Review

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Cachexia in tuberculosis in South-East Asian and African regions: knowledge gaps and untapped opportunities

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Abstract

Tuberculosis (TB) and cachexia are clinical entities that have a defined relationship, making them often found together. TB can lead to cachexia, while cachexia is a risk factor for TB. This article reviews cachexia in Tuberculosis patients in Southeast Asian and African regions by conducting a comprehensive literature search across electronic databases such as PubMed, Google Scholar, and Research Gate between 2013 and 2024 using keywords including 'Africa', 'cachexia', 'prevalence', 'implications', 'tuberculosis', and 'Southeast Asia. This article utilized only studies that satisfied the inclusion criteria, revealing knowledge gaps and untapped opportunities for cachexia in TB across Southeast Asian and African regions. Many Southeast Asian and Western Pacific patients initially receive a tuberculosis diagnosis. Sub-Saharan African countries are among the 30 high TB burden nations, according to the WHO. Food inadequacy and heightened energy expenditure can impair the immune system, leading to latent TB and subsequently, active infection. Symptoms needing attention: shortness of breath, productive cough, hyponatremia at 131 mmol/l, hypoalbuminemia at 2.1 g/dl, elevated aspartate transaminase at 75 U/l, increased lactate dehydrogenase at 654, and normocytic anemia. Comorbidities, such as kidney disease, cardiovascular disease, and asthma, can influence the nutritional status of individuals with TB. While efforts like screening, contact tracing, and utilizing gene Xpert to detect TB cases were implemented, only a few proved effective. It is essential to conduct further studies, including RCTs, in Southeast Asia and Africa to evaluate and manage cachexia in TB patients.

Keywords: Africa, cachexia, implications, prevalence, Southeast Asia, tuberculosis

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Introduction

Tuberculosis (TB) and cachexia are two clinical entities that go together as there is a defined relationship between them[1,2]. TB is a respiratory disease that affects the lungs and airways, caused by Mycobacterium tuberculosis (MTB)[3]. Cachexia, on the other hand, is a debilitating state caused by prolonged nutritional deficiency[1]. There is a clear and consistent relationship between undernutrition and TB in both developed and underdeveloped countries around the world, which has been widely documented and acknowledged[1]. Undernutrition and TB exhibit a compounding relationship in that undernutrition impairs the immune system in humans, thereby increasing the risk of latent TB progressing to an active infection[1]. In other words, TB can lead to cachexia, while cachexia is a risk factor for TB[2]. A global report by the WHO in 2019 showed that the proportion of males to females experiencing undernutrition was 2:1 among individuals diagnosed with TB[4]. Although other risk factors for TB aside from malnutrition, include; poverty, overcrowding, cigarette smoking, TB-HIV co-infection, diabetes mellitus, etc.[5,6]. Over the years, extensive research has been done to determine the relationship between cachexia and TB across the globe[1–3,7]. More than two billion people are infected by *M. tuberculosis*[8]. Annually, it is estimated that three million deaths occur worldwide as a result of TB[8]. Although TB is a disease that can be both prevented and cured, it claims the lives of approximately 1.5 million individuals annually, making it the most lethal infectious agent worldwide[9]. Several studies in Southeast Asia and Africa also indicate a high burden of TB resulting in cachexia in these regions[1–7,10–14]. There are 11 and 54 countries in Southeast Asia and Africa, respectively[15,16]. Unfortunately, only a few selected countries in these regions have conducted studies on TB and cachexia. This indicates that there is limited data regarding this issue and the possibility of under-reported cases. Despite efforts to curtail cachexia in TB in these regions, this threat persists as a significant public health concern in these regions[1,7,17–19]. There are still many undernourished individuals with TB in Southeast Asian and African regions[12,20,21]. For example, a recent study in Ethiopia showed that over 50% of individuals with TB were undernourished, with ~51% indicating a high number of old and new cases of nutritional deficiencies in individuals with TB[18]. Based on these findings, we speculate that there are knowledge gaps and untapped opportunities that need to be addressed. This article aims to critically review cachexia in tuberculosis in Southeast Asian and African regions and propose possible solutions to the problem. This article can be beneficial in developing tailored strategies aimed at tackling cachexia in people with TB in the Southeast Asian and African regions.

Methodology

In writing this review, a thorough literature search on the subject matter was done across electronic databases such as PubMed, Google Scholar, and ResearchGate between 2013 to 2024 using keywords: 'Africa', 'cachexia', 'prevalence', implications', 'Tuberculosis', and 'Southeast Asia'. Only cross-sectional studies, systemic reviews and meta-analyses, literature reviews, and case reports will be considered. On the other hand, studies such as editorials, perspectives, and commentaries were not considered.

HIGHLIGHTS

- Both the Southeast Asian and African regions share similar prevalent cases of cachexia due to TB.
- Individuals who are cachexic cachexia and have TB tend to experience delayed recovery and higher mortality rates compared to those with normal nutrition who have TB.
- Common clinical features of cachexia due to TB include; persistent productive cough, shortness of breath, and weight loss.
- Complications such as numerous random nodules scattered throughout the lung tissue on both sides, central cavitation of nodules within the upper lobe, prominent lymph nodes in the right hilum and mediastinum, and small, cystic lesions in the liver and spleen are commonly seen.
- Efforts to tackle cachexia due to TB in south-Asia and African regions should be tailored towards multisectoral approaches especially nutritional weight gain, administration of combinational TB nano vaccines, use of travel Africa phenomenon and One Health approach.

Cachexia in tuberculosis: current scenario, implications, and efforts

Prevalence of cachexia in tuberculosis in Southeast Asia and Africa

TB is the most important infectious disease with a resurgence globally[22]. In 2014, ~10 million cases of TB were documented worldwide with a death rate of almost 1.5 million[22]. The incidence of TB was found to be 20 times greater in individuals residing in low-income countries than in high-income countries[23]. According to global statistics, approximately one-fourth of all new TB cases are estimated to result from undernutrition, and TB is thought to be one of the prevailing background aetiologies of emaciation. Both the Southeast Asian and African regions share similar prevalent health issues, including TB[6,19,24,25]. The highest number of newly diagnosed TB cases occurs in the Southeast Asia and Western Pacific regions, accounting for 56% of the total global cases[26]. Research in India, Nepal, Ethiopia, Kenya, and Ghana has indicated that 50–57% of patients with TB suffer from malnutrition. Individuals with malnutrition are twice as likely to perish from TB[4,10–13,18,20,27]. In India, the WHO identified nutritional deficiencies and TB as coexisting health issues that are intricately linked and constitute interconnected public health challenges[28]. India reported a 55% prevalence of TB that was likely attributed to the impact of undernutrition[28]. Between 2013 and 2016, studies conducted in North Karnataka[29] and West Tripura in India[30] revealed the prevalence of TB among malnourished individuals was 59.1%, with a co-occurrence of 55.8% (30,31). A study in Sri Lanka found that adult TB patients had significantly lower nutritional levels than healthy individuals, and the likelihood of undernutrition was twice that of contracting active TB[31]. It was revealed that cachexia affected 51% of individuals with TB[31]. The first TB survey conducted in Vietnam between 2006 and 2007 had the objective of this survey to evaluate the current state of tuberculosis in the nation, revealing old and new cases of pulmonary TB with bacterial origin confirmed among 307 people in a population of 100 000[32]. New cases of confirmed TB were found to be four

times greater in men than in women and increased with age[32]. The most old and new cases of TB were identified in developed areas and the southern region of Vietnam[32]. Old and new cases of TB in Vietnam were found to be lower compared to other studies conducted in Asian countries with high TB prevalence, particularly in Indonesia in 2014 where the prevalence was 759 per 100 000 adults[33], the Philippines with 1159 per 100 000 individuals in 2016[34], and Myanmar with 468 per 100 000 persons in 2017[35].

Sub-Saharan African countries are among the top 30 globally with a significant burden of TB[36]. The WHO uncovered that the number of senior citizens contracting TB ranges from ~10 000 in Congo to 290 000 in South Africa, according to the latest statistics[36]. Ninety per cent per cent of adults of working age with TB are responsible for lost days of work, which in turn places an economic burden on these countries[36]. A nationwide survey in all 10 provinces of Zambia, covering 49 districts, revealed a prevalence of 319 cases of smear-positive TB per 100 000 adult population, and 568 cases of culture-positive TB per 100 000 population. Additionally, the prevalence of bacteriology has shown a rate of 638 cases of TB per 100 000 individuals[18]. Smear, culture, and bacteriology prevalence confirmed that TB was more prevalent in patients who tested positive for HIV, male patients, patients aged between 35 and 44, as well as in urban respondents[19]. A study conducted in Zambia showed that individuals from lower economic backgrounds had a greater burden of TB compared to those from higher wealth status[19]. A 2015 national survey in Ethiopia indicated that two-thirds of registered elderly individuals typically have a BMI of less than 18.5 kg/m^2[21]. A study conducted by Muse AI *et al.*[1] in the Somali region of Ethiopia, found that the ultimate old and new cases of nutritional deficiencies in individuals with TB were 44.3%, with a 95% CI of o(38.2, 49.7). Two other studies conducted in Ethiopia also revealed increased cases of nutritional abnormalities in older individuals with the disease compared to the current study specifically, one study reported a rate of 57.2%[37], while the other reported a rate of 63.2%[38]. The prevalence was 57% in Zambia and 51% in Malawi, as per studies conducted in those countries[10,39].

Aetiopathogenesis of cachexia in TB

Cachexia is a severe form of malnutrition characterized by a significant loss of weight and muscle mass due to an inadequate intake of nutrients and energy to sustain good health. It is a condition that arises when the body does not receive the necessary nutrients and energy to function properly[24]. People typically become malnourished when their diet fails to deliver sufficient food nutrients necessary for growth and development[25]. Also, disease conditions can further worsen intestinal absorption of these food nutrients[25]. Due to the intricate relationship between malnutrition and tuberculosis, insufficient dietary intake and heightened energy expenditure can compromise the immune system, consequently leading to latent tuberculosis and subsequent active infection[1]. Due to the intricate relationship between these two factors, tuberculosis exacerbates undernutrition by elevating metabolic demand and diminishing appetite[40]. Pathological features observed in patients with TB include reduced appetite, suboptimal nutritional intake, and an imbalance of micronutrients resulting from an imbalanced metabolic pathway due to the disease process[17]. Individuals who are cachexia and have TB tend to experience delayed recovery and higher mortality rates compared to those with normal nutrition who have TB[17]. At the molecular level, specific appetite-regulating hormones are altered in individuals with TB. For instance, Peptide YY2, ghrelin, and resistin are elevated, while plasma leptin is decreased[41]. After receiving treatment, the normalization of these hormones leads to an improvement in appetite and nutritional status, which can explain the low BMI and may also explain the poor dietary intake often linked with TB[41,42]. The chief defense mechanism against TB is cell-mediated immunity, which makes it a significant risk factor for the emergence of undernutrition[1]. Deterioration in nutritional status can frequently arise due to the reactivation of latent TB infection, which was previously subclinical[1]. Research conducted in Asian countries has uncovered that cachexia risk factors in TB patients often include comorbidities like HIV/AIDS and diabetes mellitus[29,30]. Studies conducted in African countries have identified significant associations between undernutrition among older persons with TB and factors such as sex, level of education, and functional status[1,20]. Figure 1 shows the aetiopathogenesis of Cachexia in TB.

Clinical manifestations

Cachexia, a condition commonly observed in TB patients[1,43], has several well-documented clinical manifestations. For example, a 47-year-old gay Filipino man with intestinal TB presented with symptoms in the Philippines, such as a persistent productive cough, shortness of breath, and weight loss that had endured for a year. On examination, the patient exhibited evidence of cachexia, as evidenced by temporal wasting[43]. This individual was experiencing mild respiratory distress, and a displayed heart rate was 93 beats per minute, while his tachypnoea was 23 per minute[43]. Zheng*et al.*[42] discovered through their case report that there was severe oral thrush but did not observe any palpable lymphadenopathy. Fine crackles were also identified as features of this medical condition[43]. Although lab results showed a typical white blood cell count, other findings were abnormal: there was anemia with normal-sized red blood cells, low sodium levels at 131 mmol/l, the albumin level was found to be low, at 2.1 g/dl, while the aspartate aminotransferase level was elevated, at 75 U/l. Similarly, the lactate dehydrogenase level was also elevated, at 654. However, the lactic acid level was within normal limits[43]. A study in Vietnam uncovered that roughly 58% of TB cases exhibited prolonged cough symptoms for 14 days or more[32]. A cross-sectional study conducted in the Somali region of Ethiopia found that ~34% of respondents had a cough that lasted for more than 1 month before a diagnosis of TB was made, while 30% experienced concurrent breathing difficulties[1]. Additionally, ~18% of the participants reported difficulties with eating, with 12% of respondents experiencing poor appetite, 4% struggling with nausea or vomiting, and less than 1% being affected by mouth ulcers[1].

Public health implications

Several public health implications of cachexia in individuals with TB have been identified[1,18,44,45]. It emerged that people with catabolic disorders like TB may experience a loss of over 20% of their weight and muscle mass within a 3–6-month period, yet still have BMI values within the normal range[46]. A national survey in India found that preschool children with low BMI for their age and low weight for height were at a higher risk of infection[47].

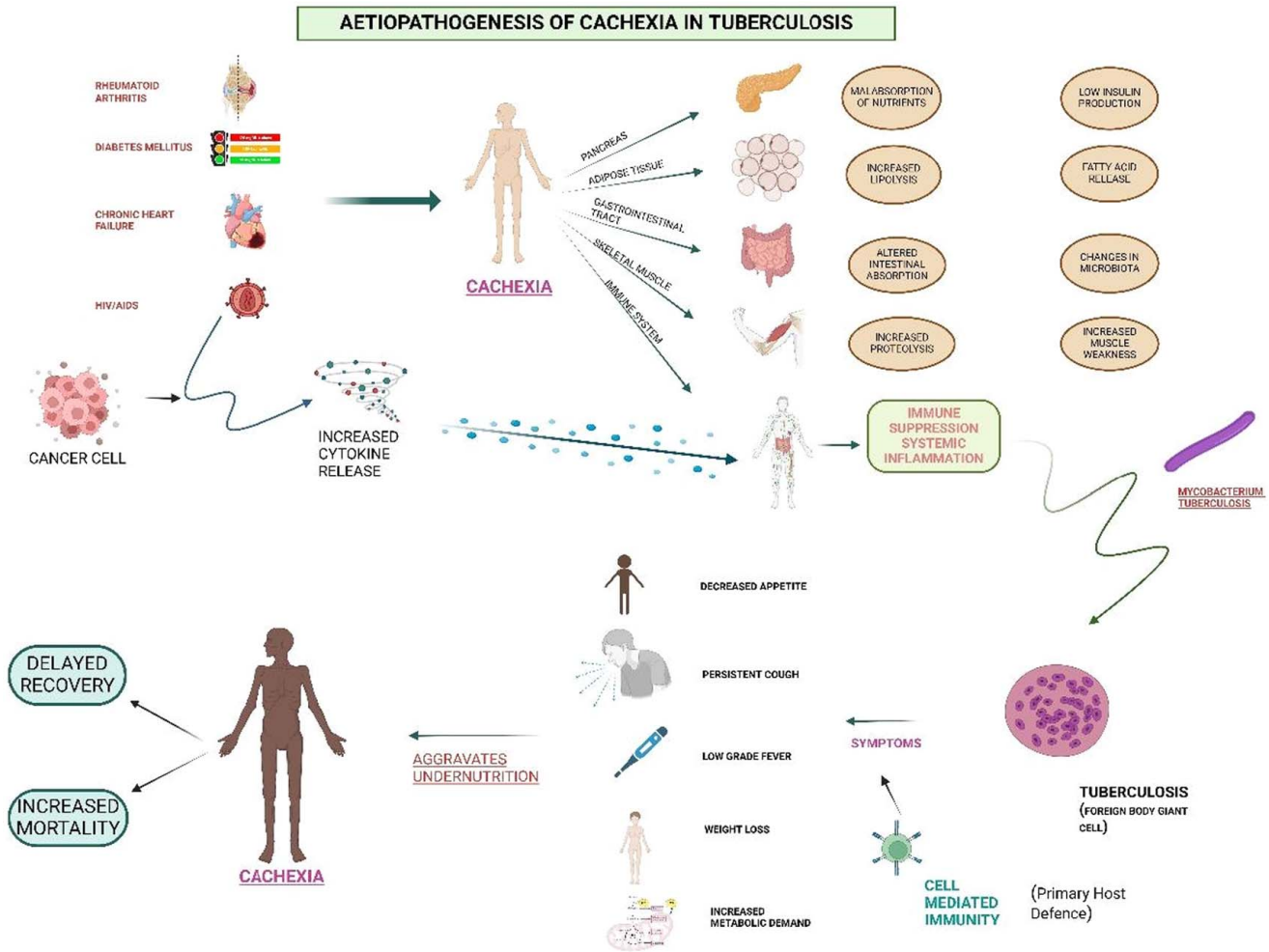

Figure 1. The aetiopathogenesis of cachexia in tuberculosis.

Muse AI *et al.*[1] in Ethiopia discovered that female respondents with TB were two times more susceptible to undernutrition than male respondents. Additionally, individuals with no formal education were four times at risk of suffering from undernutrition compared to those who were literate[1]. Conversely, individuals without formal education are four times more susceptible to experiencing malnutrition than those with formal education[1]. Individuals who suffer from enuresis and TB were found to suffer from undernutrition four times compared to mobile individuals[1].

People with less education are likely to have a limited understanding of dietary diversity and the importance of adhering to anti-TB medications[1]. According to the data, ~12% of respondents had comorbidities, including kidney-related problems, heart-related problems, and lung-related problems. For example, asthma could influence their nutritional needs[1]. A study conducted in Malawi indicated that individuals with both TB and low nutrition were two times more susceptible to premature death and long-term respiratory disease, and a lack of proper nutrition also raised the likelihood of contracting TB threefold[44]. A study conducted in Ethiopia demonstrated that the functional capacity of individuals diagnosed with TB is typically linked to their main health condition, including persons who have lower physiological capacity sometimes experience bad prognosis health outcomes[45]. Research in Zambia posited that when the HIV pandemic and poverty coincide in a country, it can increase the number of TB cases[19]. A study conducted in Nepal revealed that the burden of TB has the potential to cause economic consequences on both the micro and macro-economic levels in Nepal[48]. A case study conducted in the Philippines highlighted a few complications experienced by a cachectic patient with tuberculosis[43]. The complications consist of numerous random nodules scattered throughout the lung tissue on both sides, radiologic evidence of central cavitation of nodules within the upper lobe, prominent lymph nodes in the right hilum and mediastinum, and small, cystic lesions in the liver and spleen[43]. A computed tomography (CT) examination of the patient's abdomen was performed, utilizing intravenous administration of contrast revealing enlarged necrotic lymph nodes in the retroperitoneal, pelvic, and inguinal regions[43].

Efforts to fight cachexia in TB in Southeast Asia and Africa

Efforts to combat cachexia in conjunction with TB treatment are crucial to enhance the treatment outcome, and overall well-being of an individual with TB, and limit the chance of reinfection[1]. Counseling on nutrition has been demonstrated to ensure

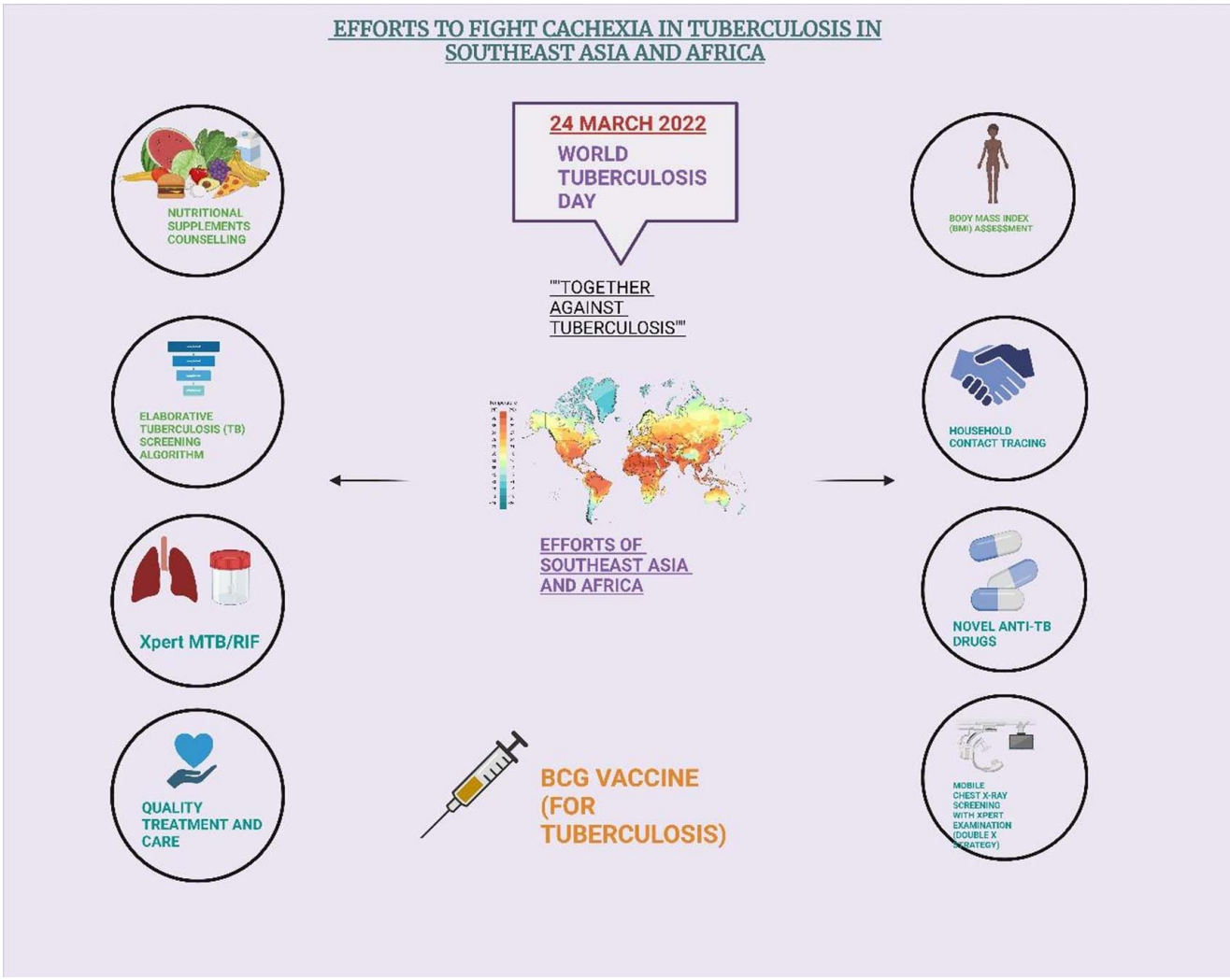

Figure 2. The efforts to fight cachexia in tuberculosis in Southeast Asia and Africa.

sufficient calorie intake, leading to enhanced and consequently crucial improvement in weight, lean body mass, and physical functional state[49]. A systematic review and meta-analysis uncovered that the majority of people diagnosed with TB are typically evaluated for only a single aspect of the malnutrition construct[6]. BMI is frequently employed as an assessment method for malnutrition in studies involving individuals with TB, even though it only partially addresses the domain of malnutrition[6]. The Zambian national survey demonstrated that implementing a comprehensive TB symptoms screening algorithm led to the establishment of more stringent screening criteria, thereby decreasing the likelihood of overlooking TB cases among the participants[19]. Unlike a study in Vietnam in 2006, which relied exclusively on cough as a conventional screening method for identifying TB among its participants, our approach incorporates various criteria for a more comprehensive and accurate detection process[50]. Unfortunately, multiple investigations have demonstrated that symptom-based dynamic TB case finding is not effective[51–55]. During the period from 2010 to 2016, innovative screening and diagnostic devices were implemented in Asian regions to identify TB cases[32,56,57]. In 2010, Vietnam implemented various interventions to alleviate the pressure of TB on the population, such as improving routine TB care and therapy, introducing novel anti-TB drugs, and employing active case finding and household contact tracing[56,57]. In 2016, Xpert MTB/Rif was utilized for all screened positive respondents in Vietnam[32] and Indonesia[33]. During the years 2016 and 2017, Xpert Ultra was utilized for the screening of TB in the surveys conducted in the Philippines and Myanmar, respectively[34,35]. In addition, the Double X Strategy, which involves chest radiograph screening, which is a mobile device, along with an examination of gene Xpert, was implemented in four locations in Vietnam. These locations, which consist of Hai Phong, Hoi An, Ca Mau, and Ho Chi Minh City, have been developed to provide support for individuals who are considered to be in a vulnerable state[58,59]. These groups at risk encompass individuals such as prisoners, coal miners, and senior citizens[60,61]. One limitation of the Double X Strategy was that only a small scale was tested with the method[62]. This procedure proved to be effective in identifying new TB cases. The screening awareness program on TB was conducted on an island known as Cu Lao Cham, where 17 recent cases were identified compared to only 2 ongoing cases before the

Table 1

The key concepts findings and limitations of the most important articles regarding cachexia in TB.

Finding	Limitation	Reference
Approximately one-fourth of all new TB cases are estimated to result from undernutrition	These figures are subjective, recent studies are required for validation	6,19, 25, 26
Research in India, Nepal, Ethiopia, Kenya, and Ghana has indicated that 50–57% of patients with TB suffer from malnutrition	These studies only cover a few countries and need more multicentred studies	10–13, 18, 20, 27
Nutritional deficiencies and TB as coexisting health issues that are intricately linked and constitute interconnected public health challenges	Nutritional deficiencies are not limited to only cachexia	29
Observed clinical features include; persistent productive cough, shortness of breath, and weight loss	There are other clinical conditions such as pneumonia and malignancies with similar presentations	46
People with less education are likely to have a limited understanding of dietary diversity and the importance of adhering to anti-TB medications	This finding depends on the study area and study participants	1
Children with both TB and low nutrition are two times more susceptible to premature death and long-term respiratory disease	This is a pediatric study	47
The functional lung capacity of individuals diagnosed with TB is typically linked to their main health condition	TB can co-exist with HIV, but not necessarily cachexia	48
mRNA vaccines can also help to fight infectious diseases by discovering the Foreign proteins and responding by producing antibodies	This study is not specific to TB	70

initiation of the program[62]. One of the benefits of the Double X Strategy is its capacity to identify overlooked instances of TB[32]. Figure 2 shows the efforts to fight cachexia in TB in Southeast Asia and Africa. Numerous studies have indicated specific strategies to fight cachexia due to TB[63–66]. For example, normal weight was identified to prevent TB[63]. Also, there is nutritional recovery if an individual with chronic TB is given a 20% protein diet[64]. Additionally, a Cochrane study found that a person suffering from cachexia due to TB could recover from the six protein-energy interventional trials because these trials aid the completion of treatment and recovery, validate improvements in physical activities and life quality related to management; and result to an increase weight gain[65]. TB vaccines such as VPM1002, M72-AS01, MIP, and GamTBVac which work through the principle of combinational effect, can improve vaccine efficacy and protection by inducing a wider immune response[66] and have been shown to prevent cachexia[67]. mRNA vaccines can also help to fight infectious diseases by discovering the foreign proteins and responding by producing antibodies[68]. Another effective way to fight cachexia due to TB is via ChatGPT, especially in clinical cases[69]. This is evidenced that pathologies can be detected through GPT-powered chatbots[69].

Conclusion

To effectively manage TB, a comprehensive evaluation of the patient's nutritional status is necessary. Such an assessment would enable the identification and management of potential complications associated with TB, as well as provide insight into how the patient's nutritional status may influence the disease's clinical progression[11]. Health authorities in Southeast Asia and African regions need to devise effective tools and diagnostic tests to evaluate cachexia in TB among affected populations in these regions, for example, adopting a phenomenon called travel Africa, where specific vaccines, gathered through ChatGPT, are needed to be recommended by healthcare professionals in both south-Asia and African regions[70]. Further epidemiological studies and randomized control trials (RCTs) should be conducted by researchers and physicians in Southeast Asia and African regions to properly evaluate and manage cachexia in TB in these regions, especially in the aspect of the One Health approach, Precision medicine approaches to harness technological advancements, eco-friendly interventions, and public campaigns[71] (Table 1).

Ethical approval

Ethics approval was not required for this review.

Consent

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Author contribution

D.M., P.P., and S.S.B.: contributed to the conception and design of the study, drafting the article, critical revision for important intellectual content, and final approval of the version to be published; R.P. and S.P.: participated in the drafting of the article, critical revision for important intellectual content, and final approval of the version to be published; D.S.D., C.T., and K.Y. G.: participated in drafting the article, critical revision for important intellectual content, and final approval of the version to be published; A., S.S.N.P., and J.C.: were involved in critical revision for important intellectual content and final approval of the version to be published; L.A., K.R.S.C., and S.S.R.M.: contributed to the critical revision for important intellectual content and final approval of the version to be published; P.S., M.A.O., M.V., and S.A.I.: participated in the final approval of the version to be published. All authors contributed to writing different parts of the manuscript, and all authors have approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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References

[1] Muse AI, Osman MO, Ibrahim AM, *et al*. Undernutrition and associated factors among adult tuberculosis patients in jigjiga public health undernutrition and associated factors among adult tuberculosis patients in jigjiga public health facilities, Somali Region, East, Ethiopia. Res Rep Trop Med 2021;12:123–33.

[2] Ockenga J, Fuhse K, Chatterjee S, *et al*. Tuberculosis and malnutrition : the European perspective. Clin Nutr [Internet] 2023;42:486–92.

[3] Narasimhan P, Wood J, Macintyre CR, *et al*. Risk factors for tuberculosis. Pulm Med 2013;2013:1–12.

[4] Global Tuberculosis Report 2019. Geneva: World Health Organization; 2019.

[5] Bisht MK, Dahiya P, Ghosh S, *et al*. The cause-effect relation of tuberculosis on the incidence of diabetes mellitus. Front Cell Infect Microbiol 2023;15:1–15.

[6] Ter Beek L, Bolhuis MS, Jager-Wittenaar H, *et al*. Malnutrition assessment methods in adult patients with tuberculosis: a systematic review. BMJ Open 2021;11:e049777.

[7] Hood MLH. A narrative review of recent progress in understanding the relationship between tuberculosis and protein energy malnutrition. Eur J Clin Nutr 2013;67:1122–8.

[8] França T, Ishikawa L, Zorzella-Pezavento S, *et al*. Impact of malnutrition on immunity and infection. J Venom Anim Toxins Incl Trop Dis 2009;15:374–90.

[9] Global Tuberculosis Report 2020. Geneva: World Health Organization; 2020.

[10] Zachariah R, Spielmann MP, Harries AD, *et al*. Moderate to severe malnutrition in patients with tuberculosis is a risk factor associated with early death. Trans R Soc Trop Med Hyg 2002;96:291–4.

[11] Dodor. EA. Evaluation of nutritional status of new tuberculosis patients at the office-kwanza regional hospital. Ghana Med J 2008;42:22–8.

[12] Subedi S, Mehta R, Parajuli P, *et al*. Nutritional status of patients with pulmonary tuberculosis receiving anti-tuberculosis treatment at BP Koirala Institute of Health Sciences, Nepal. IOSR J Nur Health Sci 2019;8:1–5.

[13] Bhargava A, Chatterjee M, Jain Y, *et al*. Nutritional status of adult patients with pulmonary tuberculosis in rural central India and its association with mortality. PLoS One 2013;8:e77979.

[14] Dargie B, Tesfaye G, Worku A. Prevalence and associated factors of undernutrition among adult tuberculosis patients in some selected public health facilities of Addis Ababa, Ethiopia: a cross-sectional study. BMC Nutr 2016;2:7.

[15] University NI. Southeast Asian countries. Cent Southeast Asian Stud [Internet]. 2024. Accessed 22 February 2024. https://www.niu.edu/clas/cseas/resources/countries.shtml#:~:text=SoutheastAsia is composed of,%2C Singapore%2C Thailand, and Vietnam

[16] Worldometer. Countries in Africa. 2024. Accessed 22 February 2024. https://www.worldometers.info/geography/how-many-countries-in-africa/

[17] Geberemeskel T, Woldeyohannes D, Demisie M, *et al*. Undernutrition and associated factors among adult tuberculosis patients in Hossana town public health facilities, Southern Ethiopia. J Trop Dis 2018;06:01.

[18] Wondmieneh A, Gedefaw G, Getie A, *et al*. Prevalence of undernutrition among adult tuberculosis patients in Ethiopia: a systematic review and meta-analysis. J Clin Tuberc Other Mycobact Dis 2021;22:100211.

[19] Kapata N, Chanda-Kapata P, Ngosa W, *et al*. The prevalence of tuberculosis in Zambia : results from the first national TB prevalence. PLoS One 2016;11:2013–4.

[20] Bhargava A, Benedetti A, Oxlade O, *et al*. Undernutrition and the incidence of tuberculosis in India: national and subnational estimates of the population-attributable fraction related to undernutrition. Natl Med J India 2014;27:128–33.

[21] A B. Guidelines for management of TB, DR-TB and Leprosy in Ethiopia. 2018.

[22] Houston AR, Lynch K, Ostrach B, *et al*. United States immigration detention amplifies disease interaction risk: a model for a transnational ICE-TB-DM2 syndemic. Glob. Public Health 2022;17:1152–71.

[23] Organization WH. Addressing poverty in TB control - options for national TB control programmes. 2005.

[24] Maleta K. Undernutrition. Malawi Med J 2006;18:189–205.

[25] Teshome MS, Gissa SB, Tefera BZ, *et al*. Undernutrition and its predictors among people living with HIV/AIDS attending antiretro_viral therapy clinic in Jimma University Specialized Hospital. Int J Nutr Metab 2017;9:67–74.

[26] WHO. Tuberculosis [Internet]. 2015. Accessed 24 February 2024. http://www.who.int/mediacentre/%0Afactsheets/factsheets/fs104/en/

[27] Nthiga I, David-Kigaru DM, Mugendi JB. The nutritional status of pulmonary tuberculosis patients aged 25-44 years attending tuberculosis clinic at Lodwar County and referral Hospital, Turkana County, Kenya. 2017;2:2455–4898.

[28] WHO. *Guideline: Nutritional care and support for patients with tuberculosis*. Geneva: World Health Organization; 2013.

[29] Indupalli AS, Sirwar SB, Shaikh K, *et al*. Nutritional status of tuberculosis cases registered under the tuberculosis unit of Gulbarga city, North Karnataka. India Int J Bioassays 2013;2:616–9.

[30] Sarkar M, Baidya S, Bhattacharya H. Undernutrition among pulmonary tuberculosis patients in West Tripura: a cross-sectional study. World J Pharm Res 2016;6:782–9.

[31] Jayasuriya NA, Nanayakkara L, Iddamalgoda NDK. Food security and nutrition among tuberculosis-infected patients. A case study among patients at the chest clinic in Sri Lanka 2014.

[32] Nguyen HV, Tiemersma EW, Nguyen HB, *et al*. The second national tuberculosis prevalence survey in Vietnam. PLoS One [Internet] 2020;15:e0232142.

[33] Pattiselanno Roberth Johan. Indonesia Health Profile—2015. Minist Heal Indones [Internet]. 2016;164. https://www.depkes.go.id/resources/download/pusdatin/profil-kesehatan-indonesia/%0Aindonesian health profile 2015.pdf.

[34] Lansang MA. National Tuberculosis Prevalence Survey 2016—Philippines. Dep Heal — Disease Prev Control Bur [Internet]. 2018.. http://www.ntp.doh.gov.ph/downloads/publications/%0APhilippines_2016National TB Prevalence Survey_March2018.pdf

[35] Aung ST. Results of National TB Prevalence Survey Myanmar, October 2017—September 2018. Dissemination meeting of Nationwide TB Prevalence Survey (2017–2018). Hotel Max, Naypyitaw [Internet]. 2019. http://mohs.gov.mm/Main/content/publication/tuberculosis-results-of-nationwide-tbprevalence%02survey-myanmar

[36] Annabel B, Anna D. Global Tuberculosis Report. 2019.

[37] Feleke BE, Feleke TE, Biadglegne F. Nutritional status of tuberculosis patients, a comparative cross-sectional study. BMC Pulm Med 2019;19:182.

[38] Hussien B, Hussen MM, Seid A, *et al*. Nutritional deficiency and associated factors among new pulmonary tuberculosis patients of Bale Zone Hospitals, southeast Ethiopia. BMC Res Notes 2019;12:751.

[39] Van Lettow M, Harries AD, Kumwenda JJ, *et al*. Micronutrient malnutrition and wasting in adults with pulmonary tuberculosis with and without HIV co-infection in Malawi. BMC Infect Dis 2004;4:61.

[40] WHO. Nutritional Care and Support for Patients with Tuberculosis. WHO Libr Cat 2013.

[41] Chang SW, Pan WS, Lozano Beltran D, *et al*. Gut hormones, appetite suppression and cachexia in patients with pulmonary TB. PLoS One 2013;8:e54564.
[42] Zheng Y, Ma A, Wang Q, *et al*. Relation of leptin, ghrelin and inflammatory cytokines with body mass index in pulmonary tuberculosis patients with and without type 2 diabetes mellitus. PLoS One 2013;8: e80122.
[43] Figueroa D, Guzman N, Isache C. Case report tuberculous enteritis : a rare complication of miliary tuberculosis. Case Rep Infect Dis 2016;2016: 3–6.
[44] Papathakis P, Piwoz E. Nutrition and tuberculosis: a review of the literature and considerations for TB Control Programs, 2010 Project. United States Agency Int Dev Africa's Heal 2008;1.
[45] Madebo T, Lindtjørn B. The impact of functional performance, HIV status, malnutrition, and clinical features on treatment outcomes of patients with pulmonary tuberculosis. Ethiop J Heal Dev 2000;14: 177–82.
[46] Gonzalez MC, Correia MITD, Heymsfield SB. A requiem for BMI in the clinical setting. Curr Opin Clin Nutr Metab Care 2017;20:314–21.
[47] Ramachandran P, Gopalan HS. Undernutrition and risk of infections in preschool children. Indian J Med Res 2009;130:579–83.
[48] Gurung GN, Chhetri PS, Jha N. The economic impact of pulmonary tuberculosis on patients and their families of Dhara municipality. Nepal Nep Med Coll J 2012;14:196–8.
[49] Kant S, Gupta H, Ahluwalia S. Significance of nutrition in pulmonary tuberculosis. Crit Rev Food Sci Nutr 2015;55:955–63.
[50] Hoa BN, Sy ND, Nhung VN, *et al*. A national survey of tuberculosis prevalence survey in Vietnam. Bull World Heal Organ 2010;88:273–80.
[51] Mor Z, Leventhal A, Weiler-Ravell D, *et al*. Chest radiography validity in screening pulmonary tuberculosis in immigrants from a high-burden country. Respir Care 2012;57:1137–44.
[52] Kancheya N, Luhanga D, Harris JB, *et al*. Integrating active tuberculosis case finding in antenatal services in Zambia. Int J Tuberc Lung Dis 2014; 18:1466–72.
[53] Mor Z, Weinstein O, Tischler-Aurkin D, *et al*. The yield of tuberculosis screening of undocumented migrants from the Horn of Africa based on chest radiography. Isr Med Assoc J 2015;17:11–3.
[54] Sekandi JN, Dobbin K, Oloya J, *et al*. Cost-effectiveness analysis of community active case finding and household con_ tact investigation for tuberculosis case detection in urban Africa. PLoS One [Internet] 2015. https://doi.org/10.%0A1371/journal.pone.0117009
[55] James R, Khim K, Boudarene L, *et al*. Tuberculosis active case finding in Cambodia: a pragmatic, cost-effectiveness comparison of three implementation models. BMC Infect Dis [Internet] 2017. https://doi.org/10.1186/%0As12879-017-2670-8
[56] Gregory JF, Nhung NV, Sy DN, *et al*. Household contact investigation for tuberculosis in Vietnam: study protocol for a cluster randomized controlled trial. BioMed Cent 2013;14. https://doi.org/10.1186/1745-6215-14-342
[57] Fox GJ, Nhung NV, Sy DN, *et al*. Contact investigation in households of patients with tuberculosis in Hanoi, Vietnam: a prospective cohort study. PLoS One 2012;7:e49880.
[58] Nguyen Anh et al. TB was detected by active case finding among adults in the general population of Ca Mau, Vietnam. In: The 5th Conference of the Union Asia-Pacific Region Sydney, Australia. 2015.
[59] Zero TB Vietnam Launch. Stop TB Partnership. 2017. http://www.stoptb.org/news/frompartners/2017/fp17_035.asp
[60] Fox GJ, Nhung NV, Sy DN, *et al*. Household-contact investigation for detection of tuberculosis in Vietnam. N Engl J Med 2018;378:221–9.
[61] Vietnam National Tuberculosis Programme. Annual report of the National Tuberculosis Programme, 2018. 2019.
[62] Martin. A. A conversation with Friends for International Tuberculosis Relief. GiveWell Organ [Internet]. 2019. Accessed 24 February 2024. https://files.givewell.org/files/conversations/FIT_05-08-19_(public).pdf
[63] Schwenk A, Macallan DC. Malnutrition and wasting. Curr Opin Clin Nutr Metab Care 2000;3:285–91.
[64] Chan J, Tian Y, Tanaka KE, *et al*. Effects of protein calorie malnutrition on tuberculosis in mice. Proc Natl Acad Sci USA 1996;93:14857–61.
[65] Sinclair D, Abba K, Grobler L, *et al*. Nutritional supplements for people being treated for active tuberculosis. Cochrane Database Syst Rev 2011; 11:CD006086.
[66] Priyanka, Abusalah MAH, Abusalah MAH, *et al*. Nanovaccines: a game-changing approach in the fight against infectious diseases. Biomed Pharmacother 2023;167:115597.
[67] Dockrell HM, McShane H, Dockrell HM, *et al*. Tuberculosis vaccines in the era of COVID-19-what is taking us so long? EBioMedicine 2022;79:103993.
[68] Priyanka, Chopra H, Chopra H, *et al*. mRNA vaccines as an armour to combat infectious diseases. Travel Med Infect Dis 2023;52:102550.
[69] Choudhary OP, Saini J, Challana A. ChatGPT for veterinary anatomy education: an overview of the prospects and drawbacks. Int J Morphol 2023;41:1198–202.
[70] Choudhary OP, Priyanka. ChatGPT in travel medicine: a friend or foe? Travel Med Infect Dis 2023;54:102615.
[71] Choudhary P, Shafaati M, Abu Salah MAH, *et al*. Zoonotic diseases in a changing climate scenario: revisiting the interplay between environmental variables and infectious disease dynamics. Travel Med Infect Dis 2024; 58:102694.