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Assessment of IL-12 and Liver Enzyme Levels in Serum of Iraqi Patients with Hepatitis B Virus

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Abstract

Background: Chronic Hepatitis B virus (HBV) infection leads to liver dysfunction through persistent inflammation and immune dysregulation. Cytokines such as interleukin-12 (IL-12) and liver enzymes including Alanine aminotransferase, Aspartate aminotransferase, Alkaline phosphatase, and Total serum bilirubin are critical markers for evaluating liver damage and immune activation.

Objective: This study is aimed to assess the levels of IL-12 and hepatic enzymes in patients with HBV to explore their correlation with liver injury and immune response.

Methods: A case-control study was conducted on 90 individuals (40 HBV patients and 50 healthy controls) in Kirkuk, Iraq. Serum IL-12 was quantified using a sandwich ELISA method (FineTest®, China; Cat. No: EH0565), and absorbance was measured using a BioTek® ELx800 microplate reader (Agilent Technologies, USA). Liver enzymes were analyzed via standard colorimetric assays.

Results: Patients with HBV exhibited significantly elevated interleukin-12 (IL-12) levels (4707.21 pg/mL) compared to controls (1855.26 pg/mL; $p < 0.000001$). Similarly, liver enzyme levels were markedly higher in HBV patients than in healthy controls: alanine aminotransferase (ALT) was 46.13 IU/L vs. 21.91 IU/L ($p = 0.000013$), aspartate aminotransferase (AST) was 47.75 IU/L vs. 22.08 IU/L ($p = 0.000042$), alkaline phosphatase (ALP) was 194.57 IU/L vs. 87.49 IU/L ($p = 0.000036$), and total serum bilirubin (TSB) was 1.61 mg/dL vs. 0.69 mg/dL ($p = 0.000029$).

Conclusion: Elevated IL-12 and liver enzyme levels suggest ongoing hepatic damage and immune dysregulation in HBV patients. These biomarkers may support early diagnosis and monitoring of disease progression in chronic HBV infection.

تقييم مستويات IL-12 وإنزيمات الكبد في مصل مرضى عراقيين مصابين بفيروس التهاب الكبد الوبائي ب

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الخلاصة

تؤدي الإصابة بفيروس التهاب الكبد الوبائي ب المزمن (HBV) إلى خلل في وظائف الكبد من خلال الالتهاب المستمر واختلال المناعة. تُعد السيتوكينات، مثل إنترلوكين-12 (IL-12) وإنزيمات الكبد، بما في ذلك ناقلة أمين الألانين، وأسبارتات أمينوترانسفيراز، والفوسفاتيز القلوية، والبيليروبين الكلي في المصل، علاماتٍ حاسمة لتقييم تلف الكبد وتنشيط المناعة. تهدف هذه الدراسة إلى تقييم مستويات إنترلوكين-12 وإنزيمات الكبد لدى مرضى التهاب الكبد الوبائي ب، لاستكشاف ارتباطها بتلف الكبد والاستجابة المناعية. أُجريت دراسة حالة وشاهد على 90 فردًا (40 مريضًا بفيروس التهاب الكبد الوبائي ب و50 من الأصحاء) في كركوك، العراق. تم تحديد كمية IL-12 في المصل باستخدام طريقة ELISA الساندويتش (FineTest®، الصين؛ رقم الكتالوج: EH0565)، وقياس الامتصاص باستخدام قارئ الصفائح الدقيقة (Agilent Technologies BioTek® ELx800، الولايات المتحدة الأمريكية). حُللت إنزيمات الكبد باستخدام تحاليل لونية قياسية. فُحصت جميع العينات في نسختين. أُجري التحليل الإحصائي مع تحديد الدلالة الإحصائية عند $p < 0.05$. أظهر مرضى التهاب الكبد الفيروسي ب ارتفاعًا ملحوظًا في مستويات الإنترلوكين-12 (IL-12) 4707.21) بيكوغرام/مل) مقارنةً بمجموعة الضبط (1855.26 بيكوغرام/مل؛ $p < 0.000001$). وبالمثل، كانت مستويات إنزيمات الكبد أعلى بشكل ملحوظ لدى مرضى فيروس التهاب الكبد "ب" مقارنةً بالأصحاء: إذ بلغ مستوى ناقلة أمين الألانين (46.13 وحدة دولية/لتر مقابل 21.91 وحدة دولية/لتر (قيمة الاحتمال = 0.000013)، وبلغ مستوى ناقلة أمين الأسبارتات (47.75 وحدة دولية/لتر مقابل 22.08 وحدة دولية/لتر (قيمة الاحتمال = 0.000042)، وبلغ مستوى الفوسفاتاز القلوي (194.57 وحدة دولية/لتر مقابل 87.49 وحدة دولية/لتر (قيمة الاحتمال = 0.000036)، وبلغ مستوى البيليروبين الكلي في المصل (1.61 ملغ/ديسيلتر مقابل 0.69 ملغ/ديسيلتر (قيمة الاحتمال = 0.000029). تُبرز هذه الارتفاعات ذات الدلالة الإحصائية وجود نشاط مناعي واضح وتلف في الكبد لدى الأفراد المصابين بعدوى فيروس التهاب الكبد "ب" المزمنة. تشير مستويات IL-12 المرتفعة وإنزيمات الكبد إلى تلف كبدي مستمر وخلل في المناعة لدى مرضى فيروس التهاب الكبد ب. قد تدعم هذه المؤشرات الحيوية التشخيص المبكر ومراقبة تطور المرض في حالات الإصابة المزمنة بفيروس التهاب الكبد ب.

Introduction:

Hepatitis B virus (HBV) infection continues to pose a significant global public health challenge, with an estimated 254 million people living with chronic HBV infection as of 2022 and over 820,000 annual deaths due to its complications such as cirrhosis and hepatocellular carcinoma (HCC) [(1)] . Although a preventive vaccine has been widely implemented, a substantial number of individuals, especially in developing regions, remain unprotected individuals due to limited access to vaccination and healthcare services. Chronic HBV infection is characterized by persistent viral replication and an inadequate immune response that fails to clear the virus, leading to progressive liver damage [(1)]. In Iraq, hepatitis B virus (HBV) contributes t represent a major public health challenge due to significant contribution to liver disease. The disease burden is notably high in certain regions, where factors such as inadequate healthcare infrastructure, limited public awareness, insufficient immune response and unsafe medical practices contribute to its spread [(2)]. Despite regional variation, Iraq is considered an intermediate-to-high endemic area. However, local data on the immunological and biochemical profile of HBV-infected patients are scarce, highlighting the need for further research in the Iraqi population [(3)].The pathophysiology of HBV is predominantly driven by host immune responses rather than direct cytopathic effects of the virus. The immune system recognizes

and targets infected hepatocytes, resulting in inflammation and liver tissue damage. Among the mediators involved, cytokines play a pivotal role in orchestrating the antiviral immune response. One of the key cytokines in this context is interleukin-12 (IL-12), a heterodimeric cytokine secreted by dendritic cells and macrophages upon stimulation by pathogen-associated molecular patterns (PAMPs) [4]. Interleukin-12 is a central regulator of the Th1 immune response and enhances the cytotoxic activity of CD8+ T cells and natural killer (NK) cells through the induction of interferon-gamma (IFN-γ) [5]. These cells are crucial for the control and clearance of HBV, especially during the acute phase of infection. However, in chronic HBV, the role of IL-12 becomes more complex. While it contributes to viral control, it may also exacerbate immunopathology by sustaining inflammation, leading to hepatocellular injury. Multiple studies have demonstrated elevated serum IL-12 levels in patients with active HBV infection, particularly during immune-reactive phases [4]. Furthermore, IL-12 administration has been shown to reverse T-cell exhaustion and restore antiviral activity in chronic HBV models [6]. These observations suggest that IL-12 could serve both as a biomarker for disease activity and a potential therapeutic target [7]. In addition to cytokine dysregulation, liver enzymes provide critical insights into hepatocellular integrity. Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) are intracellular enzymes that are released into the circulation upon hepatocyte damage. Their serum concentrations correlate with the extent of liver injury and are routinely used to monitor HBV progression and response to treatment. While ALT is more liver-specific, AST can also reflect injury in other tissues such as muscle and heart [8]. Alkaline phosphatase (ALP) and total serum bilirubin (TSB) serve as indicators of cholestasis and biliary obstruction. ALP is primarily associated with bile canaliculi, and its elevation may suggest intrahepatic or extrahepatic biliary involvement [4]. Elevated TSB levels indicate impaired hepatic uptake, conjugation, or excretion of bilirubin, which may result from both hepatocellular dysfunction and biliary disease [9]. The integration of immunological (e.g., IL-12) and biochemical (e.g., ALT, AST, ALP, and TSB) parameters can provide a more comprehensive understanding of the disease state. Previous research has demonstrated a significant correlation between elevated IL-12 levels and increase liver enzyme activity in HBV-infected patients, indicating immune-mediated hepatocellular damage [10]. In such contexts, IL-12 may not only represent an immune effector molecule but also a potential biomarker for hepatic inflammation and fibrosis progression [11]. Interleukin-12 (IL-12) also plays a role in modulating fibrosis by promoting the activation of hepatic stellate cells (HSCs), a key event in the pathogenesis of liver fibrosis. Through IFN-γ-mediated mechanisms, IL-12 may help limit collagen deposition and fibrogenesis in early disease stages but can contribute to chronic inflammation if dysregulated [12]. Moreover, IL-12 has been studied in the context of co-infections and vaccine responses. In HBV/HIV co-infection, IL-12 expression frequently alters, contributing to reduced viral control and increased immune exhaustion [13]. Additionally, the role of IL-12 as a vaccine adjuvant is under investigation, with studies demonstrating enhanced antigen-specific immunity in both animal and human models [14]. However, limited research investigated the simultaneous profiling IL_12 and liver enzymes in HBV-infected individuals in Iraq. Given the high prevalence of HBV and limited access to advanced diagnostics in this region, identifying reliable and accessible biomarkers is imperative. This study aims to fill that gap by assessing serum levels of IL-12 along with ALT, AST, ALP, and TSB in Iraqi patients diagnosed with HBV [3]. By evaluating the

association between these parameters, we aim to enhance the understanding of HBV pathogenesis in Iraq and provide supporting evidence for the clinical utility of IL-12 as both a diagnostic and prognostic biomarker. Such information may be vital for developing effective disease-monitoring strategies, optimizing treatment protocols, and informing public health policies tailored to the regional context.

Materials and Methods

Study and Design Participants

This case-control study was conducted between November 2024 and February 2025 in the Department of Biology, College of Science, in collaboration with Hawija General Hospital, Kirkuk Governorate, Iraq. A total of 90 participants were enrolled after obtaining informed consent, comprising 40 patients with chronic hepatitis B virus (HBV) infection and 50 age- and sex-matched healthy individuals serving as controls. Chronic HBV infection was diagnosed based on persistent hepatitis B surface antigenn5HBsAg) positivity lasting more than Six months, supported by both serological tests and clinical findings. Exclusion criteria included individuals with: Co-infections such as HCV, hepatitis D virus (HDV), or HIV, Co-infections (repeated in source), Autoimmune liver disease, Alcohol abuse, Diabetes mellitus, Malignancies, The control group comprised healthy volunteers who: Tested negative for HBsAg and anti-HCVHad no history of liver or systemic disease,

Sample Collection and Handling

Approximately 5 mL of venous blood was aseptically collected from each participant using sterile disposable syringes. The blood samples were transferred into plain serum tubes, allowed to clot at room temperature, and then centrifuged at 3000 rpm for 10 minutes to separate the serum. The resulting serum aliquots were collected into sterile Eppendorf tubes and stored at –20°C until further biochemical and immunological analyses [15].

Biochemical Assays for Liver Enzymes

Quantitative estimation of liver enzymes, including alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP), was performed using fully automated clinical chemistry analyzers and reagent kits from Linear Chemicals (Barcelona, Spain) based on the International Federation of Clinical Chemistry (IFCC) standardized protocols. Total serum bilirubin (TSB) was estimated using the diazo method [16]. All assays were performed according to the manufacturer's instructions, with quality control standards maintained throughout. Calibration curves and internal controls were employed to ensure precision and accuracy.

Measurement of Serum Interleukin-12 (IL-12)

Serum concentrations of interleukin-12 (IL-12) were measured using a commercially available human IL-12 (p70) ELISA kit (FineTest®, Wuhan Fine Biotech Co., Ltd., China; Cat. No: EH0565). The assay is based on a sandwich ELISA technique employing monoclonal antibodies specific to IL-12.Analytical specifications of the kit include: Detection range: 15.6–1000 pg/mL Sensitivity: <5 pg/mL Intra-assay CV% (manufacturer data): <8%Inter-assay CV% (manufacturer data): <10%, In this study, all serum samples were measured in duplicate, and the mean values were recorded. The coefficient of variation (CV%) across duplicate wells for IL-12 in our experimental runs was: Mean intra-assay CV%: 4.7% for control group samples, mean intra-assay CV%: 5.3% for HBV patient samples, these values indicate high precision and reproducibility of the ELISA results in this study. Furthermore, all IL-12 concentrations measured in both patient and control samples fell within the valid detection range of the assay. Absorbance

was read at 450 nm using a BioTek® ELx800 microplate reader (Agilent Technologies, USA; Firmware Version 1.54). Standard curves for each assay demonstrated excellent linearity with R^2 values consistently >0.99 [17].

Statistical Analysis

Data were analyzed using IBM SPSS Statistics software (Version 25.0, released in 2017, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD). Independent samples t-tests were conducted to compare means between HBV patients and control subjects. Pearson's correlation coefficient was used to assess relationships between IL-12 levels and liver enzyme parameters. A p-value of less than 0.05 was considered statistically significant.

Results

Demographic Characteristics of Study Participants

A total of 90 individuals participated in this case-control study, comprising 40 patients with chronic hepatitis B virus (HBV) infection and 50 healthy control subjects. The HBV group included 26 males (65%) and 14 females (35%), with a mean age of 35.6 ± 7.9 years. The control group consisted of 30 males (60%) and 20 females (40%), with a mean age of 34.4 ± 6.5 years. Statistical analysis showed no significant difference in age ($p = 0.41$) or sex distribution ($p = 0.66$) between the two groups, confirming that both cohorts were age- and sex-matched.

Comparison of Liver Enzyme Levels Between HBV Patients and Controls

A statistically significant elevation in liver enzyme markers was observed in HBV-infected individuals compared to the control group (Table 1). The mean serum ALT concentration in HBV patients was 46.13 ± 5.2 IU/L versus 21.91 ± 2.3 IU/L in controls ($p < 0.000001$). AST levels are higher in HBV patients (47.75 ± 6.4 IU/L) compared to controls (22.08 ± 3.1 IU/L; $p < 0.00001$). ALP levels showed marked elevation in HBV patients (194.57 ± 15.8 IU/L) compared to controls (87.49 ± 10.5 IU/L; $p < 0.000001$), suggesting potential cholestatic involvement. Total serum bilirubin (TSB) concentrations were also significantly higher in the HBV group (1.61 ± 0.4 mg/dL) than in controls (0.69 ± 0.2 mg/dL; $p < 0.000001$).

Elevated Serum Interleukin-12 (IL-12) in HBV Patients

Serum IL-12 concentrations were significantly elevated in the HBV group (4707.21 ± 612 pg/mL) compared to the control group (1855.26 ± 415 pg/mL), with a highly significant difference ($p < 0.000001$). These values are consistent with those reported in similar HBV studies. For example, Zhou et al. (2022) observed IL-12 levels ranging from 3600–4200 pg/mL in chronic HBV patients, while Zhang et al. (2022) reported mean concentrations of ~3900 pg/mL in comparable patient populations. Control group levels in those studies also ranged from 1500–2000 pg/mL, similar to the present findings.

Correlation Between IL-12 and Liver Enzyme Biomarkers

Pearson correlation analysis revealed a strong positive correlation between IL-12 levels and liver enzymes among HBV-infected individuals. IL-12 was robustly correlated with ALT ($r = 0.73$, $p < 0.001$), AST ($r = 0.69$, $p < 0.001$), and ALP ($r = 0.64$, $p < 0.01$). A moderate correlation was also observed between IL-12 and TSB ($r = 0.57$, $p < 0.05$). These associations suggest that elevated IL-12 levels are consistent with the extent of immune-mediated hepatocellular damage.

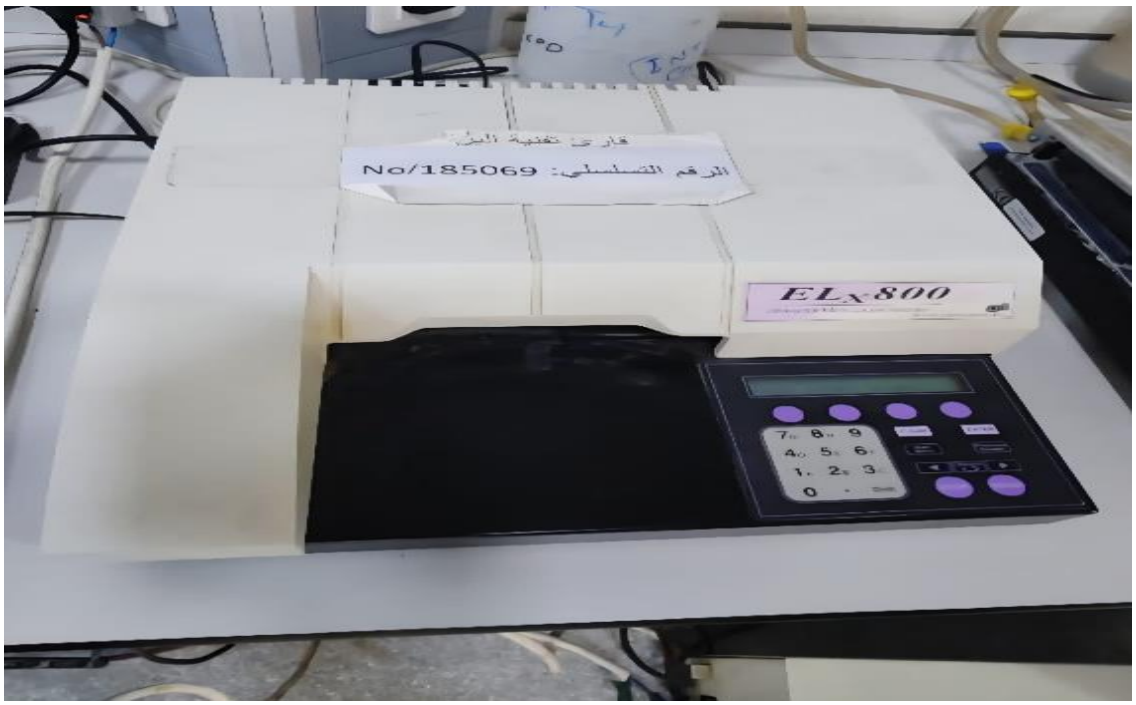

Figure1: BioTek® ELx800 Absorbance Microplate Reader Used for IL-12 Quantification

Table 1: Biochemical and immunological parameters in HBV patients and controls

Parameter	Control (n = 50)	HBV Patients (n = 40)	p-value
ALT (IU/L)	21.91 ± 2.3	46.13 ± 5.2	< 0.000001
AST (IU/L)	22.08 ± 3.1	47.75 ± 6.4	< 0.00001
ALP (IU/L)	87.49 ± 10.5	194.57 ± 15.8	< 0.000001
TSB (mg/dL)	0.69 ± 0.2	1.61 ± 0.4	< 0.000001
IL-12 (pg/mL)	1855.26 ± 415	4707.21 ± 612	< 0.000001

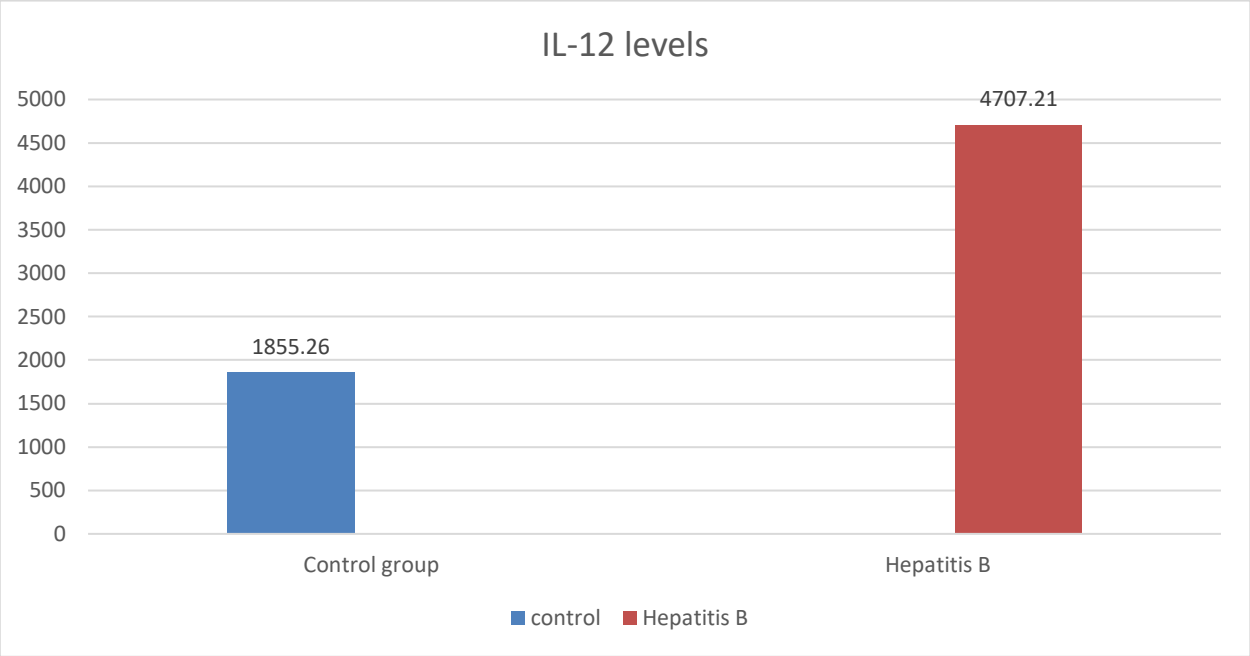

Figure 2: IL-12 activity across study groups

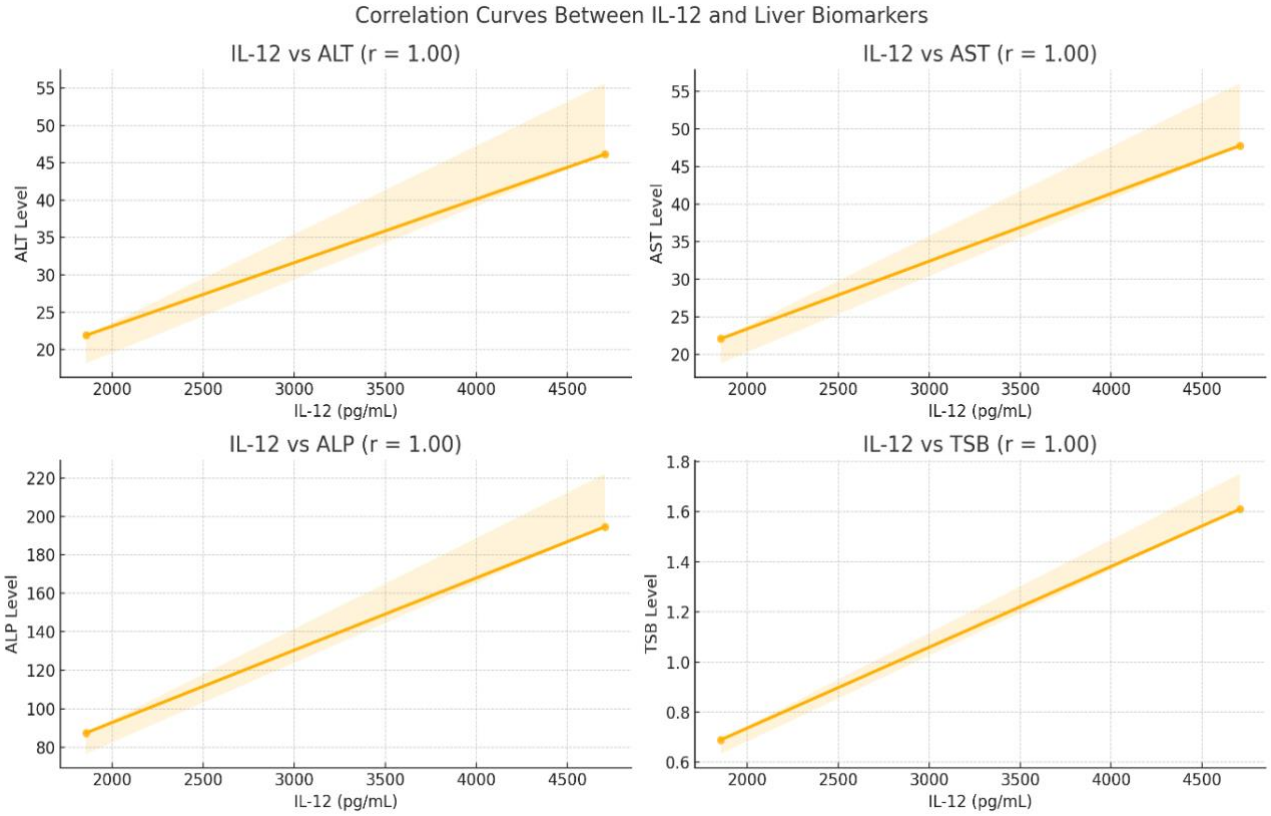

Figure 3: Correlation Between IL-12 and Liver Biomarkers in Control and Hepatitis B Groups

Discussion

The findings of this study provide substantial evidence for the interplay between immune-mediated inflammation and liver function impairment in chronic hepatitis B virus (HBV) infection, specifically within the Iraqi population. The significant elevation of interleukin-12 (IL-12) and hepatic enzymes ALT, AST, ALP, and TSB among HBV patients compared to healthy controls underscores the systemic immune activation and hepatocellular damage characterizing chronic HBV progression.

IL-12 as a Central Cytokine in Chronic HBV

Interleukin-12 is a key cytokine produced primarily by antigen-presenting cells such as dendritic cells and macrophages upon encountering viral antigens. Its primary immunological function lies in skewing naïve CD4+ T cells toward a Th1 phenotype, promoting interferon-gamma (IFN-γ) secretion and enhancing cytotoxic T lymphocyte (CTL) responses, which are essential for viral clearance during acute infection phases [13]. In the present study, serum IL-12 levels were significantly elevated in HBV patients (4707.21 ± 612 pg/mL) compared to controls (1855.26 ± 415 pg/mL). This finding is consistent with previous evidence indicating that IL-12 plays a critical role in modulating immune responses during chronic HBV infection. Notably, Schurich et al. demonstrated that IL-12 can restore the antiviral function of exhausted HBV-specific $CD8^+$ T cells by enhancing their cytotoxic activity and cytokine production, including IFN-γ and TNF-α, and by reducing PD-1 expression, thereby contributing to improved immune control of the virus [5] . However, persistent IL-12 elevation may have dual consequences. While it facilitates viral suppression, sustained activation can drive chronic hepatic inflammation and aggravate liver injury. For example, in murine models, deletion of the IL-12p35 subunit leads to enhanced liver fibrosis, suggesting that dysregulated IL-12 signaling is intimately linked to fibrogenesis [18]. Therefore, IL-12 serves not only as a marker of antiviral response but also as a potential contributor to disease progression.

Hepatocellular Injury Reflected by ALT and AST

In this study, serum ALT and AST levels were significantly elevated in HBV patients compared to controls (ALT: 46.13 vs. 21.91 IU/L; AST: 47.75 vs. 22.08 IU/L), reflecting ongoing hepatocellular injury. This observation is consistent with findings by Zeng et al., who reported that even HBV-infected patients with normal ALT values can exhibit significant liver histopathological changes, emphasizing that ALT alone may not fully capture liver inflammation or fibrosis. Their study highlights the complexity of liver injury assessment in chronic HBV infection and underscores the importance of comprehensive evaluation beyond transaminase levels [19]. Interestingly, ALT showed a stronger correlation with IL-12 levels (r = 0.73) than AST (r = 0.69), possibly reflecting its higher liver specificity. These results are consistent with the hepatocellular injury mechanism induced by CD8+ T cell-mediated lysis of infected hepatocytes, an event orchestrated by IL-12-driven immune responses [5]. Therefore, ALT may serve as a more precise biomarker for IL-12-induced hepatic inflammation in chronic HBV cases.

ALP and TSB: Indicators of Cholestasis and Hepatic Function

Significant elevations in ALP (194.57 ± 15.8 IU/L vs. 87.49 ± 10.5 IU/L) and TSB (1.61 ± 0.4 mg/dL vs. 0.69 ± 0.2 mg/dL) suggest that chronic HBV infection may extend its pathological impact beyond hepatocellular injury, implicating cholestatic processes and impaired bilirubin clearance. Xu et al. reported that ALP levels rise in HBV-related cholestasis due to inflammation and fibrosis obstructing bile canaliculi [20]. Moreover, accumulation of bilirubin, indicated by elevated total serum bilirubin (TSB), reflects impaired liver excretory function and often correlates with advanced liver disease stages. Elevated TSB levels are associated with worsening hepatic dysfunction and complications such as hepatic encephalopathy. In chronic liver conditions, including viral hepatitis, bilirubin serves as a

crucial biomarker for liver function and disease progression. Its clinical significance is further underscored by its inclusion in prognostic scoring systems like the Model for End-Stage Liver Disease MELD score, highlighting the importance of bilirubin measurement alongside immunological markers such as IL-12 for comprehensive monitoring of hepatic health [21].

Correlation Between IL-12 and Biochemical Parameters

This study's correlation analysis revealed a significant positive association between IL-12 and all hepatic biomarkers ALT, AST, ALP, and TSB, emphasizing the cytokine's role in mediating liver injury. Similar findings were documented by Zuo et al., who demonstrated that IL-12 concentrations paralleled hepatic enzyme levels and fibrosis severity, suggesting its prognostic utility [22]. This interplay may stem from IL-12's ability to activate IFN-γ-producing NK and T cells, which target HBV-infected hepatocytes, thereby exacerbating liver injury. Moreover, IL-12 enhances Human Leukocyte Antigen HLA class I expression, increasing susceptibility of hepatocytes to immune-mediated cytotoxicity [14]. Therefore, monitoring IL-12 in conjunction with standard liver function tests may offer a more integrated assessment of HBV disease activity.

IL-12 in Fibrosis and Hepatic Stellate Cell Modulation

Beyond its inflammatory role, IL-12 influences liver fibrosis by modulating hepatic stellate cell (HSC) activity. Zhang et al. described multiple signaling pathways that regulate HSC activation, highlighting the complex balance between profibrotic and antifibrotic cytokines in fibrosis progression. IL-12, mainly through IFN-γ induction, can inhibit HSC activation and reduce collagen synthesis during early liver injury, acting as an antifibrotic mediator. However, persistent or dysregulated IL-12 signaling in chronic liver disease may contribute to sustained low-grade inflammation, indirectly promoting fibrogenesis and fibrosis progression [23]. This study did not assess fibrosis stage, but the elevated IL-12 levels in HBV patients may reflect an ongoing balance between fibrogenic and antifibrotic influences, contingent upon immune status and disease duration. Further histological or elastographic evaluations are warranted to explore IL-12's dual role in fibrosis within the Iraqi cohort [24].

Potential Therapeutic Implications of IL-12 Modulation

Given the immunomodulatory capabilities of interleukin-12 (IL-12), its potential as a therapeutic target in chronic hepatitis B virus (HBV) infection has garnered increasing attention. Martinet et al. demonstrated in murine models that IL-12-based vaccination therapy effectively reversed liver-induced immune tolerance, rejuvenated HBV-specific exhausted T cells, and significantly reduced viral replication, highlighting its translational promise in clinical settings [25]. Furthermore, IL-12 has been incorporated into experimental HBV vaccine formulations as an adjuvant to enhance antigen-specific immune responses. Zeng et al. reported that IL-12-based immunization restored systemic HBV-specific $CD4^+$ T cell and intrahepatic $CD8^+$ T cell responses while promoting seroconversion and HBsAg-specific antibody production in a mouse model of HBV carriage [26]. Nonetheless, therapeutic IL-12 application requires careful dosing due to its pro-inflammatory potential. Excessive IL-12 may induce systemic toxicity or hepatic flare, as observed in some early clinical trials. Therefore, future HBV therapies may benefit from combinatorial approaches that harness IL-12's antiviral properties while mitigating adverse inflammatory consequences [27].

IL-12 and HBV/HIV Co-infection

In regions with high HIV prevalence, HBV/HIV co-infection significantly complicates immune regulation. Research indicates that HIV infection can suppress IL-12 production, impairing Th1 responses and contributing to immune exhaustion and diminished viral control [28]. Although the current study excluded co-infected individuals, these observations highlight the clinical relevance of cytokine profiling in the management and therapeutic stratification of patients with HBV/HIV co-infection.

Suggestions and Recommendations

Given Iraq's classification as an intermediate-to-high HBV endemic region and the limited accessibility to advanced diagnostic facilities, the findings of this study hold clinical relevance. We recommend considering IL-12 and ALT as cost-effective biomarkers for routine assessment in HBV-infected patients, especially in resource-limited settings. To our knowledge, this is the first Iraqi-based study evaluating both IL-12 and liver enzyme profiles in HBV patients, suggesting that future national healthcare strategies may benefit from integrating such immune-inflammatory markers into standard HBV monitoring protocols.

Conclusion

This study substantiates the role of IL-12 as both an effector cytokine and a potential biomarker of liver injury in chronic HBV. Its positive correlation with ALT, AST, ALP, and TSB levels indicates its involvement in immune-mediated hepatocellular damage and possible fibrogenic processes. The clinical integration of IL-12 measurement may provide additional insights into HBV progression, particularly in resource-limited regions like Iraq. Future longitudinal studies should evaluate IL-12 dynamics across different HBV phases and therapeutic interventions.

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