.

Alcohol consumption was assessed using the Alcohol Use Disorders Identification Test (AUDIT) tool, with scores ranging from 0 to 40. Alcohol consumption score of 0–7 indicated low risk, 8-15 increasing risk, 16–19 high risk, and ≥20 possible dependence. Psychological well-being was measured using the World Health Organization (WHO) Five Well-Being Index over the past two weeks. The overall score was 0–20, with a total score of ≥15 suggesting good psychological well-being, and below 15 indicating poor psychological well-being.

Food insecurity was measured using the Food Insecurity Experience Scale (FIES), the global reference scale developed by the Food and Agriculture Organization (FAO). The FIES questionnaire consisted of nine items, each scored 1 for a positive response and 0 for a negative response. Total scores ranged from 0 to 8, with 0–3 indicating no or only mild food insecurity, 4–6 moderate food insecurity, and 7–8 severe food insecurity. For this study, participants with FIES scores of 0–3 were classified as food secure, while those who scored 4–8 were considered food insecure.

### 2.2. Study design and population

We used a quasi-experimental study design since food insecurity, as the primary exposure, cannot be randomly assigned to the participants. Instead, using existing observational data, participants were categorized as food secure or food insecure. The lack of randomization introduces selection bias and confounds the exposure and outcome relationship. To address the limitations, we employed doubly robust estimation, a causal inference method that combines both the inverse probability of treatment weighting (IPTW) using propensity scores to balance observed covariates between the exposed and unexposed groups with an outcome regression model [15]. This approach ensures an unbiased estimation of the exposure-outcome relationship if at least one model is correctly specified, but not necessarily both. The approach improves causal inference by emulating a randomized trial since systematic differences between the groups are removed. Overall, the approach strengthens the validity of cause-effect estimates.

### 2.3. Variables and measurements: Exposure and outcomes

The exposure was food security, with individuals categorized as food-insecure (exposed) or food-secure (unexposed) based on established cut-offs on the FIES scale. The primary outcome was hazardous alcohol consumption based on AUDIT scores. Individuals with scores of 16 or higher comprised the hazardous alcohol consumption group, while those with scores below 16 formed the non-hazardous alcohol consumption category. This threshold reflects a focus on more severe patterns of alcohol use than typically captured by standard lower cut-offs, allowing the identification of individuals with more severe or clinically significant alcohol-related risk. The secondary outcome was psychological well-being, dichotomized into good or poor well-being based on a validated cut-off on the WHO Five Well-Being Index. The reference category for the outcome was good psychological well-being.

The covariates included age, sex, marital status, educational level, employment status, TB treatment history, type of anti-TB regimen, household violence, dietary diversity, TB-related stigma, alcohol consumption, cigarette smoking, chronic disease, feeding problems, HIV serostatus, and health facility level.

### 2.4. Statistical analysis

Analysis was performed in R version 4.0.2. We derived SES using Multiple Correspondence Analysis of 15 binary household asset variables and categorized participants into low, moderate, and high SES based on normalized tertile scores. In descriptive analysis, categorical variables like sex were summarized using frequencies and percentages. To evaluate the effect of food insecurity on psychological well-being, we applied doubly robust estimation using augmented inverse probability treatment weighting. This approach combined both a propensity score based exposure model and an outcome regression model, ensuring unbiased effect estimation if either model was correctly specified, but not both [16]. The covariates were selected based on prior studies and expert knowledge, ensuring they were pre-exposure variables to avoid adjusting for post-treatment confounders. The exposure model was a logistic regression estimating the probability of experiencing food insecurity as a function of the relevant covariates. From the exposure model, propensity scores were predicted, and inverse probability of treatment weights (IPTW) were used for weighting the groups based on the propensity scores. The exposed group was weighted using the inverse of the propensity scores (1/propensity score) while the unexposed group was weighted using 1/(1-propensity score). This created a pseudo-population where the covariates were balanced between the

groups. Covariate balance was assessed using absolute standardized mean differences (SMD), with values ≤ 0.1 indicating balance. Additionally, propensity score histograms were plotted and visually inspected to assess the overlap between groups. A distributional similarity in propensity scores confirmed the balance. Conversely, the outcome model was a generalized estimating equation (GEE) for the outcome and covariates within each exposure group—we fit two outcome regression models. The GEE employed an exchangeable correlation structure and a log link function with the family as a Poisson distribution, adjusted for clustering at the health facility level. Counterfactual outcomes were predicted separately for the exposed and unexposed groups. We then combined the IPTW-weighted exposure model and the covariate-adjusted outcome model to compute the average causal effect (ACE) for each exposure group based on the potential outcomes framework. Finally, the effect of food insecurity on the primary and secondary outcomes was reported as the causal risk ratio (RR) and 95 % CI. The causal RR is a relative measure of the ACE.

## 3. Human subjects

Ethical approval was obtained from the Clarke International University Research Ethics Committee (CIU-REC, reference number CLARKE-2024-1100, dated July 23, 2024). Administrative clearance was provided by the Kampala Capital City Authority Directorate of Public Health and Environment (reference number DPHE/KCCA/1301/01, dated Aug 13, 2024). Participants provided written informed consent.

### 3.1. Reporting of findings

Findings are reported following the improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: The TREND statement.

## 4. Results

### 4.1. Participant characteristics

We studied 818 participants (Table 1), and they were mostly aged ≥ 25 years (62.6 %) and slightly more than half were males (52.9 %). Also, 60.4 % had reached secondary school education or higher, 68.7 % were married, and they were equally distributed across the three SES strata. About 43.4 % fell in the increasing-risk alcohol consumption category, 13.3 % were cigarette smokers, and 53.2 % were newly diagnosed with pulmonary TB.

**Table 1**
Participant characteristics.

| Variables | Level | Overall (n = 818) |
|---|---|---|
| Health facility | Kisenyi Health Centre IV | 202 (24.7) |
| | Kawaala HC III | 180 (22.0) |
| | Komamboga HC III | 180 (22.0) |
| | Kitebi HC III | 180 (22.0) |
| | Kisugu HC III | 76 (9.3) |
| Age categories (years) | <25 | 306 (37.4) |
| | ≥25 years | 512 (62.6) |
| Sex | Male | 433 (52.9) |
| | Female | 385 (47.1) |
| Educational level | Primary or None | 324 (39.6) |
| | Secondary and above | 494 (60.4) |
| Marital status | Married | 562 (68.7) |
| | Not married | 256 (31.3) |
| SES | Low | 283 (34.6) |
| | Moderate | 280 (34.2) |
| | High | 255 (31.2) |
| Employment status | None | 312 (38.1) |
| | Small-scale business | 506 (61.9) |
| Cigarette smoker | Yes | 109 (13.3) |
| | No | 709 (86.7) |
| TB treatment history | New | 435 (53.2) |
| | Previously treated | 383 (46.8) |

### 4.2. Covariate balance before and after IPTW

Table 2 presents the covariate balance before and after applying IPTW, assessed using SMDs. Before IPTW, substantial imbalance was observed across several covariates, including study sites (health facilities), employment status, and SES, with SMDs exceeding the conventional threshold of 0.1. Age categories (SMD = 0.066) and level of education (SMD = 0.083) demonstrated marginal imbalance, suggesting near but not complete balance before weighting. After IPTW, all SMDs were < 0.1, suggesting that excellent covariate balance across the exposure groups had been achieved.

### 4.3. Effect of food insecurity on hazardous alcohol consumption and psychological well-being

Table 3 presents differences in hazardous alcohol consumption and psychological well-being by food insecurity status. Additionally, the table shows the effect of food insecurity on hazardous alcohol consumption and psychological well-being. Of the 818 participants, 153 (18.7 %) had hazardous alcohol consumption, while 316 (38.6 %) had poor psychological well-being.

In Table 3, the prevalence of hazardous alcohol consumption was significantly higher among food-insecure individuals (21.3 %) compared to those who were food-secure (15.2 %) ($P = 0.034$). Additionally, a slightly lower proportion of food-insecure individuals had good psychological well-being compared to food-secure individuals: 59.6 % vs. 63.8 %, respectively ($P = 0.244$). The estimated causal RR for food insecurity on hazardous alcohol consumption was 1.43 (95 % CI: 1.21–1.69), and that on poor psychological well-being was 1.06 (95 % CI: 0.81–1.37).

**Table 2**
Covariate balance before and after IPTW.

| Covariate balance before IPTW | Exposed | | Unexposed | | SMD |
|---|---|---|---|---|---|
| Variables | Mean | SD | Mean | SD | |
| Health facility | 2.34 | 1.25 | 2.85 | 1.30 | −0.39 |
| Age categories | 1.65 | 0.48 | 1.62 | 0.49 | 0.07 |
| Sex | 1.47 | 0.50 | 1.47 | 0.50 | −0.01 |
| Level of education | 1.63 | 0.48 | 1.59 | 0.49 | 0.08 |
| Employment status | 1.66 | 0.47 | 1.60 | 0.49 | 0.12 |
| Socioeconomic status | 1.86 | 0.79 | 2.01 | 0.82 | −0.19 |
| Household violence | 1.60 | 0.49 | 1.62 | 0.49 | −0.05 |
| Cigarette smoker | 1.34 | 0.48 | 1.36 | 0.48 | −0.04 |
| History of TB treatment | 1.72 | 0.45 | 1.74 | 0.44 | −0.05 |
| Chronic disease | 1.86 | 0.35 | 1.87 | 0.34 | −0.03 |
| Feeding problems | 1.46 | 0.50 | 1.47 | 0.50 | −0.02 |
| **Covariate balance after IPTW** | | | | | |
| **Variables** | **Mean** | **SD** | **Mean** | **SD** | **SMD** |
| Health facility | 2.36 | 1.24 | 2.36 | 1.25 | <0.01 |
| Age categories | 1.65 | 0.48 | 1.65 | 0.48 | <0.01 |
| Sex | 1.47 | 0.50 | 1.46 | 0.50 | 0.01 |
| Level of education | 1.63 | 0.48 | 1.63 | 0.48 | <0.01 |
| Employment status | 1.66 | 0.48 | 1.65 | 0.48 | <0.01 |
| Socioeconomic status | 1.87 | 0.79 | 1.86 | 0.80 | 0.01 |
| Household violence | 1.60 | 0.49 | 1.59 | 0.49 | 0.01 |
| Cigarette smoker | 1.35 | 0.48 | 1.34 | 0.48 | 0.01 |
| History of TB treatment | 1.72 | 0.45 | 1.72 | 0.45 | −0.01 |
| Chronic disease | 1.86 | 0.35 | 1.86 | 0.35 | 0.01 |
| Feeding problems | 1.46 | 0.50 | 1.46 | 0.50 | 0.01 |

Note: SMD < 0.1 suggests a balanced covariate; SD denotes the standard deviation.

**Table 3**
Effect of food insecurity on hazardous alcohol consumption and psychological well-being.

| Level | Food insecurity | | P-value | Causal effect of food insecurity |
|---|---|---|---|---|
| | No (n = 343) | Yes (n = 475) | | |
| **Hazardous alcohol consumption** | | | | RR (95 % CI) |
| No | 291 (84.8) | 374 (78.7) | 0.034 | 1 |
| Yes | 52 (15.2) | 101 (21.3) | | 1.43*** (1.21–1.69) |
| **Psychological wellbeing** | | | | RR (95 % CI) |
| Good | 219 (63.8) | 283 (59.6) | 0.244 | 1 |
| Poor | 124 (36.2) | 192 (40.4) | | 1.06 (0.81–1.37) |

**Note:** RR: Causal risk ratio are exponentiated coefficients; 95 % confidence intervals are in brackets; Statistical significance codes at 5 % level: *** $p < 0.001$, ** $p < 0.01$, p<*0.05.

## 5. Discussion

In this study, we evaluated the effect of food insecurity on hazardous alcohol consumption and psychological well-being among people with drug-susceptible pulmonary TB across five health facilities in Kampala, Uganda. We found that food insecurity was significantly associated with a higher likelihood of hazardous alcohol consumption. However, its association with psychological well-being was only modest and not statistically significant.

Our finding that food insecurity is associated with a higher likelihood of hazardous alcohol consumption aligns with our hypothesis and theory of change. This relationship may operate through multiple pathways. For example, food insecurity can cause chronic stress, prompting some people with TB to use alcohol as a coping mechanism for emotional distress [17]. Another possible explanation for our finding is that alcohol is widely consumed in the general population. Uganda has one of the highest alcohol consumption rates in Africa, with an annual per capita intake of 12.2 L—nearly double the regional average of 6.3 L [18]. In this context, alcohol is widely available, and social norms often encourage sharing and gifting alcohol among peers. As a result, easy access to alcohol, coupled with psychosocial stressors, may predispose people with TB to hazardous alcohol use as a coping mechanism. Moreover, many TB programs lack routine alcohol screening and intervention services, potentially delaying the identification and support of individuals with harmful alcohol use. Therefore, a combination of factors increases the likelihood of hazardous alcohol consumption among people with TB who experience food insecurity.

Relatedly, A study among people with HIV, regardless of TB status, found that food insecurity was associated with a higher likelihood of hazardous alcohol consumption, although the association was not statistically significant [19]. Compared to our study, this previous research involved a smaller sample size and likely included fewer individuals with TB. Nevertheless, it provides contextual evidence supporting a potential link between food insecurity and hazardous alcohol use. Two South African studies conducted in non-TB populations also reported a link between food insecurity and hazardous alcohol consumption [20,21].

Although food insecurity has only a modest and statistically nonsignificant association with the likelihood of poor psychological well-being, the directionality of the relationship holds substantial clinical and public health significance. This is because of the potential implications of food insecurity for mental health interventions in TB care. The probable increase in the risk of poor psychological well-being, although not significant, may be explained by stress associated with uncertainty about food availability. People with TB who experience food insecurity are more likely to report psychological health challenges, such as depression and anxiety, associated with food search. We did not collect data on depression and anxiety, and hence cannot verify these findings. However, evidence from a systematic review and *meta*-analysis showed that food insecurity increases the risk of depression by nearly 1.5-fold and stress by 34 %, but the effect on anxiety was not significant [22]. The observed trend toward increased risk of poor psychological well-being warrants further investigation, perhaps using large sample sizes from longitudinal studies. This is because food insecurity has the potential to contribute to psychological distress, which then suppresses appetite and leads to energy imbalance and undernutrition. Given that undernutrition reduces sputum smear conversion and treatment success rates among people with pulmonary TB [23], the need to tackle food insecurity cannot be overemphasized.

### 5.1. Implications of findings

Our finding has important implications for TB program design. It highlights the need for integrated public health strategies that simultaneously address food insecurity, alcohol consumption, and psychological well-being. Effective TB care should integrate alcohol screening and treatment interventions, access to nutritious food, and mental health support for individuals experiencing food scarcity. This will go a long way in improving the nutritional status of people with TB, including treatment outcomes and quality of life. Ultimately, this may contribute to the 2035 WHO End TB goals—reducing TB deaths by 95 %, reducing TB incidence by 90 %, and reducing catastrophic costs incurred by people with TB and affected families to 0 % [24].

## 6. Study strengths and limitations

This study has some important strengths. Few studies have explored the causal ralationship between food insecurity, alcohol consumption, and psychological well-being. Our findings contribute to this evolving evidence base. We applied a doubly robust estimation approach—a rigorous causal inference method that yields consistent results provided only one of the models is correctly specified, but not necessarily both [15]. The large sample size enhanced the precision of the causal estimates. Also, the use of robust analytical methods and standardized instruments for key measures—food insecurity, psychological well-being, and alcohol use—strengthened the internal validity. However, there are some limitations. The cross-sectional design limits the interpretation of the causal inference, as temporality cannot be fully established. Reverse associations between food insecurity and hazardous alcohol consumption or psychological well-being are possible. Nevertheless, food insecurity is a biologically and socially plausible determinant of alcohol consumption and psychological well-being and may also precede both outcomes. Residual confounding may persist due to unmeasured variables such as dietary behaviors, food types and quantities, religion, and medication side effects, among others. Psychological well-being was assessed using the WHO Five Well-Being Index, and alcohol consumption was measured with the AUDIT tool. Although both tools are widely used and validated for screening, the self-reported nature of the data introduces potential recall and reporting biases, which may limit the precision of estimated associations and preclude causal inference. Also, the screening might have led to an overestimation because a single tool was used. A sequential or parallel use of a diagnostic tool would have improved the accuracy of the measure. We applied a more stringent definition of hazardous alcohol consumption, targeting individuals at greater clinical risk due to more severe patterns of alcohol use. The study was conducted in a predominantly urban setting, so the findings may not fully generalize to rural populations, where food access, dietary patterns, and socioeconomic conditions differ. Future research should adopt longitudinal study designs and include diverse geographic settings to better clarify the complex relationships between food insecurity and psychological health among people with TB. There are also

methodological limitations that should be considered. We used doubly robust estimation to reduce confounding, but it cannot fully eliminate bias from unmeasured confounders. IPTW can be sensitive to propensity scores close to 0 or 1, potentially producing unstable weights [15]. Alternative weighting methods, such as standardized mortality ratio weighting or weighted odds ratios, have been recommended, but they also have limitations related to assumptions, interpretability, and sensitivity to model specification [25–27].

## 7. Conclusion and recommendations

Food insecurity has a strong and significant association with a higher likelihood of hazardous alcohol consumption, but it was not significantly related to poor psychological well-being among people with TB in Kampala, Uganda. Nevertheless, the direction and magnitude of the observed association with poor psychological well-being highlight its clinical and public health relevance. This finding suggests a potential need to address food insecurity as a risk factor for hazardous alcohol consumption and a possible influencer of mental well-being, across TB programs as outlined in Pillar 2 of the WHO Start TB Strategy. Future research should design longitudinal studies to examine causal relationships and inform the development of sustainable, context-specific strategies to reduce the psychological burden of food insecurity.

## Ethical statement

Ethical approval was obtained from the Clarke International University Research Ethics Committee (CIU-REC, reference number CLARKE-2024-1100, dated July 23, 2024). Administrative clearance was provided by the Kampala Capital City Authority Directorate of Public Health and Environment (reference number DPHE/KCCA/1301/01, dated Aug 13, 2024). Participants provided written informed consent.

## CRediT authorship contribution statement

**Jonathan Izudi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Saidi Appeli:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Francis Bajunirwe:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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## Declaration of competing interest

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

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## References

[1] Balinda IG, Sugrue DD, Ivers LC. More than malnutrition: a review of the relationship between food insecurity and tuberculosis. Open Forum Infect Dis 2019;6(4):ofz102. https://doi.org/10.1093/ofid/ofz102. Epub 2019/04/06; PubMed PMID: 30949541; PubMed Central PMCID: PMCPMC6441779.
[2] Campanera M, Gasull M, Gracia-Arnaiz M. Food security as a social determinant of health: tackling inequalities in primary health care in Spain. Health Hum Rights 2023;25(1):9–21. Epub 2023/06/0PubMed PMID: 37266309; PubMed Central PMCID: PMCPMC9973507.
[3] Ayiraveetil R, Sarkar S, Chinnakali P, Jeyashree K, Vijayageetha M, Thekkur P, et al. Household food insecurity among patients with pulmonary tuberculosis and its associated factors in South India: a cross-sectional analysis. BMJ Open 2020;10(2). https://doi.org/10.1136/bmjopen-2019-033798. Epub 2020/03/0; PubMed PMID: 32114470; PubMed Central PMCID: PMCPMC7050349.
[4] Berhe G, Enquselassie F, Aseffa A. Assessment of risk factors for development of active pulmonary tuberculosis in northern part of Ethiopia: a matched case control study. Ethiop Med J 2013;51(4):227–37. Epub 2014/04/05. PubMed PMID: 24696973.
[5] Silverman J, Krieger J, Kiefer M, Hebert P, Robinson J, Nelson K. The relationship between food insecurity and depression, diabetes distress and medication adherence among low-income patients with poorly-controlled diabetes. J Gen Intern Med 2015;30(10):1476–80. https://doi.org/10.1007/s11606-015-3351-1. Epub 2015/04/29; PubMed PMID: 25917659; PubMed Central PMCID: PMCPMC4579205.
[6] Tomita A, Ramlall S, Naidu T, Mthembu SS, Padayatchi N, Burns JK. Major depression and household food insecurity among individuals with multidrug-resistant tuberculosis (MDR-TB) in South Africa. Soc Psychiatry Psychiatr Epidemiol 2019;54(3):387–93. https://doi.org/10.1007/s00127-019-01669-y. Epub 2019/02/14; PubMed PMID: 30758540; PubMed Central PMCID: PMCPMC6439252.
[7] Soboka M, Tesfaye M, Adorjan K, Krahl W, Tesfaye E, Yitayih Y, et al. Effect of food insecurity on mental health of patients with tuberculosis in Southwest Ethiopia: a prospective cohort study. BMJ Open 2021;11(9):e045434. https://doi.org/10.1136/bmjopen-2020-045434. Epub 2021/10/01; PubMed PMID: 34588229; PubMed Central PMCID: PMCPMC8479992.
[8] Wang Q, Dima M, Ho-Foster A, Molebatsi K, Modongo C, Zetola NM, et al. The association of household food insecurity and HIV infection with common mental disorders among newly diagnosed tuberculosis patients in Botswana. Public Health Nutr 2022;25(4):913–21. https://doi.org/10.1017/s1368980020004139. Epub 2020/10/20; PubMed PMID: 33070794; PubMed Central PMCID: PMCPMC8053731.
[9] Sweetland AC, Kritski A, Oquendo MA, Sublette ME, Norcini Pala A, Silva LRB, et al. Addressing the tuberculosis-depression syndemic to end the tuberculosis epidemic. Int J Tuberculos Lung Dis : Off J Int Union Against Tuberculos Lung Dis 2017;21(8):852–61. https://doi.org/10.5588/ijtld.16.0584. Epub 2017/08/09; PubMed PMID: 28786792; PubMed Central PMCID: PMCPMC5759333.
[10] Weiangkham D, Umnuaypornlert A, Saokaew S, Prommongkol S, Ponmark J. Effect of alcohol consumption on relapse outcomes among tuberculosis patients: a systematic review and meta-analysis. Front Public Health 2022;10:962809. https://doi.org/10.3389/fpubh.2022.962809. Epub 2022/11/22; PubMed PMID: 36408038; PubMed Central PMCID: PMCPMC9669980.
[11] Abdulla JH, Gebremichael B, Maruta MB, Yuye I, Mohammed A, Debella A, et al. Nearly one out of every five adult TB patients suffered from food insecurity in Grawa District, Eastern Ethiopia: a multicenter facility-based cross-sectional study. Front Public Health 2023;11:1177618. https://doi.org/10.3389/fpubh.2023.1177618. Epub 2023/06/26; PubMed PMID: 37361149; PubMed Central PMCID: PMCPMC10288987.
[12] Kyazze S, Appeli S, Izudi J. Determinants of underweight and overweight/obesity among people with tuberculosis in Kampala, Uganda: a cross-sectional study. medRxiv. 2025:2025.04.30.25326716. doi: 10.1101/2025.04.30.25326716.
[13] Izudi J, Bajunirwe F, Cattamanchi A. Increase in rifampicin resistance among people previously treated for TB. Public Health Action 2023;13(1):4–6. https://doi.org/10.5588/pha.22.0047. Epub 2023/05/08; PubMed PMID: 37152209; PubMed Central PMCID: PMCPMC10162363.
[14] Izudi J, Okello G, Bajunirwe F. Low treatment success rate among previously treated persons with drug-susceptible pulmonary tuberculosis in Kampala, Uganda. J Clin Tuberculos Other Mycobacter Dis 2023;32:100375. https://doi.org/10.1016/j.jctube.2023.100375. Epub 2023/05/22; PubMed PMID: 37214160; PubMed Central PMCID: PMCPMC10199253.
[15] Izudi J, Cattamanchi A, Bajunirwe F. Causal inference methodologies to assess the effect of missed clinic visits on treatment success rate among people with tuberculosis in rural Uganda. BMC Med Res Method 2025;25(1):104. https://doi.org/10.1186/s12874-025-02553-x. Epub 2025/04/18; PubMed PMID: 40247175; PubMed Central PMCID: PMCPMC12004605.
[16] Funk MJ, Westreich D, Wiesen C, Stürmer T, Brookhart MA, Davidian M. Doubly robust estimation of causal effects. Am J Epidemiol 2011;173(7):761–7. https://doi.org/10.1093/aje/kwq439. Epub 2011/03/10; PubMed PMID: 21385832; PubMed Central PMCID: PMCPMC3070495.
[17] Weiser SD, Young SL, Cohen CR, Kushel MB, Tsai AC, Tien PC, et al. Conceptual framework for understanding the bidirectional links between food insecurity and HIV/AIDS. Am J Clin Nutr 2011;94(6):1729s–39s. https://doi.org/10.3945/ajcn.111.012070. Epub 2011/11/18; PubMed PMID: 22089434; PubMed Central PMCID: PMCPMC3226026.
[18] Izudi J, Nasuuna EM, Appeli S, Bajunirwe F. Effect of COVID-19 pandemic on smoking, alcohol consumption, and substance use in persons aged 15 years and

older in Uganda. Sci Rep 2025;15(1):14817. https://doi.org/10.1038/s41598-025-99861-5. Epub 2025/04/29; PubMed PMID: 40295868; PubMed Central PMCID: PMCPMC12037852.

[19] Raja A, Heeren TC, Walley AY, Winter MR, Mesic A, Saitz R. Food insecurity and substance use in people with HIV infection and substance use disorder. Subst Abus 2022;43(1):104–12. https://doi.org/10.1080/08897077.2020.1748164. Epub 2020/05/07; PubMed PMID: 32374225; PubMed Central PMCID: PMCPMC7644575.

[20] Dewing S, Tomlinson M, le Roux IM, Chopra M, Tsai AC. Food insecurity and its association with co-occurring postnatal depression, hazardous drinking, and suicidality among women in peri-urban South Africa. J Affect Disord 2013;150(2):460–5. https://doi.org/10.1016/j.jad.2013.04.040. Epub 2013/05/28; PubMed PMID: 23707034; PubMed Central PMCID: PMCPMC3762324.

[21] Kalichman SC, Simbayi LC, Kagee A, Toefy Y, Jooste S, Cain D, et al. Associations of poverty, substance use, and HIV transmission risk behaviors in three South African communities. Soc Sci Med 2006;62(7):1641–9. https://doi.org/10.1016/j.socscimed.2005.08.021. Epub 2005/10/11; PubMed PMID: 16213078.

[22] Pourmotabbed A, Moradi S, Babaei A, Ghavami A, Mohammadi H, Jalili C, et al. Food insecurity and mental health: a systematic review and meta-analysis. Public Health Nutr 2020;23(10):1778–90. https://doi.org/10.1017/s136898001900435x. Epub 2020/03/17; PubMed PMID: 32174292; PubMed Central PMCID: PMCPMC10200655.

[23] Izudi J, Bajunirwe F, Cattamanchi A. Negative effects of undernutrition on sputum smear conversion and treatment success among retreatment cases in Uganda: a quasi-experimental study. J Clin Tuberculos Other Mycobacter Dis 2024;35:100422. https://doi.org/10.1016/j.jctube.2024.100422. Epub 2024/03/04; PubMed PMID: 38434999; PubMed Central PMCID: PMCPMC10907175.

[24] Floyd K, Glaziou P, Houben R, Sumner T, White RG, Raviglione M. Global tuberculosis targets and milestones set for 2016–2035: definition and rationale. Int J Tuberculos Lung Dis : Off J Int Union Against Tuberculos Lung Dis 2018;22(7):723–30. https://doi.org/10.5588/ijtld.17.0835. Epub 2018/06/20; PubMed PMID: 29914597; PubMed Central PMCID: PMCPMC6005124.

[25] Ali MS, Groenwold RH, Klungel OH. Best (but oft-forgotten) practices: propensity score methods in clinical nutrition research. Am J Clin Nutr 2016;104(2):247–58. https://doi.org/10.3945/ajcn.115.125914. Epub 2016/07/15; PubMed PMID: 27413128.

[26] Brookhart MA, Wyss R, Layton JB, Stürmer T. Propensity score methods for confounding control in nonexperimental research. Circ Cardiovasc Qual Outcomes 2013;6(5):604–11. https://doi.org/10.1161/circoutcomes.113.000359. Epub 2013/09/12; PubMed PMID: 24021692; PubMed Central PMCID: PMCPMC4032088.

[27] Heagerty PJ, Zeger SL. Multivariate continuation ratio models: connections and caveats. Biometrics 2000;56(3):719–32. https://doi.org/10.1111/j.0006-341x.2000.00719.x. Epub 2000/09/14; PubMed PMID: 10985208.