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ORIGINAL ARTICLE

Evaluation of Inflammatory Cytokines and Vitamin D3 Serum Levels in Patients with Tuberculosis in Baghdad, Iraq

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ABSTRACT

Background: Tuberculosis (TB) due to *Mycobacterium tuberculosis* infection is a public health issue frequently connected with cytokine storm. Vitamin D3 deficiency was shown to increase the susceptibility to TB. This study assessed the serum levels of inflammatory cytokines and vitamin D3 in Iraqi patients infected to TB.

Methods: A total of 3 mL of blood was collected from 72 TB patients and 72 healthy controls to evaluate the interleukin-2 (IL-2), IL-10, and IL-17 levels by Enzyme-Linked Immunosorbent Assay (ELISA), and the vitamin D3 level using auto-analyzer.

Results: A significant increase in IL-2 (p<0.0001), IL-10 (p<0.0001), and IL-17 (p<0.05) in TB patients was noticed compared to control group. A significant decrease in vitamin D3 was observed in TB patients compared to control group (p<0.02). Among TB patients a significant increase was seen in IL-2 (p<0.002), IL-10 (p<0.05), and non-significant increase in IL-17 (p<0.13). A significant decrease in vitamin D3 (p<0.05) was demonstrated among drug resist patients compared to drug sensitive patients within TB group.

Conclusion: IL-2, IL-10, and IL-17 serum levels were illustrated to be useful immunodiagnostic markers between TB-infected patients and TB-uninfected individuals. Vitamin D3 was demonstrated to have supportive role in TB patients.

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Introduction

Mycobacterium tuberculosis is the causative agent of Tuberculosis disease and the leading cause of morbidity and mortality globally (1). Cytokines are low molecular weight (135 KDa) soluble proteins secreted by immune and non-immune cells. They have a substantial role in communication between the immune cells and act as chemical signal messengers between the immune cells. Cytokines modulate and regulate the growth, differentiation, activity and migration of cells, inflammation, immunity, and tissue repair. In general, cytokines are produced by immune cells like T cells, macrophages, dendritic cells (DCs), natural killer (NK) cells, and B cells, and other cells like Schwann, endothelial, and mast cells (2, 3).

Cytokines may affect the same cell that produced them (autocrine action), have the effect on nearby cells (paracrine action), or impact distant cells (endocrine action). Cytokines have a Pleiotropy property, which

means one cytokine can affect different cell types, or different cell types that secrete the same cytokine. Also, cytokines are redundant in their activity, as different cytokines perform similar functions (2, 3). According to the structure and function of cytokines, they are classified into interleukin (IL), interferon (IFN), tumor necrosis factor (TNF), chemokine, transforming growth factor (TGF) and colony stimulating factor (CSF) (4).

Interleukin 2 (IL-2) is secreted by activated CD4+ Th1 cells and is produced by CD8+ T cells, NK cells, and DCs. Interleukin 2 (IL-2) has a prominent role in the immune system and tolerance and prevents autoimmune diseases by promoting the differentiation of naïve T cells into regulatory T cells and induces apoptosis (5). IL-2 contributes to both the induction and suppression of inflammation and can act as a pro-inflammatory cytokine by promoting the activation of T cells, DCs, and NK cells, and as an anti-inflammatory cytokine (6). IL-2 is essential for Th-17 and Treg cells development, promotes proliferation of NK cells and increases their cytotoxic function (7). IL-2 also acts as a B cell growth factor and stimulates antibody synthesis; while these roles are important in granuloma formation during TB infection. During TB infection, IL-2 has a role in the cell-mediated immune response and granuloma formation by inducing the proliferation and activation of T cells (8).

Interleukin 10 (IL-10) is an immunosuppressive protein produced by various immune cells, such as monocytes, DCs, mast cells and B and T cells, especially regulatory T cells (Treg cells). IL-10 has an important role in the inflammatory immune response to pathogens. It is also involved in autoimmunity, cancers, sterile wound healing, and homeostasis (9). IL-10 is an anti-inflammatory cytokine that regulates the immune response and inflammation by suppressing the pro-inflammatory production and affecting the growth, differentiation, and proliferation (10). It prevents the production of pro-inflammatory cytokines, like Interferon gamma (IFN-γ), which is important in macrophage activation (11).

A subset of CD4+ T cells called T helper 17 cells (Th-17) produce Interleukin 10 (IL-17) (12). IL-17 consists of six members of ILA, ILB, ILC, ILE, ILD, and ILF. IL-17 has a central role in the activation of neutrophils in infected tissues (13). Neutrophil helps granuloma formation during TB infection (14). The T helper 17 cells are controlled by IL-10 and TGF-β to prevent their over-stimulation. IL-17A can be produced by other cells such as, CD4+ and CD8+ T cells, NK cells, and neutrophils; and affect the target cells like, T cells, epithelial cells, fibroblasts, macrophages, and also B cells, to produce cytokines and antibodies and induce inflammation that helps immunity against TB (13).

It seems nutrition has an important role to control many diseases (15). Vitamin D3 is a fat-soluble vitamin known for calcium homeostasis, has a role in calcium absorption, and maintains bone mineral density. Vitamin D3 is a multi-functional vitamin and plays an important role in several biological processes such as immune regulation, cellular proliferation and differentiation, central nervous system function, and provides immunity against microbial pathogens (16). Several studies have shown that vitamin D3 deficiency is a risk factor for TB infection (17, 18).

Vitamin D3 contributes to the innate immunity due to its role in regulating macrophages' function and stimulating the human anti-mycobacterial activity. Some researchers have shown their role in enhancing phagocytosis of macrophages, stimulating production of cathelicidin anti-microbial peptide, and cytokines. It also accelerates the death of intracellular *M. tuberculosis*, and the binding of vitamin D3 with its receptor that may prevent or limit *M. tuberculosis* infection by regulating the expression of genes involved in the cytokine production (19).

Materials and Methods

Seventy two TB patients (out of 438) as new TB and under-treated TB patients, together with 72 healthy controls were enrolled in this study in 2025. A total of 3 mL of venous blood was taken from an infected person and the healthy control group, transferred into a gel tube, left to clot, and centrifuged. The serum was kept in the freezer until use. The Ethics Committee of Mustansiriyah University oversaw and approved this study (Ethics code: BCSMU/1221/00050M). The serum concentration levels of IL-2, IL-10, and IL-17 were determined using Shanghai Coon Koon Biotech kits (China), based on the principle of double antibody sandwich technology enzyme linked immune-sorbent assay (ELISA). The Abbott Architect *i*-1000 (auto-analyzer) was used to determine the Vitamin D3 serum level. Normal range of Vitamin D3 was considered 30-40 ng/mL.

The statistical analysis was carried out by SPSS software (Version 20, Chicago, IL, USA). The ANOVA one way test was used to analyze repeated measures between tested groups. Data were expressed as mean±SD and other descriptive statistics. For the descriptive analysis, they were subjected to Chi-square test. Values of $p>0.05$ were considered statically non-significant while $p\leq0.05$ were considered significant. Correlation coefficient between difference parameters in this study was determined too.

Table 1: Distribution of patients and the healthy controls in relation to age and sex.

Age (Years)	Patients			Healthy controls		
	Male	Female	Total	Male	Female	Total
11-20	5	4	9	6	5	11
21- 30	7	10	17	11	5	16
31- 40	13	7	20	10	9	19
41- 50	13	2	15	7	8	15
51- 60	7	1	8	6	2	8
61- 70	1	1	2	2	1	3
71- 80	1	0	1	0	0	0
Total number	47	25	72	42	30	72
Percentage	65.27	34.72	100	58.33	41.66	100

Table 2: Serum concentration of IL-2, IL-10, IL-17 and vitamin D3 among drug resistant and drug sensitive patients when compared to control group.

Immune marker		Drug resistant patients	Drug sensitive patients	Control groups
IL-2	No.	34	38	72
(pg/mL)	Mean	2862.85	2596.04	108.27
	P value	0.002** sig		0.0001** sig
IL-10 (pg/mL)	N	34	38	72
	Mean	159.48	134.31	44.50
	P value	0.01** sig		0.0001** sig
IL-17 (pg/mL)	N	34	38	72
	Mean	12.40	13.47	7.05
	P value	0.13** Non-sig		0.05** sig
Vitamin D3 (ng/mL)	N	34	38	72
	Mean	13.64	19.65	29.58
	P value	0.05** sig		0.02** sig

**$P \leq 0.05$ is considered statistically significant, IL=Interleukin.

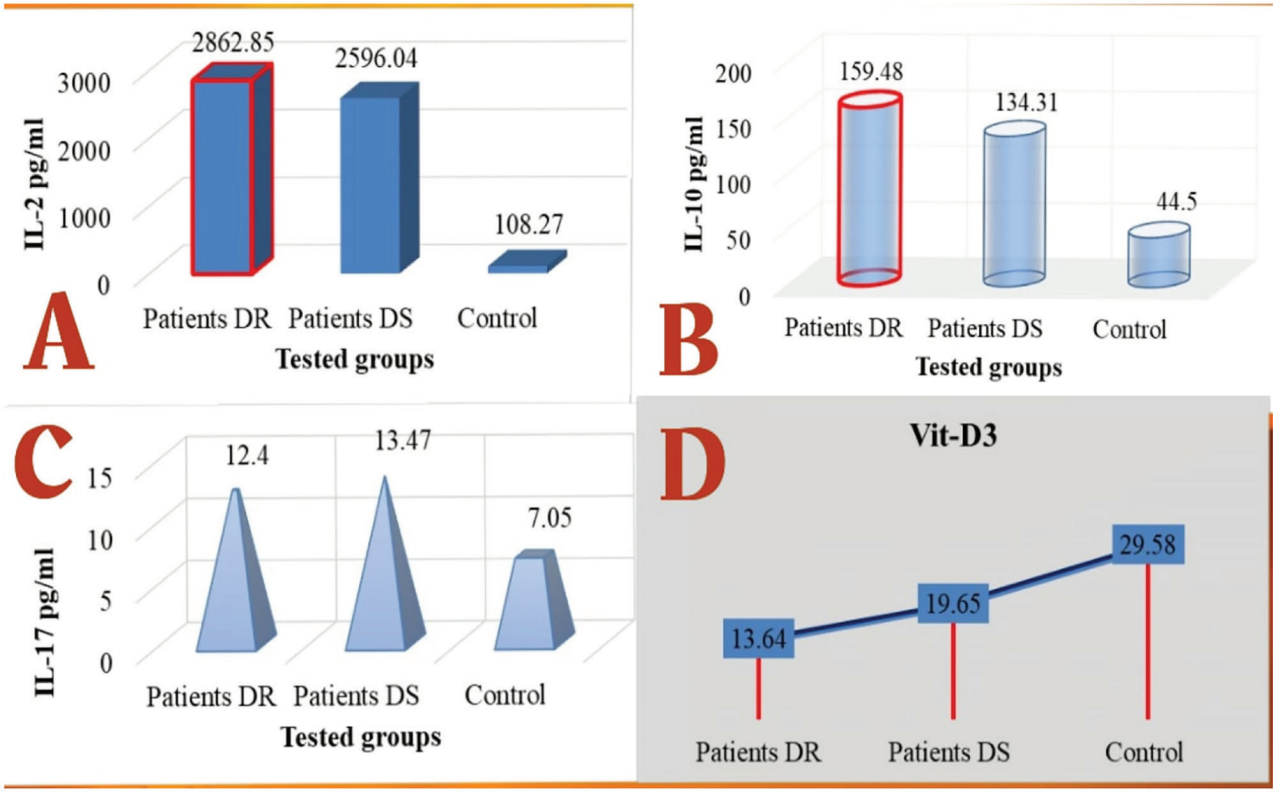

Figure 1: Serum concentration of IL-2, IL-10, IL-17 and vitamin D3 among tested groups. Vit-D3: Vitamin D3, DR: Drug-resistance, DS: Drug-sensitive.

Results

Patients were separated into seven age groups, each increasing by 10 years, ranging from 11-20 to 71–80 years; while the mean age was 36.31±13.6 years. The age of healthy controls was divided into 6 groups, each increasing by 10 years, ranging from 11-20 to 61-70 years; while the mean age was 35.8±13.2 years (Table 1). There was a significant difference between male and female patients (p<0.002). The ratio of male-to-female was 2:1, where most of the infected patients were male [n=47 (65.27%)], and the minority infected patients were female [n=25 (34.72%)]. This ratio may be attributed to physiological differences between males and females that result in males being more susceptible to TB infection than females.

A significant increase in the serum concentration of IL-2 in the TB patients was noticed when compared to the control group (p<0.0001). Among TB patients, a significant increase in the serum concentration of IL-2 was demonstrated among drug-resistant and drug-sensitive patients within TB patients (p<0.002) (Table 2 and Figure 1A). A significant increase in the serum concentration of IL-10 in the TB patients was observed when compared to the control group (p<0.0001). Among TB patients, the a significant increase in the serum concentration of IL-2 was visible among drug-resistant and drug-sensitive patients within TB patients (p<0.002) (Table 2 and Figure 1B).

Table 3: The correlations of age, IL-2, IL-10, IL-17 with vitamin D3 in drug-resistance TB patients.

Correlations						
Drug-resistance patients		**Age**	**IL-2**	**IL-10**	**IL-17**	**Vitamin D3**
Age	Pearson correlation	1	-0.228	0.068	0.085	0.115
	Sig. (2-tailed)		0.194	0.703	0.632	0.515
	No.	34	34	34	34	34
IL-2	Pearson correlation	-0.228	1	-0.057	0.134	-0.121
	Sig. (2-tailed)	0.194		0.750	0.450	0.496
	No.	34	34	34	34	34
IL-10	Pearson correlation	0.068	-0.057	1	0.765**	0.051
	Sig. (2-tailed)	0.703	0.750		0.000	0.775
	No.	34	34	34	34	34
IL-17	Pearson correlation	0.085	0.134	0.765**	1	-0.020
	Sig. (2-tailed)	0.632	0.450	0.000		0.911
	No.	34	34	34	34	34
Vitamin D3	Pearson correlation	0.115	-0.121	0.051	-0.020	1
	Sig. (2-tailed)	0.515	0.496	0.775	0.911	
	No.	34	34	34	34	34

** Correlation was significant at 0.01 level (2-tailed), Il: Interleukin, No.: Number, TB: Tuberculosis.

Table 4: The correlations of age, IL-2, IL-10, IL-17 with vitamin D3 in drug-sensitive TB patients.

Correlation						
Drug-sensitive patients		**Age**	**IL-2**	**IL-10**	**IL-17**	**Vitamin D3**
Age	Pearson correlation	1	-0.015	-0.159	-0.191	-0.224
	Sig. (2-tailed)		0.928	0.341	0.251	0.177
	No.	38	38	38	38	38
IL-2	Pearson correlation	-0.015	1	0.165	0.614**	0.702**
	Sig. (2-tailed)	0.928		0.322	0.000	0.000
	No.	38	38	38	38	38
IL-10	Pearson correlation	-0.159	0.165	1	0.600**	0.502**
	Sig. (2-tailed)	0.341	0.322		0.000	0.001
	No.	38	38	38	38	38
IL-17	Pearson correlation	-0.191	0.614**	0.600**	1	0.820**
	Sig. (2-tailed)	0.251	0.000	0.000		0.000
	No.	38	38	38	38	38
Vitamin D3	Pearson correlation	-0.224	0.702**	0.502**	0.820**	1
	Sig. (2-tailed)	0.177	0.000	0.001	0.000	
	No.	38	38	38	38	38

** Correlation was significant at the 0.01 level (2-tailed), Il: Interleukin, No.: Number, TB: Tuberculosis.

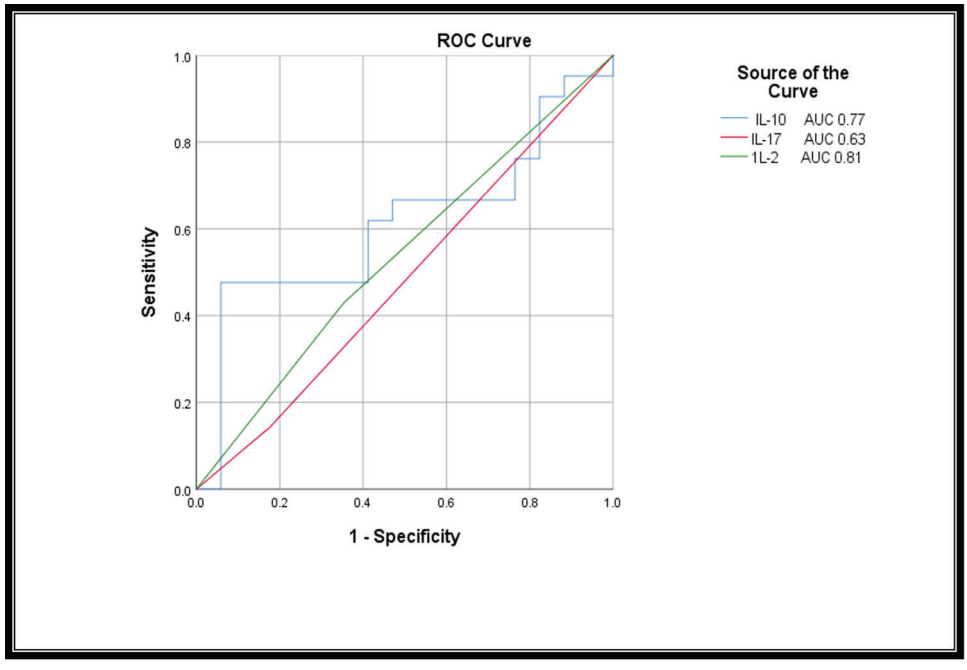

Figure 2: Area under the curve (AUC)/Receiver operating characteristic for IL-2, IL-10, and IL-17.

A significant increase in the serum concentration of IL-17 was seen in the TB patients when compared to the control group (p<0.05). Among TB patients, a non-significant increase in the serum concentration of IL-17 was exhibited among drug-resistant and drug-sensitive patients within TB patients (p<0.13) (Table 2 and Figure 1C). A significant decrease in the serum concentration of vitamin D3 in the TB patients was displayed in comparison to the control group (p<0.02). Among TB patients, a significant decrease in the serum concentration of vitamin D3 was illustrated among drug-resistant and drug-sensitive patients within TB patients (p<0.05) (Table 2 and Figure 1D).

A positive correlation was shown between serum IL-10 and IL-17 in the drug-resistant patients (Table 3), and between serum IL-2 and IL-17, serum IL-2 and vitamin D3, serum IL-10 and IL-17, serum IL-10 and vitamin D3 and serum IL-17 and vitamin D3 in drug-sensitive patients (Table 4). In our results, the under the curve (AUC) of IL-2 was good, IL-10 was fair, and IL-17 was poor that means these immune markers can be used to distinguish between TB and non-TB patients. However, combining them may improve the AUC. It should be noted that individual cytokines may not be sufficient, but combining them may improve the diagnostic accuracy (Figure 2).

Discussion

Tuberculosis is still a major public health problem worldwide. A series of studies have shown that CD4+ T cells and IFN-γ-producing cells play important roles in controlling both bacterial growth and immunopathology during *M. tuberculosis* infection, and previous studies have shown that IL-2, IL-10, IL-17, and vitamin D3 are associated with both protection and pathology in the context of an *M. tuberculosis* infection (20-23). During TB infection, the levels of cytokines rise and decline upon recovery. Also, TB infection leads to the formation of granulomas in lung tissue (24).

Moreover, the infection sets off a violent inflammatory reaction that might harm lung cells, leading to a rise in apoptotic cells that local macrophages perform phagocytosis. Upon phagocytosis, macrophages release pro-inflammatory cytokines that recruit other immune cells and cause acute inflammation in lung tissue, triggering fever and increased fibrosis (25). Among the cells recruited to the site of infection, regulatory T cells (Treg cells), which are important mediators of immune regulation; they control the level of cellular immune responses to TB. Treg cells secrete IL-10, an important regulatory cytokine that suppresses excessive T cell responses and balances the immune response (26).

In our study, the IL-2 concentration showed significant differences between the study groups, with higher levels observed in TB patients. IL-2 has a pleiotropic effect on the immune system and plays a critical role in the defense against TB infection and acts as pro-inflammatory cytokine to promote the activation of T cells, DCs, and NK cells, and is essential for development of Th-17 and Treg cells (6). The IL-17 concentration showed a significant difference between study groups, with an increase in TB patients. IL-17 is produced by T helper 17 cells (Th-17) and is a pro-inflammatory cytokine that

has a central role in the activation and recruitment of neutrophils into infected tissue (12). Th-17 cells are controlled by IL-10 and TGF-β to prevent their over-stimulation (13).

The IL-10 concentration showed a significant difference between study groups, with an increase in TB patients. IL-10 is an immunosuppressive protein with anti-inflammatory function that is produced by various types of the immune cells, such as T cells, especially Tregular cell (9), and regulate the immune response and inflammation by suppressive the pro-inflammatory actions and affect several other cell types, such as macrophages, monocytes, DCs and T cells and lead to reduction in immune response and tissue damage (10).

During TB infection, cytokines work as a cascade network and a variety of pro-inflammatory and anti-inflammatory cytokines are produced, and delivered into the site of infection to control inflammation and prevent tissue damage (2). Other studies showed that IL-2, IL-10, and IL-17 levels were higher in TB patients than in control groups (27-29). The study by Sampath *et al.* showed that the patients with drug resistant TB patients exhibited significantly increased levels of IL-2, IL-10, and IL-17 in comparison to drug sensitive TB patients when compared to the control group (28).

The positive correlation between cytokines means that both are produced in tandem, which indicates an effective immune response. The elevated cytokine levels in drug resistant TB are attributed to the fact that recovery from this disease takes longer than recovery from drug sensitive TB, and therefore, immunity persists longer and leads to elevated cytokine levels in the serum of TB patients. During drug resistance TB infection, treatment is difficult because the bacilli are unresponsive to treatment, and the immune system is likely to be disturbed (28, 30).

The pro-inflammatory cytokines are produced in large quantities to activate and recruit other immune cells and contribute to inflammation. Excessive immune response can lead to tissue damage. Conversely, anti-inflammatory cytokines are also produced, which in turn prevent an excessive immune response, suppress inflammation, and prevent tissue damage. Therefore, maintaining a balance between pro- and anti-inflammatory cytokines is essential and crucial (31).

The cytokines IL-2 and IL-17 are pro-inflammatory ones that play important roles in the activation, differentiation, and recruitment of other immune cells. High levels of these cytokines enhance an individual's immunity against TB. The positive correlation between IL-2 with IL-17 is important as both have similar roles, promote inflammation against TB, and contribute to controlling the infection. IL-2 is essential for the proliferation and activation of T cells too, while IL-17 helps recruit neutrophils and other immune cells to the inflammatory site of infection. These cytokines work together to control *M. tuberculosis* infection (32). The positive correlation between IL-10 with IL-17 is an interesting correlation, given their opposing roles. Since IL-17 is a pro-inflammatory substance and high levels of it cause inflammation and recruit other immune cells to the site of infection, but it's excessive production causes tissue damage, on other hand, the IL-10 is anti-inflammatory cytokine and contributes in regulate and balance the immune response, suppressive inflammation and prevents tissue damage (32).

Vitamin D3 concentration showed significant differences between the study groups, with low levels observed in TB patients when compared with the control group. Mamadapur *et al.* reported that the vitamin D3 deficiency was more prevalent in patients with TB than in healthy controls (18). Hem *et al.* demonstrated that low vitamin D3 deficiency was associated with TB (33). The deficiency of vitamins is one of the old problems. Since the 1930s, public health officials in the USA and UK have used immunization of foods to reduce vitamin D3 deficiency. Vitamin D3 synthesis depends on exposure to ultraviolet radiation, and there are many factors influencing it, such as sunlight angle, air pollution, latitude, and skin pigmentation. In addition, Iraqi individuals have a high level of vitamin D3 deficiency compared to neighboring countries (34).

This situation has shown that low vitamin D3 level has been associated with an increased susceptibility to active TB. Low vitamin D3 levels vary depending on the population studied, adherence to food enrichment policies, demographic characteristics, and geographic location (35). The high rate of vitamin D3 deficiency among Iraqis, despite high levels of sun exposure, may be attributed to a lack of knowledge and awareness of vitamin D3 sources, its benefits, the factors that cause elevated levels, and the consequences of deficiency on overall health (36).

Our results indicated a significant decrease in vitamin D3 level among drug resistant and drug sensitive TB patients. The same result was presented before (37). Vitamin D3 supports the immune response and promotes and regulates immune responses. Vitamin D3 plays an important role in the immune system, as it enhances the production of antimicrobial peptides like cathelicidin, which help fight TB. It also contributes to regulating the immune response, balancing antimicrobial activity

with the regulation of inflammation (8).

The ratio of male-to-female in our study was 2:1, where most of the infected patients were male, and the minority infected patients were female. This ratio may be attributed to physiological differences between males and females that result in males being more susceptible to TB infection than females and it may be attributed to X-linked genetics, differences in nutrition between males and females, and immune response (37). The ratio of male-to-female of 2:1 was also reported by other studies (37-40).

Conclusion

The immune markers of IL-2, IL-10, and IL-17 were shown to provide a useful immunodiagnostic tests to discriminate between TB infected and TB uninfected individual. Vitamin D3 deficiency was demonstrated to impair the immune response, balancing antimicrobial activity with the regulation of inflammation, and increasing susceptibility to TB.

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Authors' Contribution

TAH: Writing, review and editing, validation, software, resources, visualization, investigation, formal analysis and data curation. KHR: Writing, original draft, visualization, supervision, and project administration.

Conflict of Interest

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

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