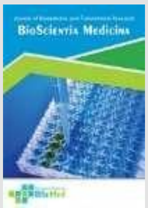
Bioscientia Medicina: Journal Of Biomedicine & Translational Research

eISSN (Online): 2598-0580



Bioscientia Medicina: Journal of Biomedicine & Translational Research

Journal Homepage: www.bioscmed.com

Unraveling the Link between Obesity and Tuberculosis: A Systematic Review of the Underlying Mechanisms

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ARTICLE INFO

Keywords:
BMI
Diabetes mellitus
Immune system
Obesity
Tuberculosis

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All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.37275/bsm.v9i2.1205

A B S T R A C T

Background: Tuberculosis (TB) and obesity are significant global health concerns with potentially complex interactions. Obesity, through its effects on metabolism, inflammation, and the immune system, may influence TB susceptibility, progression, and treatment outcomes. This systematic review aims to analyze the published literature on the relationship between obesity and TB, focusing on the underlying mechanisms. **Methods:** A systematic search of PubMed, Science Direct, and Google Scholar was conducted for articles published in the last 10 years. The search strategy included keywords such as "tuberculosis," "TB," "obesity," and "BMI." Articles were selected using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. **Results:** The review identified 11 studies that met the inclusion criteria. The studies revealed a complex relationship between obesity and TB, with nutritional status, immunity, and diabetes mellitus (DM) playing key roles. Obesity can alter the immune response to TB, potentially increasing the risk of disease and affecting treatment efficacy. **Conclusion:** The relationship between obesity and TB is multifaceted, with obesity potentially influencing both disease susceptibility and outcomes. Further research is needed to fully elucidate the underlying mechanisms and to develop targeted interventions for individuals with both obesity and TB.

1. Introduction

Tuberculosis (TB) remains a formidable global health challenge, casting a long shadow over public health efforts worldwide. The World Health Organization (WHO) estimates that approximately 1.5 million people succumbed to TB in 2020, making it one of the top 10 causes of death globally. The causative agent, Mycobacterium tuberculosis, primarily targets the lungs but can also spread to other organ systems, leading to a spectrum of clinical manifestations. The incidence of TB is intricately linked to a complex interplay of factors, including socioeconomic status, malnutrition, overcrowded living conditions, and the prevalence of HIV infection. Obesity, characterized by an excessive accumulation of body fat, has reached epidemic proportions worldwide. The WHO estimates that over 1.9 billion adults were overweight in 2016, with over 650 million classified as obese. This global surge in obesity rates has profound public health implications, as it is a major risk factor for a constellation of chronic diseases, including type 2 diabetes mellitus (DM), cardiovascular disease, and certain types of cancer. In recent years, the spotlight has been increasingly focused on the intricate relationship between obesity and TB. While both conditions are recognized as major global health threats, their interaction and the underlying mechanisms that govern their association remain incompletely understood.[1-4]

The impact of obesity on TB susceptibility, progression, and treatment outcomes is a complex and multifaceted issue. Some studies have suggested that obesity may increase the risk of TB, while others have found no association or even a protective effect. This intricate relationship is likely influenced by a constellation of factors, including nutritional status, immune function, and the presence of DM. Malnutrition, a well-established risk factor for TB, weakens the body's defenses and increases vulnerability to the disease. However, the role of obesity, a form of malnutrition characterized by excessive energy intake and/or inadequate energy expenditure, in TB susceptibility is less clear-cut. Obesity can lead to chronic low-grade inflammation, which may impair immune function and increase susceptibility to infections, including TB.[5-7]

The immune system plays a central role in defending the body against invading pathogens, including Mycobacterium tuberculosis. Obesity can exert a profound impact on immune function, potentially altering the delicate balance between host defense and pathogen evasion. Adipose tissue, particularly visceral fat, produces pro-inflammatory cytokines that can disrupt immune homeostasis. Obesity can also impair the function of key immune cells, such as macrophages and T cells, which are essential for controlling TB infection. DM, a metabolic disorder characterized by elevated blood sugar levels, is a well-established risk factor for TB. Obesity is a major risk factor for DM, and the presence of both conditions may synergistically increase the risk of TB. DM can impair immune function and increase susceptibility to infections, including TB.[8-10] This systematic review aims to delve into the published literature on the relationship between obesity and TB, focusing on the underlying mechanisms that govern this complex interplay.

2. Methods

In order to conduct a comprehensive and systematic review of the literature, we performed a thorough search of three prominent electronic databases: PubMed, Science Direct, and Google Scholar. The search was limited to articles published in the last 10 years (2014-2024) to ensure that the review captured the most recent and relevant research findings. The search strategy employed a combination of keywords relevant to the research topic, including "tuberculosis," "TB," "obesity," and "BMI." This combination of keywords was chosen to capture articles that explored the relationship between obesity and TB, using BMI as a measure of obesity. To further refine the search and ensure the inclusion of relevant studies, the search was limited to articles published in English and Indonesian. This language restriction was put in place due to the authors' language proficiency, allowing for accurate and thorough analysis of the included articles.

The inclusion and exclusion criteria were established to ensure that only relevant and high-quality studies were included in the review. The inclusion criteria were as follows; Researching TB and obesity; Including BMI or body mass index; Articles in Indonesian and English; Full text, open access; Articles published in 2014-2024; Observational study research designs including cross-sectional, case-control, and cohort; Articles or studies discussing the relationship between obesity and TB incidence. These inclusion criteria ensured that the review included original research articles that investigated the relationship between obesity and TB, were written in languages that the authors could readily analyze, and were published within the specified time frame. The exclusion criteria were as follows; Articles originating outside the databases mentioned (PubMed, ScienceDirect, and Google Scholar); Articles that were systematic reviews. These exclusion criteria were put in place to avoid the inclusion of duplicate articles and to focus the review on original research articles rather than reviews of existing literature.

Following the database search, the authors carefully screened the search results and retrieved the full text of potentially eligible studies in PDF format. Each study was then rigorously assessed against the predetermined inclusion and exclusion criteria to ensure its relevance and appropriateness for inclusion in the review. Data extraction was performed by two independent reviewers using a standardized data extraction form. This process ensured that the data extracted from each study was consistent and accurate. Any disagreements that arose during the data extraction process were resolved through discussion and consensus between the two reviewers.

3. Results

Figure 1 presents a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram, a standardized way to visually represent the process of identifying and selecting studies for a systematic review. The process began by searching through databases (likely PubMed, ScienceDirect, and Google Scholar as mentioned in the methods section) which yielded 999 records. This is the initial pool of potentially relevant articles. From the initial 999 records, duplicates were identified and removed, leaving 609 unique records. These 609 records were then screened based on their titles and abstracts. This initial screening process eliminated 338 records that did not meet the inclusion criteria for the review (e.g., wrong topic, wrong study design). This left 363 records that appeared potentially relevant. The remaining 363 records were then assessed in full-text form. This more detailed evaluation allowed the reviewers to carefully determine if the articles truly met all the inclusion criteria and did not meet any exclusion criteria. During this stage, another 14 articles were excluded. This could be due to various reasons such as: not actually addressing the research question in detail, being the wrong type of study (e.g., a review article instead of an original research article), or having poor methodological quality. This rigorous screening process resulted in a final set of 11 studies that met all the inclusion criteria and were deemed suitable for inclusion in the systematic review and quantitative synthesis.

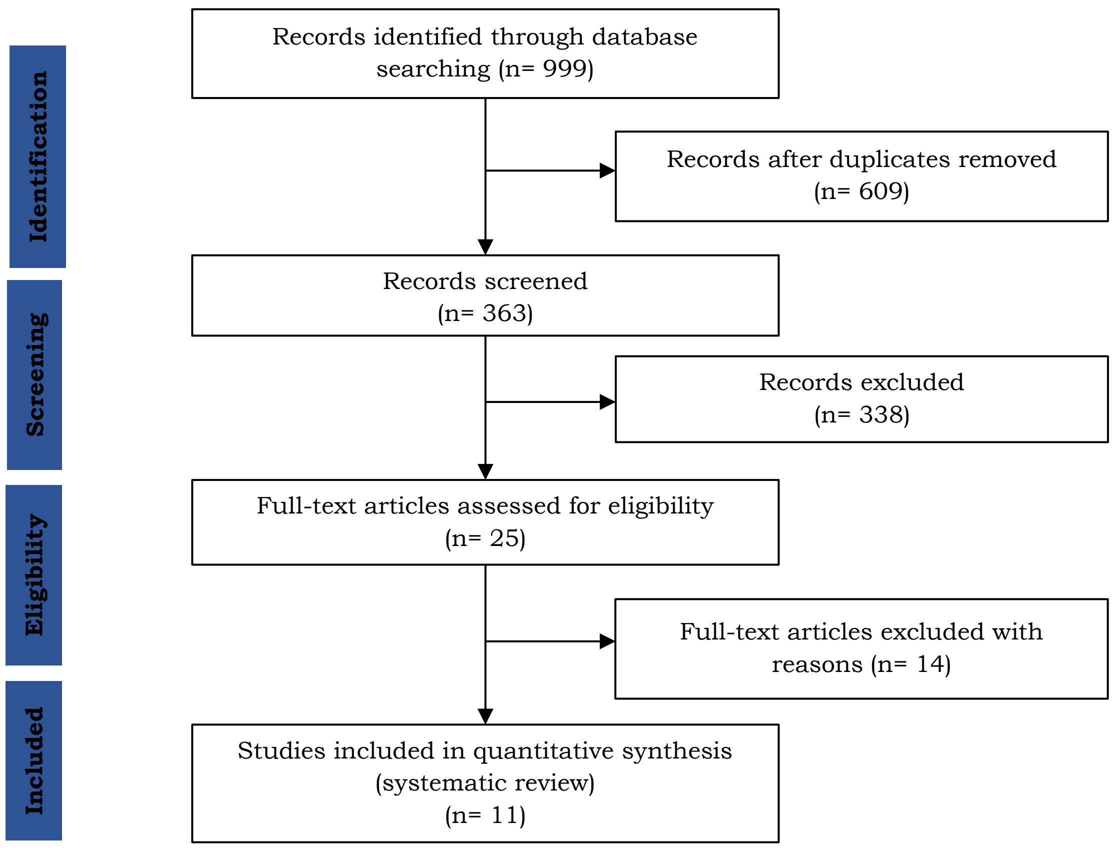

Figure 1. PRISMA flow diagram.

Table 1 provides a concise summary of the key characteristics of the 11 studies included in the systematic review, offering insights into the diversity and scope of the research on the relationship between obesity and tuberculosis (TB); Author (Year): This column identifies the primary author and year of publication for each study, allowing readers to quickly locate the original research articles; Location: This column indicates the country or region where each study was conducted. The included studies span a diverse geographical range, including Taiwan, China, India, South Africa, Korea, Canada, and Indonesia. This diversity enhances the generalizability of the review's findings; Sample Size: This column provides the number of participants included in each study, ranging from 108 to 301,183. The inclusion of studies with varying sample sizes allows for a comprehensive understanding of the obesity-TB relationship across different population scales; Study Design: This column specifies the type of study design employed in each study. The majority of the studies are cohort studies, which follow a group of individuals over time to assess the incidence of TB in relation to obesity. The inclusion of cross-sectional studies, which provide a snapshot of the relationship between obesity and TB at a specific point in time, adds another dimension to the review. Additionally, one study employs a case report design, providing in-depth information on a small group of TB patients with and without diabetes; Outcomes: This column describes the primary outcome measures or research questions addressed in each study. The outcomes are diverse, reflecting the multifaceted nature of the obesity-TB relationship. Some studies focus on the association between obesity and the risk of TB, while others explore the interaction of nutritional status and diabetes on TB, the dose-response relationship between body mass index (BMI) and TB, and the impact of lifestyle factors and comorbidities on obesity and overweight.

Table 2 delves into the specific findings of the 11 studies included in the systematic review, highlighting the complex and often nuanced relationship between obesity and tuberculosis (TB); Lin et al. (2018): This study emphasizes the complex and nonlinear relationship between obesity, diabetes mellitus (DM), and the risk of pulmonary TB. It suggests that DM may act as a mediator between BMI and pulmonary TB, and that individuals with both obesity and DM might have a lower, though not statistically significant, risk of developing pulmonary TB compared to those with normal BMI without DM; Cai et al. (2017): This study found a significant association between BMI and impaired fasting glucose (IFG) and DM in TB patients. Overweight and obesity were positively associated with DM and IFG, particularly in those with a BMI ≥ 23.41 kg/m²; Kubiak et al. (2019): This study revealed that both BMI and DM were associated with newly diagnosed active TB but not with latent tuberculosis infection (LTBI). Interestingly, while DM posed the highest risk of active TB in overweight/obese adults, the overall burden of active TB associated with DM was similar in normal and overweight/obese individuals; Chen et al. (2022): This study identified an antilog-linear dose-response relationship between BMI and the incidence of pulmonary TB. Overweight/obesity was negatively associated with the development of pulmonary TB in the general population, particularly in women and the elderly, suggesting a potential protective effect; Otang-Mbeng et al. (2017): This study found significant associations between obesity and arthritis, hypertension, and pulmonary TB, highlighting the interconnectedness of these conditions; Kim et al. (2018): This large study indicated that a high BMI could reduce the risk of TB, but a very high BMI did not further reduce the risk of pulmonary TB in young women or DM in Koreans; Lu et al. (2021): This study highlighted DM as a significant risk factor for TB, with individuals with DM having a 2.26 times higher risk of developing TB than those without DM. Interestingly, people with a BMI > 24 kg/m² and DM had the same risk as overweight participants without DM, suggesting that DM might be the primary driver of TB risk in this group; Jiang et al. (2024): This study found that individuals with a normal BMI were almost three times more likely to develop pulmonary TB compared to those with obesity. A BMI below normal increased the likelihood of developing TB tenfold compared to obesity, further supporting the notion of a protective effect of higher BMI against TB; Yen et al. (2017): This study confirmed the association between obesity and overweight with a lower risk of active TB; Badawi et al. (2021): This study found an inverse association between BMI and LTBI, suggesting that higher BMI might be protective against LTBI. However, the authors cautioned against interpreting this association as causal; Harso et al. (2017): This study, based on hospital records, found that TB-DM comorbidity was more frequent in elderly patients and those who were relatively overweight compared to TB patients without DM.

Table 1. Study characteristics.

No.	Author (Year)	Location	Sample size	Study design	Outcomes
1	Lin et al. (2018)	Taiwan	491	Cohort	Association of obesity, diabetes, and risk of tuberculosis
2	Cai et al. (2017)	China	3,505	Cohort	Association between body mass index and diabetes mellitus in tuberculosis patients
3	Kubiak et al. (2019)	India	2,032	Cross-sectional	Interaction of nutritional status and diabetes on active and latent tuberculosis
4	Chen et al. (2022)	China	26,022	Cohort	Dose-response relationship between body mass index and tuberculosis
5	Otang-Mbeng et al. (2017)	South Africa	118	Cross-sectional	Lifestyle factors and co-morbidities associated with obesity and overweight
6	Kim et al. (2018)	Korea	301,183	Cohort	Association of body mass index with incidence of tuberculosis
7	Lu et al. (2021)	China	108	Cohort	Association of BMI, diabetes, and risk of tuberculosis
8	Jiang et al. (2024)	China	246	Cohort	Tuberculosis incidence and risk factors in the elderly population
9	Yen et al. (2017)	Taiwan	42,028	Cohort	Obesity/overweight reduces the risk of active tuberculosis
10	Badawi et al. (2021)	Canada	5,156	Cross-sectional	Obesity and prevalence of latent tuberculosis
11	Harso et al. (2017)	Indonesia	7 hospitals	Case report	Sociodemographic factors and nutritional status of tuberculosis patients with and without diabetes

Table 2. The relationship between obesity and TB.

No.	Author (Year)	Country	Sample size	Finding
1	Lin et al. (2018)	Taiwan	491	Obesity, DM, and the risk of pulmonary TB are complex and nonlinear. DM as a mediator of BMI and pulmonary TB. People with obesity and DM have a lower risk of developing pulmonary TB compared to people with normal BMI without DM, but the risk is not statistically significant.
2	Cai et al. (2017)	China	3,505	BMI is significantly associated with impaired fasting glucose (IFG) and DM in TB patients. Overweight and obesity are positively associated with DM and IFG in patients with pulmonary TB. BMI ≥23.41 kg/m² (Q4) increasing the prevalence of DM and IFG.
3	Kubiak et al. (2019)	India	2,032	BMI and DM were associated with newly diagnosed active TB, but not with latent tuberculosis infection (LTBI). DM has the highest risk of developing active TB in overweight/obese adults, but the burden of active TB associated with DM is similar in normal and overweight/obese adults.
4	Chen et al. (2022)	China	26,022	There is an antilog-linear dose-response relationship between BMI and the incidence of pulmonary TB. Overweight/obesity is negatively associated with the development of pulmonary TB in the general population and subgroups of women and the elderly.
5	Otang-Mbeng et al. (2017)	South Africa	118	Arthritis, hypertension, and pulmonary tuberculosis have significant associations with obesity.
6	Kim et al. (2018)	Korea	301,183	A high BMI can reduce the risk of TB. Very high BMI does not reduce the risk of pulmonary TB in young women or DM in Koreans.
7	Lu et al. (2021)	China	108	People with DM have a 2.26 times higher risk of developing TB than people without DM. People with BMI > 24 kg/m² and diagnosed with DM have the same risk as overweight participants without DM. DM with a BMI < 24 kg/m² is a risk factor for developing active TB (compared to non-DM with a BMI < 24 kg/m²).
8	Jiang et al. (2024)	China	246	Normal BMI is almost three times more likely to develop pulmonary TB compared to obesity. A BMI below normal is ten times more likely to develop TB than obesity.
9	Yen et al. (2017)	Taiwan	42,028	Obesity and overweight are associated with a lower risk of active TB.
10	Badawi et al. (2021)	Canada	5,156	Improvement in BMI was significantly associated with a lower risk of LTBI. The observed inverse association between obesity and LTBI reflects an association between the two conditions but should not be interpreted as an inference of causation.
11	Harso et al. (2017)	Indonesia	7 hospitals	Based on TB-DM records in 2014, comorbidity of TB and DM occurred more frequently in elderly patients and those relatively overweight compared to TB patients without DM.

Table 3 focuses specifically on the studies from the systematic review that found an association between obesity and a reduced risk of tuberculosis (TB). This provides a closer look at a particularly interesting aspect of the obesity-TB relationship that challenges the traditional view of obesity as a risk factor for infectious diseases; Chen et al. (2022): This study in China, with a large sample size of 26,022 individuals, found an "antilog-linear dose-response relationship" between BMI and the incidence of pulmonary TB. This means that as BMI increased, the risk of TB decreased, but not in a perfectly linear fashion. Importantly, they found that being overweight or obese was negatively associated with developing pulmonary TB in the general population and specifically in women and the elderly; Kim et al. (2018): This Korean study, with an even larger sample size of 301,183, also supported the idea that higher BMI could reduce the risk of TB. However, they added an interesting caveat: a *very* high BMI did not seem to further reduce the risk of pulmonary TB in young women or in individuals with diabetes. This suggests that there might be a "sweet spot" in terms of BMI for TB protection, and exceeding that might not confer additional benefits; Yen et al. (2017): This Taiwanese study, with a sample size of 42,028, simply confirmed the association between obesity and overweight with a lower risk of active TB.

Table 3. Several studies found that obesity was associated with a reduced risk of TB.

No.	Author (Year)	Country	Sample size	Finding
1	Chen et al. (2022)	China	26,022	There is an antilog-linear dose-response relationship between BMI and the incidence of pulmonary TB. Overweight/obesity is negatively associated with the development of pulmonary TB in the general population and subgroups of women and the elderly.
2	Kim et al. (2018)	Korea	301,183	A high BMI can reduce the risk of TB. Very high BMI does not reduce the risk of pulmonary TB in young women or DM in Koreans.
3	Yen et al. (2017)	Taiwan	42,028	Obesity and overweight are associated with a lower risk of active TB.

Table 4 dives deeper into the underlying mechanisms that might explain the complex relationship between obesity and TB, drawing on findings from five of the studies included in the systematic review; Lin et al. (2018): This Taiwanese study highlights the intricate interplay between obesity, diabetes (DM), and pulmonary TB. It suggests that the relationship is not straightforward, with DM potentially acting as a mediator between BMI and TB risk. Interestingly, people with both obesity and DM might have a lower risk of developing pulmonary TB compared to those with normal BMI without DM, although this difference wasn't statistically significant. This finding hints at the complex interplay of metabolic factors in TB susceptibility; Cai et al. (2017): This Chinese study found a significant association between BMI and impaired fasting glucose (IFG) and DM in TB patients. Overweight and obesity were positively associated with DM and IFG, particularly in those with a BMI ≥ 23.41 kg/m². This suggests that obesity, particularly in higher ranges, might exacerbate metabolic dysfunction in TB patients, potentially influencing disease progression and outcomes; Kubiak et al. (2019): This Indian study adds another layer of complexity by differentiating between active TB disease and latent TB infection (LTBI). Both BMI and DM were associated with newly diagnosed active TB but not with LTBI. Interestingly, while DM posed the highest risk of active TB in overweight/obese adults, the overall burden of active TB associated with DM was similar in normal and overweight/obese individuals. This suggests that the interplay between obesity, DM, and TB might differ depending on the stage of TB infection; Lu et al. (2021): This Chinese study emphasizes the role of DM as a significant risk factor for TB, independent of BMI. People with DM had a 2.26 times higher risk of developing TB than those without DM. Notably, people with a BMI > 24 kg/m² and diagnosed with DM had the same risk as overweight participants without DM. This underscores the importance of DM as a key driver of TB risk, potentially overshadowing the influence of BMI in certain individuals; Harso et al. (2017): This Indonesian study, based on hospital records, found that TB-DM comorbidity was more frequent in elderly patients and those who were relatively overweight compared to TB patients without DM. This further supports the link between obesity, DM, and TB, particularly in older individuals who might be more susceptible to the combined effects of these conditions.

Table 4. Underlying mechanisms of obesity and TB.

No.	Author (Year)	Country	Sample size	Finding
1	Lin et al. (2018)	Taiwan	491	Obesity, DM, and the risk of pulmonary TB are complex and nonlinear. DM as a mediator of BMI and pulmonary TB. People with obesity and DM have a lower risk of developing pulmonary TB compared to people with normal BMI without DM, but the risk is not statistically significant.
2	Cai et al. (2017)	China	3,505	BMI is significantly associated with impaired fasting glucose (IFG) and DM in TB patients. Overweight and obesity are positively associated with DM and IFG in patients with pulmonary TB. BMI ≥23.41 kg/m² (Q4) increasing the prevalence of DM and IFG.
3	Kubiak et al. (2019)	India	2,032	BMI and DM were associated with newly diagnosed active TB, but not with latent tuberculosis infection (LTBI). DM has the highest risk of developing active TB in overweight/obese adults, but the burden of active TB associated with DM is similar in normal and overweight/obese adults.
4	Lu et al. (2021)	China	108	People with DM have a 2.26 times higher risk of developing TB than people without DM. People with BMI > 24 kg/m² and diagnosed with DM have the same risk as overweight participants without DM. DM with a BMI < 24 kg/m² is a risk factor for developing active TB (compared to non-DM with a BMI < 24 kg/m²).
5	Harso et al. (2017)	Indonesia	7 hospitals	Based on TB-DM records in 2014, comorbidity of TB and DM occurred more frequently in elderly patients and those relatively overweight compared to TB patients without DM.

4. Discussion

The relationship between obesity and tuberculosis (TB) is a complex interplay influenced by numerous interconnected factors. While our systematic review highlighted the seemingly paradoxical findings – obesity sometimes increases and sometimes decreases TB risk – understanding the underlying mechanisms is crucial to unraveling this intricate connection. Classically, malnutrition has been strongly linked to increased TB susceptibility. This is because malnutrition weakens the immune system, making individuals more vulnerable to infections. However, obesity presents a unique form of malnutrition – overnutrition. While characterized by excess energy intake, it can often coexist with micronutrient deficiencies and metabolic imbalances that compromise immune function. One of the key ways obesity may increase TB risk is through chronic, low-grade inflammation. Adipose tissue, particularly visceral fat, acts as an endocrine organ, releasing pro-inflammatory cytokines (like TNF-alpha, IL-6) that disrupt immune homeostasis. This chronic inflammatory state can impair the body's ability to mount an effective immune response against Mycobacterium tuberculosis. On the other hand, some studies suggest that obesity could offer a protective effect against TB. One hypothesis is that individuals with higher BMI might have greater energy reserves and nutritional stores to draw upon during the energy-intensive process of fighting infection. This could provide an advantage in combating the metabolic demands of TB. It's crucial to remember that obesity doesn't equate to optimal nutrition. Individuals with obesity may still have deficiencies in essential micronutrients (vitamin D, zinc, iron) that are critical for immune function and TB defense. Therefore, focusing solely on BMI might oversimplify the picture. Obesity can profoundly impact the function of various immune cells critical in the fight against TB. Macrophages cells engulf and destroy Mycobacterium tuberculosis. Obesity can impair macrophage function, reducing their ability to phagocytose (engulf) the bacteria and effectively kill them. This allows the bacteria to survive and potentially proliferate within macrophages. T cells, particularly CD4+ T cells, are essential for orchestrating the immune response against TB. Obesity can lead to a decrease in the number and function of these cells, hindering the body's ability to control TB infection. This can result in a less effective adaptive immune response, making individuals more susceptible to active TB disease or reactivation of latent TB infection. Obesity can also alter the balance of different types of immune responses. It can promote a shift towards a Th2-dominant response (associated with antibody production and allergic reactions) and away from a Th1 response (crucial for cell-mediated immunity against intracellular pathogens like Mycobacterium tuberculosis). This imbalance can further compromise the body's ability to effectively combat TB. While obesity generally disrupts immune function, it's possible that certain obesity-induced immune changes might inadvertently hinder Mycobacterium tuberculosis. For example, alterations in lipid metabolism or specific inflammatory pathways could create an environment less hospitable to the bacteria's survival or replication. This area warrants further investigation. DM, a chronic metabolic disorder characterized by hyperglycemia (high blood sugar), significantly impairs immune function. This makes individuals with DM more susceptible to various infections, including TB. High blood sugar levels can hinder the ability of immune cells, like neutrophils and macrophages, to effectively engulf and destroy bacteria. DM can also negatively impact T cell function, affecting their ability to recognize and eliminate infected cells. Obesity is a major risk factor for DM. When obesity and DM coexist, their combined impact on immune dysfunction can synergistically increase the risk of TB. This is supported by studies in our review that found a higher risk of TB in individuals with both obesity and DM compared to those with obesity alone. Importantly, our review highlighted that DM often acts as an independent risk factor for TB, regardless of BMI. This emphasizes the critical need for effective DM management in TB prevention and treatment, even in individuals who are not obese. Understanding these underlying mechanisms is crucial for developing targeted interventions to address the complex interplay between obesity and TB. Delineating the precise molecular and cellular pathways linking obesity, inflammation, immune dysfunction, and TB susceptibility. Developing personalized risk assessment and intervention strategies that consider individual factors like BMI, body composition, metabolic health, and nutritional status. Exploring potential immunomodulatory therapies that could mitigate the negative impact of obesity on the immune response to TB. Implementing integrated healthcare approaches that address both obesity and TB, recognizing their interconnectedness and shared risk factors. By further unraveling these complex mechanisms, we can pave the way for more effective prevention and treatment strategies for both obesity and TB, ultimately improving global health outcomes.[11-14]

The findings of our systematic review underscore the importance of recognizing the complex interplay between obesity and tuberculosis (TB) in clinical practice. Moving beyond simply viewing obesity as a potential risk factor, clinicians need to understand the nuanced ways it can influence TB susceptibility, progression, and treatment outcomes. Clinicians are well-versed in recognizing traditional TB risk factors like HIV infection, malnutrition, and crowded living conditions. However, it's crucial to incorporate obesity into this risk assessment framework, acknowledging its potential to modulate TB risk both positively and negatively. BMI alone is not sufficient. Clinicians should consider the individual's overall metabolic health, including the presence of diabetes (DM), dyslipidemia, and other obesity-related comorbidities. This comprehensive assessment allows for a more accurate estimation of TB risk and guides tailored interventions. Obesity can influence the clinical presentation of TB, potentially masking or mimicking symptoms. For instance, fatigue and shortness of breath, common TB symptoms, might be attributed to obesity itself, leading to delayed diagnosis. Clinicians should maintain a high index of suspicion for TB in individuals with obesity, even if their symptoms are atypical. While universal TB screening might not be feasible, targeted screening is essential for individuals with obesity, particularly those with additional risk factors like DM, history of latent TB infection (LTBI), or close contact with TB patients. Clinicians should utilize appropriate screening tools, including tuberculin skin tests (TST) or interferon-gamma release assays (IGRAs), to identify individuals with LTBI. Prompt diagnosis and treatment of LTBI can prevent progression to active TB disease. Healthcare visits provide opportunities for opportunistic TB screening in individuals with obesity. This is particularly important in settings with a high prevalence of TB or when individuals present with symptoms suggestive of TB, such as persistent cough, fever, weight loss, or night sweats. Clinicians should actively counsel and educate patients with obesity about the potential link between obesity and TB. Emphasizing the importance of lifestyle modifications as a cornerstone of TB prevention and overall health management is crucial. Provide guidance on adopting a balanced and nutritious diet that supports immune function and helps achieve and maintain a healthy weight. This may involve referral to a registered dietitian for personalized dietary counseling. Encourage regular physical activity, tailored to the individual's abilities and preferences. Exercise has numerous benefits, including improving immune function, reducing inflammation, and aiding in weight management. Offer behavioral support and resources to help patients make sustainable lifestyle changes. This may include referral to weight management programs, support groups, or mental health professionals. In individuals with both obesity and DM, optimizing DM management is paramount. Achieving and maintaining good glycemic control is crucial not only for preventing diabetes-related complications but also for reducing TB risk. Clinicians should emphasize the importance of medication adherence and provide support to ensure patients are taking their prescribed medications as directed. Closely monitor blood glucose levels, HbA1c, and other relevant metabolic parameters to assess DM control and adjust treatment as needed. Educate patients about the link between DM and TB, emphasizing the importance of DM management in reducing their risk of TB and other infections. Obesity can alter the pharmacokinetics of TB medications, potentially affecting their absorption, distribution, metabolism, and excretion. Clinicians should be aware of these potential interactions and consider adjusting dosages or treatment regimens accordingly. Obesity can be associated with various factors that might hinder treatment adherence, such as stigma, depression, and physical limitations. Clinicians should address these barriers and provide support to ensure patients complete their full course of TB treatment. Individuals with obesity might be at a higher risk of developing certain TB-related complications, such as multidrug-resistant TB (MDR-TB) or extrapulmonary TB. Clinicians should closely monitor for these complications and provide prompt and appropriate treatment. By integrating the findings of our systematic review into clinical practice, healthcare providers can play a crucial role in preventing and managing TB in individuals with obesity. Keeping abreast of the latest research on the obesity-TB connection and emerging evidence-based guidelines. Providing patient-centered care that considers individual needs and preferences. Working collaboratively with other healthcare professionals, such as dietitians, endocrinologists, and mental health professionals, to provide comprehensive care. Advocating for policies and programs that support healthy lifestyles and address the social determinants of health that contribute to both obesity and TB. By adopting a proactive and holistic approach, clinicians can empower individuals with obesity to reduce their risk of TB, improve treatment outcomes, and achieve optimal health.[15-17]

Our systematic review not only sheds light on the intricate relationship between obesity and tuberculosis (TB) at the individual level but also carries significant implications for public health strategies and interventions. By recognizing the interconnectedness of these two global health challenges, we can develop more effective and holistic approaches to prevention and management. Traditionally, public health interventions have often addressed obesity and TB in silos. However, our findings highlight the need for an integrated approach that recognizes the shared risk factors and synergistic effects of these conditions. Both obesity and TB are influenced by common social determinants of health, such as poverty, food insecurity, inadequate housing, and limited access to healthcare. Public health interventions should target these upstream determinants to create supportive environments that promote healthy behaviors and reduce the risk of both conditions. Developing comprehensive strategies that address both obesity and TB can lead to synergistic benefits. For example, programs promoting healthy eating and physical activity not only reduce obesity risk but also strengthen immune function and decrease TB susceptibility. Effective integrated approaches require collaboration and coordination among various stakeholders, including healthcare providers, public health agencies, community organizations, and policymakers. Public health efforts should focus on creating environments that support healthy lifestyle choices. Improving access to affordable, nutritious foods in underserved communities. Creating safe and accessible spaces for physical activity, such as parks, walking trails, and recreational facilities. Implementing policies to restrict the marketing of unhealthy foods and beverages, particularly to children. Empowering individuals and communities with knowledge and skills to make healthy choices is essential. Providing education on healthy eating habits, portion control, and label reading. Encouraging regular physical activity through community programs, workplace initiatives, and school-based interventions. Offering behavioral counseling and support to help individuals adopt and maintain healthy lifestyles. Promoting healthy lifestyles from an early age is crucial. School-based programs that incorporate nutrition education, physical activity, and healthy lifestyle promotion can help establish healthy habits and prevent obesity and its associated complications, including TB. Obesity and TB disproportionately affect vulnerable populations, such as those with lower socioeconomic status, racial and ethnic minorities, and individuals living in marginalized communities. Developing and implementing targeted interventions that address the unique needs and challenges of vulnerable populations. Engaging with communities to understand their specific needs and preferences and to ensure that interventions are culturally appropriate and accessible. Addressing barriers to healthcare access, such as cost, transportation, and language barriers. Addressing the social and economic factors that contribute to health disparities is crucial. Implementing policies to reduce poverty and income inequality. Ensuring access to safe and affordable nutritious food for all. Improving housing conditions and access to quality education. Identifying populations and communities at high risk for both conditions. Monitoring the prevalence and incidence of obesity and TB over time. Early detection of TB outbreaks, particularly in congregate settings or high-risk communities. Assessing the effectiveness of programs and policies in reducing obesity and TB rates. Identifying areas where programs can be improved to maximize their impact. Guiding resource allocation to ensure that interventions are reaching the populations most in need. Promoting data sharing and collaboration among public health agencies, researchers, and healthcare providers can enhance surveillance efforts and facilitate the development of evidence-based interventions. Addressing the intertwined challenges of obesity and TB requires a comprehensive and collaborative public health approach. By integrating interventions, promoting healthy lifestyles, prioritizing vulnerable populations, and strengthening surveillance and monitoring, we can make significant strides in reducing the burden of these conditions and improving global health outcomes.[18-20]

5. Conclusion

Obesity and TB are global health concerns with a complex and multifaceted relationship. This systematic review, conducted in line with PRISMA guidelines, provides a comprehensive analysis of the underlying mechanisms linking obesity and TB, drawing on evidence from 11 eligible studies. Our findings highlight the diverse and often contradictory nature of this relationship, with obesity sometimes increasing and sometimes decreasing TB risk. The review underscores the critical role of nutritional status, immunity, and diabetes mellitus (DM) in the interplay between obesity and TB. It emphasizes how obesity, through its effects on metabolism, inflammation, and immune function, may influence TB susceptibility, progression, and treatment outcomes. While obesity can lead to chronic low-grade inflammation and impair immune function, potentially increasing TB risk, it can also offer a protective effect against TB, possibly due to greater energy reserves and nutritional stores. The review also points to the significant role of DM as an independent risk factor for TB, regardless of body mass index (BMI). The presence of both obesity and DM can synergistically increase the risk of TB, underscoring the importance of effective DM management in TB prevention and treatment. These findings have significant implications for clinical practice and public health interventions. Clinicians need to consider obesity and its related metabolic factors when assessing and managing TB risk in individuals, while public health strategies should integrate approaches to address both obesity and TB, recognizing their shared risk factors and synergistic effects. Further research is needed to fully elucidate the complex mechanisms linking obesity and TB, develop targeted interventions, and improve global health outcomes.

6. References

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