A roadmap for integrating nutritional assessment, counselling, and support into the care of people with tuberculosis

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Undernutrition—the leading risk factor for tuberculosis worldwide—is associated with impaired immunity, more extensive disease, delayed sputum conversion, and worse treatment outcomes, including mortality. In this Health Policy, we propose a comprehensive roadmap for integrating nutritional assessment, counselling, and support into tuberculosis treatment as part of person-centred care. At treatment initiation, we recommend standard nutritional assessment with anthropometric measurements and haemoglobin estimation, in addition to macronutrient and micronutrient support alongside nutritional counselling. Weight should be monitored during treatment and lack of weight gain at the end of the intensive phase should prompt an investigation of causes, such as food insecurity, poor treatment adherence, malabsorption, uncontrolled diabetes, or drug resistance. At the end of treatment, we recommend reassessing anthropometric measures to assess nutritional recovery. People with tuberculosis who remain underweight should receive close follow-up to detect early relapse. We call for annual reporting of nutritional metrics by WHO, explicit inclusion of nutritional assessment and care in national strategic plans, domestic or international support of nutritional programmes for people with tuberculosis, increased support for operational research initiatives, and integration of nutritional care into the WHO Multisectoral Accountability Framework at national and regional levels.

Lancet Glob Health 2025; 13: e967–73

Published Online March 19, 2025 https://doi.org/10.1016/S2214-109X(25)00021-X

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Introduction

Approximately a quarter of humans globally are latently infected with *Mycobacterium tuberculosis*, but progression to active disease is prevented in the majority of infections by cell-mediated immunity.[1,2] Micronutrients and macronutrients are vital in immune system function, serving as cofactors for enzymes and substrates for the proliferation of immune cells and antibodies.[3] Undernourished individuals have impaired cell-mediated immune responses to *M tuberculosis* and exhibit a peripheral immune response profile marked by increased inflammation, which might negatively affect their risk of disease progression, disease severity, and treatment outcomes.[2] HIV infection is associated with the highest risk of tuberculosis, but nutritionally acquired immunodeficiency syndrome (N-AIDS) is the most prevalent globally.[1] More tuberculosis cases worldwide are attributable to undernutrition than HIV infection because of the greater burden of undernutrition.[1]

The N-AIDS–tuberculosis syndemic is underpinned by a bidirectional biological relationship with similar social determinants of health driving both undernutrition and tuberculosis.[1] Additionally, individual determinants (eg, age, alcoholism, parasitic infections, and HIV/AIDS) and health-care determinants (eg, diagnostic and therapeutic delays, and inadequate primary health services) drive undernutrition among people with tuberculosis and their household contacts.[4] Undernutrition reduces the immune response to tuberculosis, can reduce drug adherence, and can increase the risk of drug toxicity.[1,2] Furthermore, undernourished individuals might have reduced respiratory capacity due to anaemia and reduced respiratory muscular strength.[5,6] These factors drive unfavourable outcomes, such as death, treatment failure, loss to follow-up, and relapse.[1] Individuals emerging from tuberculosis treatment with persistent undernutrition could have poor functional recovery. Additionally, N-AIDS increases the risk of disease progression among household contacts. This relationship is summarised in a conceptual framework (figure 1).

Undernutrition is a modifiable risk factor that can be identified and corrected through cost-effective interventions. Despite existing WHO guidelines, assessment of and care for N-AIDS are not yet standard elements of tuberculosis treatment.[7] We provide a roadmap for implementing nutritional assessment, counselling, support, and monitoring in standard tuberculosis care (figure 2).

Treatment initiation

Assess and report baseline nutritional status

Undernutrition in people with tuberculosis is most often a combination of pre-existing undernutrition and tuberculosis-related undernutrition. Current WHO guidelines recommend nutritional assessment at treatment initiation.[7] Anthropometric measurements can provide vital prognostic information as BMI (for adults) or weight-for-height Z score (for children) can be easily collected by tuberculosis programme personnel.[1] Mid-upper arm circumference is also an appealing, low-cost alternative measurement, particularly in children and in pregnant adults, but the lack of universal cutoffs in adults might limit comparability across diverse regions.[8] Studies from high-burden countries among adults and

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adolescents with both drug-susceptible and drug-resistant tuberculosis have consistently found low BMI and low mid-upper arm circumference to predict adverse outcomes and mortality.[1,9,10] However, although bodyweight is often measured for dose calculation, height, which is needed for calculating BMI and weight-for-height Z score, is often not measured in practice, leading to challenges in assessing nutritional status.

Unlike rates of HIV infection, which are uniformly reported in WHO's annual global tuberculosis report, there is no standard mechanism for reporting rates of undernutrition among people with tuberculosis.[11] Instead, we are dependent on epidemiological studies that represent a few selected populations and restricted time periods. A systematic review identified only 57 studies from 1990 to 2022 that evaluated nutritional metrics among people with tuberculosis and reported a 48% prevalence of undernutrition.[12] Systematic collection and reporting of BMI and weight-for-height Z score data at treatment initiation in annual tuberculosis reports would reveal the scale of the problem, the main priorities, and strategise locally contextualised action on this modifiable risk factor. In the future, we need new tools to assess and measure the nutritional status of patients with tuberculosis that are scalable, cost-effective, validated against clinical outcomes, and able to address heterogeneity across populations and states of inflammation. What gets measured gets managed—not assessing nutritional status results in missed opportunities to address this modifiable comorbidity.[11]

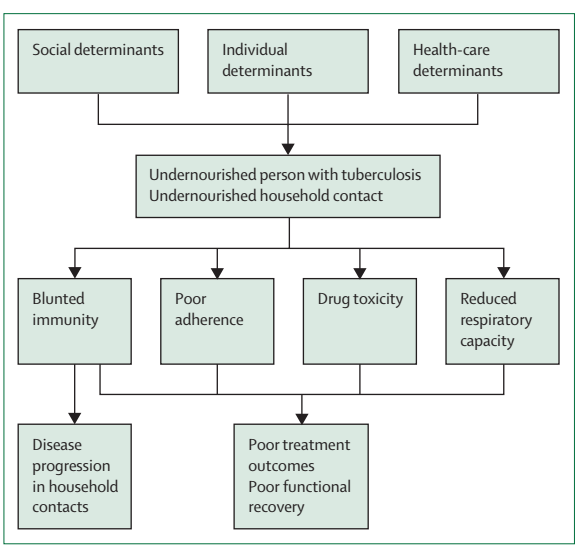

Figure 1: **Conceptual framework of determinants of undernutrition in people with and at risk of tuberculosis**
A conceptual framework of how social, health-care, and individual determinants contribute to undernutrition in people with tuberculosis and their household contacts, driving unfavourable outcomes, such as relapse, recurrence, and poor functional recovery. Key mechanisms include blunted immunity, poor adherence, drug toxicity, and reduced respiratory capacity.

Evaluate and manage anaemia

Anaemia among people with tuberculosis is common (ranging from 30% to 94%) and multifactorial.[13,14] At treatment initiation, most individuals have anaemia of inflammation, which should resolve with effective tuberculosis treatment alone. However, nutritionally driven anaemia, particularly iron deficiency anaemia, often coexists with tuberculosis. People with tuberculosis and anaemia have a nearly three-fold increased risk of mortality.[13] Haemoglobin estimation should be a routine measurement in people with tuberculosis as it has prognostic value. Furthermore, anaemia can be severe enough to necessitate inpatient care and blood transfusion. Deworming could also be indicated in some settings.

Caution is warranted when managing iron deficiency. Iron is an obligate cofactor for mycobacterial enzymes that modulate metabolism and replication,[15] and as a result, mycobacteria have evolved intense iron-scavenging mechanisms. At treatment initiation, people with tuberculosis could have elevated concentrations of hepcidin to restrict mycobacterial growth. Hepcidin is a peptide hormone that controls the absorption of dietary iron by downregulating ferroportin—the protein responsible for iron transport into circulation and release

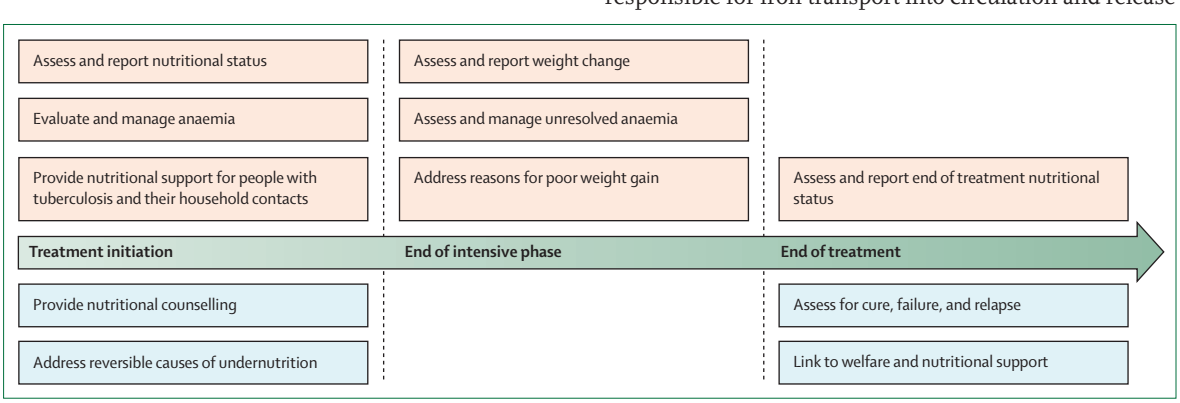

Figure 2: **Roadmap of interventions at different stages of treatment for people with tuberculosis**
Interventions at different stages of treatments to improve outcomes, mitigate risk, and address underlying determinants. High-priority interventions are shown in orange.

of iron from storage sites.[16] Supraphysiological iron supplements at treatment initiation are more likely to be poorly bioavailable and could benefit the mycobacteria rather than the individual. Therefore, iron deficiency anaemia should be addressed later during treatment.

Provide nutritional support for people with tuberculosis and their household contacts

The mortality risk due to tuberculosis is highest in the first 2 months of treatment.[10] Guinea pig models have shown that repletion with protein-rich foods rapidly restores cellular immune responses to *M tuberculosis* with resultant reductions in mortality.[2] A similar effect might occur in humans as well. Therefore, prompt initiation of nutritional support after diagnosis is probably more effective than delayed provision of supplementation.

Although the 2013 WHO guidelines do not recommend specialised nutritional support for people with tuberculosis, they emphasise that severely underweight individuals, moderately underweight children, pregnant people, and those with drug-resistant tuberculosis should receive nutritional care consistent with general WHO recommendations.[7] We recommend expanding this recommendation to people with drug-susceptible tuberculosis who are moderately (BMI 16–17 kg/m²) or severely (BMI <16 kg/m²) underweight as studies have shown an increased risk of mortality in these populations.[10]

Inexpensive food baskets to supplement the diets of people with tuberculosis, such as those provided in the RATIONS study (1200 kcal/day including 52 g of protein), can meaningfully improve nutritional recovery and possibly treatment outcomes.[17] A cluster-randomised trial from Odisha, India showed that people with tuberculosis that received standard therapy alone had an approximately 50–80% higher risk of unfavourable outcomes (ie, death, loss to follow-up, and treatment failure) than those receiving food baskets.[18] A 2023 systematic review also concluded that nutritional support improves treatment adherence.[19]

More research is necessary to determine the optimal composition of food baskets for people with tuberculosis and to tailor them to different populations, including people with severe undernutrition, people with diabetes, children, pregnant people, or those having diets with a single dominant source of calories such as rice or maize. Ultimately, the needs of people with tuberculosis depend on their baseline food security, dietary intake, dietary habits, and preferences, and developing food baskets requires a deeper understanding of these factors through diverse research approaches, including mixed methods, ethnographic, and qualitative studies. Food baskets must align with the preferences and cultural context of each population. One example is the food kit that the Government of Kerala (India) used to reduce food insecurity during the COVID-19-induced lockdowns. In addition to dry rations, the kit also provided condiments, spices, and tea, which probably increased food use.[20] Implementation research is necessary to determine the acceptability, feasibility, appropriateness, and sustainability of different delivery methods in different contexts.

For severely undernourished individuals, inpatient care might be necessary at treatment initiation to ensure adequate dietary intake and avoid refeeding syndrome. Differentiated care strategies, such as the TN-KET (ie, the Tamil Nadu-Kasanoi Erappila Thittam) initiative in south India, have begun triaging people with tuberculosis with BMI less than 14 kg/m² and those with BMI 14–16 kg/m² with oedema to inpatient care, where they receive therapeutic milk supplementation for nutritional rehabilitation and are closely monitored after they initiate tuberculosis treatment.[21]

Cash transfers have also been used to improve food access among people with tuberculosis. A systematic review of cash transfers found that receiving cash transfers was associated with a more than 75% improved odds of positive tuberculosis treatment outcomes.[22] An analysis of 54·5 million recipients from Brazil's Bolsa Familia programme found that conditional cash transfers were associated with an approximately 30% reduction in tuberculosis mortality and a 40% reduction in tuberculosis incidence.[23] Whether this benefit was caused by reductions in undernutrition is unclear. As a general principle, cash transfers work best for impoverished populations with access to functioning markets. Although studies have shown improvements in food security among people with tuberculosis receiving cash transfers,[23] there is no available evidence showing improvements in tangible nutritional metrics. This research gap must be addressed.

Although many existing nutritional subsidies focus on the nutritional needs of people with tuberculosis, economic shocks due to tuberculosis can affect all people in a household, further increasing the risk of tuberculosis incidence among household contacts. The RATIONS study provided empirical evidence that household-level nutritional support among impoverished households can reduce disease incidence among household contacts by approximately 40%.[24] Moreover, models suggest that nutritional interventions for household contacts would be cost-effective.[25] Nutritional interventions should be agnostic to the drug-resistance profiles and might have special relevance for undernourished household contacts of individuals with moderate drug-resistant tuberculosis who are at increased risk of incident drug-resistant tuberculosis.[26] Nutritional support might be important for those exposed to extensively or pre-extensively drug-resistant tuberculosis as they currently lack pharmaceutical options for preventive therapy. Given these studies,[24–26] the quantity of food provided should support the entire household.

Nutritional support addresses multiple issues and can be viewed as an essential therapy for undernourished people with tuberculosis, a preventive therapy for household

contacts, social protection against food insecurity and associated undernutrition in a milieu of tuberculosis-related economic distress, and an incentive for people with tuberculosis and their contacts to engage with care. Most importantly, when people affected by tuberculosis in impoverished communities are asked how to improve outcomes, they frequently request nutritional support.[1]

Provide nutritional counselling

Ensuring proper food use is also crucial. Impoverished people with tuberculosis can be at risk of nutrient deficiencies due to lower dietary diversity.[1] Although both in-kind and cash transfers can improve dietary diversity, nutritional misconceptions and traditional beliefs might lead to suboptimal use. When done effectively and in a culturally competent way, counselling might be a vital enabler to improve the use of in-kind or cash support for nutrition in people with tuberculosis. Counselling could improve the consumption of locally available foods rich in micronutrients and address dietary misconceptions prevalent in the community.[27] Nutritional counselling might also help manage the symptoms and side-effects of tuberculosis drugs, such as nausea and vomiting, anorexia, diarrhoea, and altered taste. WHO guidelines already recommend nutritional counselling for people with tuberculosis,[7] but nutritional counselling should not be added to the daily tasks of overworked tuberculosis programme workers as they might not have the time or expertise to perform these tasks effectively. With training, compensation, and ready-to-use counselling guides, community health workers might be better suited for nutritional counselling.[28]

Address reversible causes of undernutrition

Most of the weight loss among people with tuberculosis is caused by the disease's effects on metabolism and appetite, as well as food insecurity.[1] Individuals might also have other reversible causes of undernutrition, such as HIV and diabetes. Therefore, people with tuberculosis should undergo routine screening for these conditions. In tropical and subtropical regions with high prevalence rates of enteropathogens, testing and treatment might be warranted among undernourished people with tuberculosis.[1] Depression, malabsorption, and alcohol use disorder are other reversible causes that might occur in people with tuberculosis.[4] As tuberculosis treatment providers might lack the expertise and resources to care for several of these reversible causes, providers can screen and link people with tuberculosis with the care they require. Considering and addressing reversible causes of undernutrition for people with tuberculosis constitutes person-centred care.

End of intensive phase

Assess and report weight changes

Weight gain is a well established prognostic biomarker for people with tuberculosis. Historically, reporting weight monthly was a standard part of the original International Union Against Tuberculosis and Lung Disease and WHO DOTS system. Tuberculosis clinicians know that return of appetite and weight gain—often within a couple of weeks of treatment initiation—reflects effective treatment, whereas stagnant weight might suggest ineffective treatment. In a large Indian cohort, lack of weight gain during tuberculosis treatment was associated with a five-fold increase in mortality (adjusted incidence rate ratio 5·16; 95% CI 1·57–17·65) and a 70% increase in unfavourable outcomes.[10] In this cohort, 60% of people with tuberculosis did not gain weight at the end of the intensive phase. Conversely, approximately 60% of people with tuberculosis enrolled in the RATIONS study gained 5% of their baseline bodyweight,[17] which was associated with an approximately 60% reduction in mortality.

The threshold of 5% bodyweight gain at the end of the intensive phase has been associated with a decreased risk of relapse in other studies of both drug-susceptible and drug-resistant tuberculosis.[1] More research is needed to validate this threshold, but it might be a good target for the end of the intensive phase, especially for individuals who lost weight during treatment or who were undernourished at treatment initiation. Weight gain might also necessitate adjusting doses of tuberculosis medications to ensure adequate pharmacokinetic exposure and avoid the emergence of drug resistance, particularly among children who do not gain weight.[4] Given the prognostic importance and clinical implications of weight gain at the end of the intensive phase, measuring, recording, and reporting weight at the intensive phase should be a standard component of tuberculosis care.

Assess and manage unresolved anaemia

Unlike inflammatory anaemia, anaemia due to nutritional deficiencies does not respond to tuberculosis treatment alone.[14] A 2023 study from Puducherry, India found that 65% of people with tuberculosis who were anaemic at baseline remained anaemic despite completing tuberculosis treatment. Independent predictors of anaemia include being underweight, poor socioeconomic status, and low iron intake based on dietary recall.[29] Testing for persisting anaemia at the end of the intensive phase can help identify individuals with nutritional anaemias due to vitamin and mineral deficiencies, of which iron, folate, and B12 deficiencies are the most common.

The end of the intensive phase, particularly after sputum conversion, is probably the best time to administer micronutrient supplements that include iron. Compared with the time of treatment initiation, the mycobacterial load and hepcidin concentrations are lower by the end of the intensive phase, making supplementation safer and enhancing absorption of iron supplementation.[13,14] The role of malaria and intestinal

parasitic infections must be considered based on the context. Biochemical assessments for B12 and folate supplementation might be needed in individuals with normocytic or macrocytic anaemia.[14]

Address reasons for poor weight gain

Lack of weight gain at the end of the intensive phase should also prompt investigation for underlying causes. Several actionable factors, such as food insecurity, poor adherence to treatment, poor drug absorption, drug resistance, and comorbid conditions (eg, untreated diabetes or HIV infection) can cause stagnant or decreasing weight despite intensive therapy. These factors can and must be remedied with specific actions, such as enhanced treatment support with frequent check-ins with community health workers, drug susceptibility testing and correction of the drug regimen, therapeutic drug monitoring and dose adjustment, and provision of nutritional support and counselling. Lack of weight gain is an inexpensive and accessible biomarker that can alert clinicians to insidious concerns, and, therefore, should be assessed routinely in people with tuberculosis.

End of treatment

Assess and report nutritional status

Recording weight at the end of treatment might be a practical and inexpensive method of directly assessing the overall effect of treatment; microscopy and culture become negative long before the end of treatment, and abnormalities on chest imaging often do not resolve entirely by the end of treatment. Weight might be the only measurable metric among people with extrapulmonary tuberculosis. Why, then, is measuring weight not routine? We do not have clear metrics about nutritional recovery at the end of treatment and the quantity of weight gain that indicates treatment success. This gap can be remedied through systematic assessment and reporting.[11] With robust data, we might be able to determine a target weight gain or BMI at the end of treatment to provide assurance of adequate treatment.

Assess for relapse if undernourished

Lack of weight gain at the end of treatment should prompt an assessment for clinical failure and emerging resistance, just as it would at the end of the intensive phase. Nutritional status at the end of treatment is also a valuable prognosticator for relapse or recurrence.[1] Indeed, people with tuberculosis who remain undernourished at the end of treatment might lack the immune response needed to clear remaining bacilli, resulting in early relapse. In high tuberculosis burden settings, people with tuberculosis might also be at risk of reinfection and recurrence of disease.[1] Therefore, individuals who are undernourished at the end of treatment should receive radiographic and clinical evaluation 3–6 months after treatment completion to ensure early detection of relapse.

Link to welfare and nutritional support schemes

Food insecurity after tuberculosis treatment can perpetuate a vicious cycle of poverty, undernutrition, and disease. Although national tuberculosis programmes cannot be tasked with ongoing nutritional care for people with tuberculosis after treatment, they can assist individuals with navigating referrals to appropriate services. Many people with tuberculosis might be eligible for, but unaware of, nutritional support services and social welfare programmes, such as healthy breakfast and lunch programmes for children, take-home rations for pregnant and lactating people, transport concessions, and similar benefits. Linkages to such social services can ease food insecurity and improve person-centred outcomes.

National tuberculosis programme personnel already have high clinical and administrative burdens. To avoid overwhelming them with additional responsibilities, tuberculosis programme workers must be provided clear guidance about existing nutrition and social security schemes available in the country, and policy makers should also consider financial incentives. Technical innovations linking people with tuberculosis registered in national databases to available welfare programmes could also ease administrative burdens for programme personnel. Community health workers might also have an important role to play in post-tuberculosis nutritional care by conducting post-treatment nutritional assessment, monitoring, and support.[28]

Conclusion

The goal of tuberculosis diagnosis and treatment is not just to eliminate *M tuberculosis* from the bodies of individuals, but also to restore their health and capability to care for themselves and their families. Prioritising nutrition offers myriad positive externalities with beneficial effects on other infectious and non-infectious diseases, children's physical and cognitive growth, and economic productivity.[25] Nutrition is a cross-cutting issue, and addressing undernutrition among people with tuberculosis and those at risk for tuberculosis will help attain the UN's universal health-care goals and contribute to the attainment of the second Sustainable Development Goal: zero hunger. Integrating nutritional assessment, counselling, monitoring, and support throughout tuberculosis treatment is crucial for providing holistic, person-centred care. Some actions, such as nutritional assessment and prompt nutritional support for severely undernourished people with tuberculosis, should be prioritised immediately (figure 2). Subsequently, integrating nutritional care for people with tuberculosis and tuberculosis survivors into broader health services, such as primary care and maternal health programmes, could further enhance reach and impact of tuberculosis programmes.

Recognising the importance of undernutrition as a barrier to tuberculosis elimination, the 2023 UN

High-Level Meeting committed to multisectoral action on undernutrition. This commitment must be upheld as most tuberculosis programmes currently lack funding and specific expertise to manage undernutrition. The first tangible step that must be taken urgently is to start collecting and reporting national-level nutritional data for people with tuberculosis, which can be incorporated as a key tuberculosis metric in WHO annual reports. Furthermore, specific nutritional objectives should be incorporated into national strategic plans, and funding for nutritional supplementation programmes should be part of funding requests to The Global Fund to Fight AIDS, Tuberculosis, and Malaria, and other international aid agencies. Concurrently, research agendas should prioritise undernutrition operational studies as they pertain to tuberculosis, along with training programmes for public health scientists working on the N-AIDS–tuberculosis syndemic in the most affected regions.[30] Lastly, nutritional assessment and care should be integrated into the implementation of the WHO Multisectoral Accountability Framework at national and regional levels.

Nutritional care should not be seen as an optional luxury but as a medical necessity—an intervention as fundamental as the medicines we prescribe. Feeding people is not just an act of compassion, it is a cornerstone of effective, person-centred tuberculosis care.

Contributors

PS, CFM, MB, AB, and RMGJH conceptualised the paper. MEC, MRD, and PS wrote the first draft. MB, CFM, AB, JPC, SM, RMGJH, JH, MO, KGK, JLF, CC, PT, LML, and SKH reviewed and edited the draft. All authors contributed to the writing, critical revision, and discussions of the scope of this Health Policy, and approved the final manuscript.

Declaration of interests

SM has shares and holds an unpaid board position at VitaScan, a startup commercialising point-of-care assays for micronutrient status, based partially on technology developed in his research laboratory at Cornell University. All other authors declare no competing interests.

Acknowledgments

We thank Anne Fan Liu for reviewing numerous drafts of the manuscript and offering thoughtful comments and edits. PS was supported by funds from the National Institutes of Health (NIH; K01AI167733-01A1), the Burroughs Wellcome/American Society of Tropical Medicine & Hygiene Postdoctoral fellowship, CRDF Global (DAA3-19-65673-1), the Warren Alpert Foundation (6005415), and a career investment award by the Department of Medicine at Boston University Chobanian & Avedisian School of Medicine. JPC was supported by grants from NIH/National Institute of Allergy and Infectious Diseases (K24AI114444), and Emory/Georgia TB Research Advancement Center (P30AI168386). SKH was supported by an NIH and Fogarty International Center grant (D43TW012247). The funders had no role in the writing of this article.

References

1 Dauphinais MR, Koura KG, Narasimhan PB, et al. Nutritionally acquired immunodeficiency must be addressed with the same urgency as HIV to end tuberculosis. *BMC Glob Public Health* 2024; **2:** 1–9.

2 Cegielski J, McMurray D. The relationship between malnutrition and tuberculosis: evidence from studies in humans and experimental animals. *Int J Tuberc Lung Dis* 2004; **8:** 286–98.

3 Venter C, Eyerich S, Sarin T, Klatt KC. Nutrition and the immune system: a complicated tango. *Nutrients* 2020; **12:** 818.

4 Sinha P, Lönnroth K, Bhargava A, et al. Food for thought: addressing undernutrition to end tuberculosis. *Lancet Infect Dis* 2021; **21:** e318–25.

5 Arora NS, Rochester DF. Respiratory muscle strength and maximal voluntary ventilation in undernourished patients. *Am Rev Respir Dis* 1982; **126:** 5–8.

6 Ouellette DR. The impact of anemia in patients with respiratory failure. *Chest* 2005; **128** (suppl)**:** s576–82.

7 WHO. Nutritional care and support for patients with tuberculosis. Nov 13, 2013. https://www.who.int/publications/i/item/9789241506410 (accessed Dec 24, 2024).

8 Locks LM, Parekh A, Newell K, et al. The ABCDs of nutritional assessment in infectious diseases research. *J Infect Dis* 2024; published online Nov 6. https://doi.org/10.1093/infdis/jiae540.

9 Engoru S, Bajunirwe F, Izudi J. Malnutrition and unsuccessful tuberculosis treatment among people with multidrug-resistant tuberculosis in Uganda: a retrospective analysis. *J Clin Tuberc Mycobact Dis* 2024; **37:** 100477.

10 Sinha P, Ponnuraja C, Gupte N, et al. Impact of undernutrition on tuberculosis treatment outcomes in India: a multicenter prospective cohort analysis. *Clin Infect Dis* 2022; **76:** 1483–91.

11 McQuaid CF, Sinha P, Bhargava M, Weerasuriya C, Houben RM, Bhargava A. Tuberculosis and nutrition: what gets measured gets managed. *Lancet Respir Med* 2023; **11:** 308–10.

12 Li A, Yuan SY, Li QG, Li JX, Yin XY, Liu NN. Prevalence and risk factors of malnutrition in patients with pulmonary tuberculosis: a systematic review and meta-analysis. *Front Med* 2023; **10:** 1173619.

13 Nienaber A, Uyoga MA, Dolman-Macleod RC, Malan L. Iron status and supplementation during tuberculosis. *Microorganisms* 2023; **11:** 785.

14 Minchella PA, Donkor S, Owolabi O, Sutherland JS, McDermid JM. Complex anemia in tuberculosis: the need to consider causes and timing when designing interventions. *Clin Infect Dis* 2015; **60:** 764–72.

15 Agoro R, Mura C. Iron supplementation therapy, a friend and foe of mycobacterial infections? *Pharmaceuticals*. 2019; **12:** 75.

16 Nemeth E, Ganz T. Hepcidin and iron in health and disease. *Annu Rev Med* 2023; **74:** 261–77.

17 Bhargava A, Bhargava M, Meher A, et al. Nutritional support for adult patients with microbiologically confirmed pulmonary tuberculosis: outcomes in a programmatic cohort nested within the RATIONS trial in Jharkhand, India. *Lancet Glob Health* 2023; **11:** e1402–11.

18 Mahapatra A, Thiruvengadam K, Nair D, et al. Effectiveness of food supplement on treatment outcomes and quality of life in pulmonary tuberculosis: phased implementation approach. *PLoS One* 2024; **19:** e0305855.

19 Wagnew F, Gray D, Tsheten T, Kelly M, Clements ACA, Alene KA. Effectiveness of nutritional support to improve treatment adherence in patients with tuberculosis: a systematic review. *Nutr Rev* 2023; **82:** 1216–1225.

20 Jayalakshmi R, Kannan S. Maintaining food security during difficult times: an experience of COVID-19 in Kerala. *Res Sq* 2021; published online Sept 1. https://doi.org/10.21203/rs.3.rs-864547/v1 (preprint).

21 Shewade HD, Frederick A, Kiruthika G, et al. The first differentiated TB care model from India: delays and predictors of losses in the care cascade. *Glob Health Sci Pract* 2023; **11:** e2200505.

22 Richterman A, Steer-Massaro J, Jarolimova J, Luong Nguyen LB, Werdenberg J, Ivers LC. Cash interventions to improve clinical outcomes for pulmonary tuberculosis: systematic review and meta-analysis. *Bull World Health Organ* 2018; **96:** 471–83.

23 Jesus GS, Gestal P, Silva AF, et al. Effects of conditional cash transfers on tuberculosis incidence and mortality according to race, ethnicity and socioeconomic factors in the 100 Million Brazilian Cohort. *Nat Med* 2025; published online Jan 3. https://doi.org/10.1038/s41591-024-03381-0.

24 Bhargava A, Bhargava M, Meher A, et al. Nutritional supplementation to prevent tuberculosis incidence in household contacts of patients with pulmonary tuberculosis in India (RATIONS): a field-based, open-label, cluster-randomized, controlled trial. *Lancet* 2023; **402:** 627–40.

25 Sinha P, Lakshminarayanan SL, Cintron C, et al. Nutritional supplementation would be cost-effective for reducing tuberculosis incidence and mortality in India: the Ration Optimization to Impede Tuberculosis (ROTI-TB) model. *Clin Infect Dis* 2022; **75:** 577–85.

26 Izudi J, Engoru S, Bajunirwe F. Malnutrition is a risk factor for tuberculosis disease among household contacts: a case-control study in Uganda. *IJID Reg* 2024; **12:** 100409.
27 Pajanivel R, Boratne AV, Raj RV. Impact of dietary counseling on the nutritional status and quality of life among pulmonary tuberculosis patients: a randomized control trial. *Indian J Tuberc* 2022; **69:** 201–06.
28 Sinha P, Shenoi SV, Friedland GH. Opportunities for community health workers to contribute to global efforts to end tuberculosis. *Glob Public Health* 2019; **15:** 474–84.
29 Leon J, Sarkar S, Basu D, Nanda N, Joseph NM. Predictors of change in the anemia status among pulmonary tuberculosis patients following anti-tuberculosis treatment in Puducherry, India. *Cureus* 2023; **15:** e44821.
30 Carwile M, Pan SJ, Zhang V, et al. National Institutes of Health funding for tuberculosis comorbidities is disproportionate to their epidemiologic impact. *Open Forum Infect Dis* 2023; **11:** ofad618.