Open Access Research Journal of
Biology and Pharmacy
Journals home page: https://oarjbp.com/
ISSN: 2782-9979 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(RESEARCH ARTICLE)

Check for updates

Evaluation of changes in creatine kinase and lactate dehydrogenase levels in patients with bacterial infection

Bootan Fahmi Mohammed *

Department of Clinical Laboratory Sciences, College of Pharmacy, University of Kirkuk, Kirkuk, Iraq.

Open Access Research Journal of Biology and Pharmacy, 2026, 16(02), 095-104

Publication history: Received on 21 February 2026; revised on 04 April 2026; accepted on 07April 2026

Article DOI: https://doi.org/10.53022/oarjbp.2026.16.2.0032

Abstract

Background: Bacterial infections contribute to the high rates of morbidity in the world, and this is largely because these infections can cause cellular and tissue damage. Biochemical markers such as creatine kinase (CK) and lactate dehydrogenase (LDH) are the main markers used to determine tissue damage, although the changes in these markers during bacterial infections and their relationship to the severity of the infection remain poorly understood.

Methods: A cross-sectional analytical study design was adopted for the research. The research was conducted in Al-Hawija General Hospital in Iraq from December 2025 to February 2026. A total of 150 samples were collected for the research, comprising 100 bacterial infection patients and 50 healthy controls. Biochemical analysis of CK and LDH levels in the blood samples of the participants was carried out by an automated enzymatic kinetic method. The data analysis of the results was done by the SPSS version 26 statistical tool. The results are expressed as mean and SD. The significance level of $p < 0.05$ is considered for the results.

Results: The levels of CK and LDH in patients infected by bacteria were significantly higher compared to those in healthy controls (CK: 210 ± 45 U/L vs. 120 ± 30 U/L, $p < 0.001$; LDH: 480 ± 90 U/L vs. 220 ± 50 U/L, $p < 0.001$). Sepsis infection showed the highest levels of these enzymes, while urinary tract infections showed the lowest levels. The levels of these enzymes increased proportionally in accordance with the severity of the infections. LDH levels were more sensitive to tissue damage. Patients aged 60+ years had higher levels of these enzymes compared to those aged <60 years. However, gender had no influence on the levels of these enzymes. After one week of antibiotic treatment, the levels of these enzymes decreased significantly: CK from 210 to 160 U/L, LDH from 480 to 320 U/L.

Objective: The objectives of this study were to assess the changes in serum CK and LDH levels in patients with established bacterial infections, to determine the relationship between these enzymes and the nature and severity of infection, to determine the impact of age and gender on enzyme levels, and to monitor the effects of antibiotic treatment.

Keywords: Bacterial Infections; Creatine Kinase (CK); Lactate Dehydrogenase (LDH); Tissue Damage; Infection Severity; Biomarkers; Antibiotic Therapy

1. Introduction

Bacterial infections are a major public health problem globally and are a significant cause of morbidity and mortality among all age groups. Bacterial infections may vary from localized diseases such as urinary tract infections and pneumonias to generalized diseases such as sepsis and meningitis [1;2]. The pathophysiology of bacterial infections is a complex process involving the interaction of the invading bacteria and the host cells by activating the immune response and causing inflammation and damage to the body [3]. The monitoring of various biochemical markers, which indicate cellular injury, is considered to be of prime importance for understanding the severity of disease, deciding on appropriate treatment, and predicting clinical outcomes [4].

* Corresponding author: Bootan Fahmi Mohammed

Among various such markers, creatine kinase and lactate dehydrogenase have been studied extensively as sensitive markers of cellular and tissue injury. CK is an enzyme present in the cytosol of cells, predominantly in skeletal, cardiac, and to a certain extent, brain tissue. This enzyme is of prime importance in cellular metabolism, as it catalyzes the reversible phosphorylation of creatine [5]. Elevated levels of CK in the bloodstream usually point to some injury in the skeletal muscles, heart, or some signs of stress. In the context of bacterial infections, the increase in CK levels can be due to tissue invasion, toxins, or secondary complications such as sepsis-induced myopathy [6].

LDH is an enzyme found in almost every tissue of the body, such as the heart, liver, muscles, kidneys, and lungs. LDH catalyzes the conversion of lactate and pyruvate, which is a key event in cellular respiration [7]. Because of its wide tissue distribution, LDH is a sensitive but nonspecific index of cellular damage. Elevated levels of serum LDH have been found in a number of conditions, including hemolytic disorders, myocardial infarction, liver dysfunction, and infectious diseases. In bacterial infections, elevated levels of LDH are due to generalized tissue damage and cellular necrosis caused by the host's inflammatory response [8].

Several studies have highlighted the diagnostic and prognostic value of CK and LDH in infectious diseases. For instance, elevated CK and LDH levels have been reported in patients with severe sepsis, bacterial pneumonia, and systemic inflammatory responses, correlating with disease severity and adverse clinical outcomes [9;10]. Despite this, limited studies have systematically evaluated the dynamic changes of these enzymes in different types of bacterial infections, their relationship with infection severity, and their potential role in monitoring treatment response [11].

Knowledge of the patterns of CK and LDH abnormalities in bacterial infections can offer the medical practitioner a powerful tool in the early risk stratification, therapeutic response, and risk of complications in bacterial infections [12;13]. Additionally, the use of these enzymes in conjunction with other conventional clinical parameters can help in the precise management strategies in bacterial infections [14;15].

In view of the above, the current research is designed to investigate the changes in the levels of CK and LDH among bacterial infection patients, the relationship between the two enzymes and the type and severity of the bacterial infections, the effect of age and gender on the two enzymes, and the dynamic changes in the two enzymes after antibiotic treatment. It is believed that this current research will contribute to the full understanding of the role of biochemical tests in bacterial infections and the role of CK and LDH as adjunctive tools.

2. Materials and Methods

2.1. Study Design

The present study was performed as an analytical cross-sectional study from December 2025 to February 2026, aiming to assess the change in creatine kinase (CK) and lactate dehydrogenase (LDH) levels in bacterial-infected patients and the association with the severity of the bacterial infection within a certain period of time, without the intervention of the researchers.

2.2. Study Setting

The study was conducted in Al-Hawija General Hospital and its affiliated health centers in Al-Hawija District, Kirkuk Governorate, Iraq. This hospital and health centers are considered major centers for receiving patients infected with different bacterial infections. The main sources of patients were the internal medicine department and the emergency department, and the necessary biochemical investigations were conducted in the hospital laboratories.

2.3. Sample Size and Study Population

The total number of participants in this study was 150, divided into two groups. The patient group comprised 100 patients with bacterial infections, as confirmed through clinical assessment and laboratory tests, while the control group comprised 50 healthy individuals with no signs of any acute or chronic illness. Participants were randomly sampled using simple random sampling, where both genders and different age groups were represented from hospital attendees during this study.

2.4. Inclusion Criteria

Individuals with a confirmed diagnosis of bacterial infections on the basis of clinical symptoms with laboratory evidence such as increased inflammatory markers or bacterial cultures were included. The participants had to be 18 years or older. Healthy controls for the study were included if they had no medical history that might interfere with the outcome.

2.5. Exclusion Criteria

Chronic health conditions such as liver disease, kidney disease, heart disease, and muscular diseases that affect the level of CK were excluded. Patients with recent surgeries, physical injuries, and those on medication that affects the level of enzymes were also excluded to ensure accuracy.

2.6. Sample and Data Collection

Clinical and demographic information was obtained from medical records and direct interviews with patients using a data collection form. Data collected included demographic information such as age and sex, infection severity and type, medical history, behavioral factors like smoking, etc.

2.7. Laboratory Analysis

Laboratory tests were carried out at Al-Hawija General Hospital by automated clinical chemistry analyzers following the manufacturers' calibration procedures. Blood specimens of 5 mL each were drawn in dry tubes, allowed to clot, then centrifuged at 3000 rpm for 10 minutes. Serum specimens were then kept frozen at −20°C until tested. [16;17].

The activity of CK was determined using a kinetic enzymatic method, which is based on measuring the change in absorbance at 340 nm, which is directly proportional to enzyme activity [18]. LDH activity was determined using a kinetic spectrophotometric method, which measures the rate of change in absorbance at 340 nm, which is directly proportional to enzyme activity in the sample [19]. All tests were conducted using standard protocols with quality control measures in place to ensure accuracy of results.

2.8. Statistical Analysis

The data was analyzed using SPSS version 26. Quantitative data was represented as mean ± SD, whereas qualitative data was represented as frequency and percentages. The t-test was applied to compare two groups for quantitative data, whereas ANOVA was applied to compare more than two groups, particularly to compare the severity of infection. The relationship between enzyme levels and severity was analyzed using Pearson correlation coefficients. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of CK and LDH Levels Between Patients and Healthy Controls

The results of this study revealed a significant increase in CK and LDH levels in patients with bacterial infections when compared to healthy individuals. The level of CK in patients with bacterial infections was found to be 210 ± 45 U/L, whereas in healthy individuals, it was 120 ± 30 U/L. Similarly, LDH levels were found to be 480 ± 90 U/L in patients with bacterial infections, whereas in healthy individuals, they were 220 ± 50 U/L. Statistical significance was found to be high in this study for both CK and LDH levels, which is p < 0.001.

Table 1 Comparison of CK and LDH Levels Between Patients and Controls

Enzyme	Patient Group (n=100)	Control Group (n=50)	p-value
CK (U/L)	210 ± 45	120 ± 30	<0.001
LDH (U/L)	480 ± 90	220 ± 50	<0.001

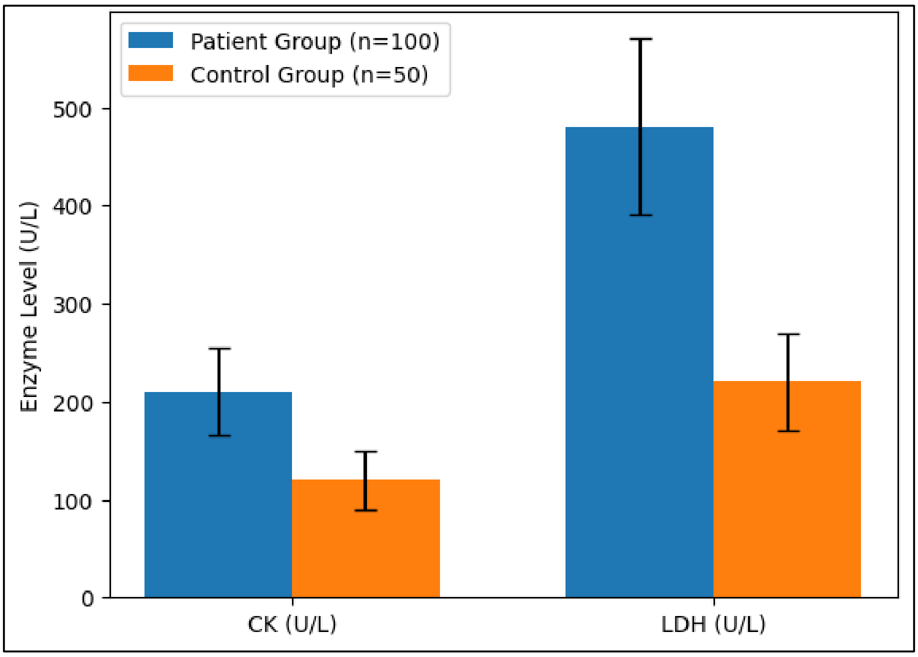

Figure 1 Bar chart showing elevated CK and LDH levels in patients compared to healthy controls

3.2. Enzyme Levels According to Infection Type

The CK and LDH enzyme levels were also analyzed based on the types of infections. Sepsis had the highest level of both enzymes, whereas urinary tract infections had the lowest average level of CK and LDH enzymes, showing that the extent of cell damage varies with different types of infections.

Table 2 CK and LDH Levels by Infection Type

Infection Type	No. of Patients	CK (U/L) Mean ± SD	LDH (U/L) Mean ± SD
Pneumonia	45	205 ± 40	470 ± 85
Sepsis	30	230 ± 35	560 ± 70
Meningitis	15	215 ± 30	500 ± 65
Urinary Tract Infection	10	190 ± 25	380 ± 40

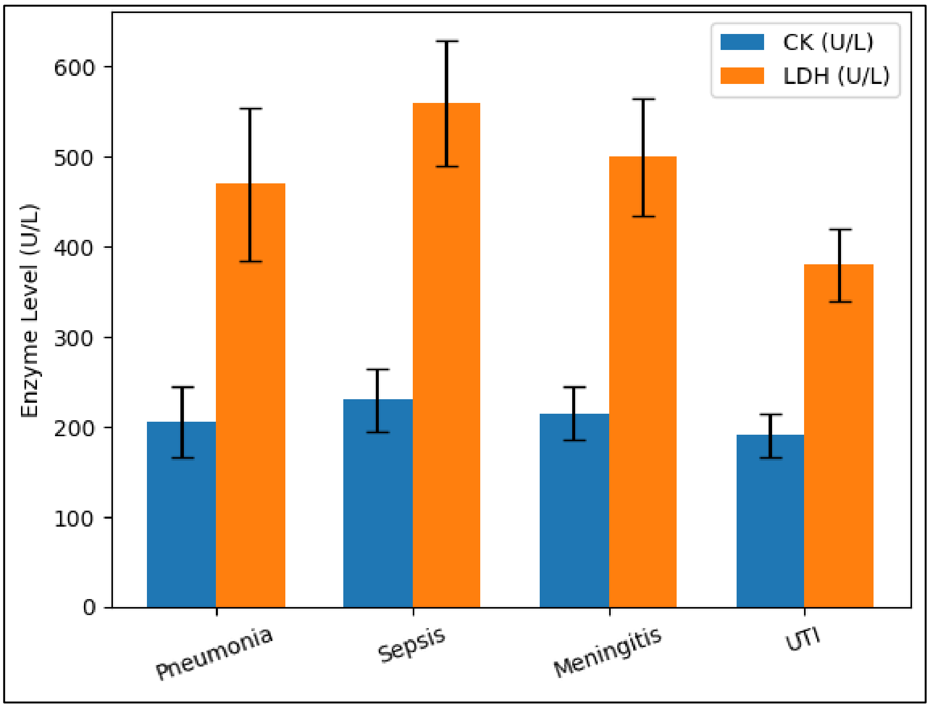

Figure 2 Graphical representation of CK and LDH levels by infection type

3.3. Effect of Infection Severity on Enzyme Levels

The patients were classified according to the severity of infection. Both enzymes increased in severity of the disease. LDH has shown higher sensitivity compared to CK.

- LDH: Mild - 380 ± 40, Moderate - 430 ± 50, Severe - 560 ± 70
- CK: Mild - 190 ± 30, Moderate - 200 ± 35, Severe - 230 ± 40

Table 3 CK and LDH Levels by Infection Severity

Infection Severity	No. of Patients	CK (U/L) Mean ± SD	LDH (U/L) Mean ± SD
Mild	25	190 ± 30	380 ± 40
Moderate	40	200 ± 35	430 ± 50
Severe	35	230 ± 40	560 ± 70

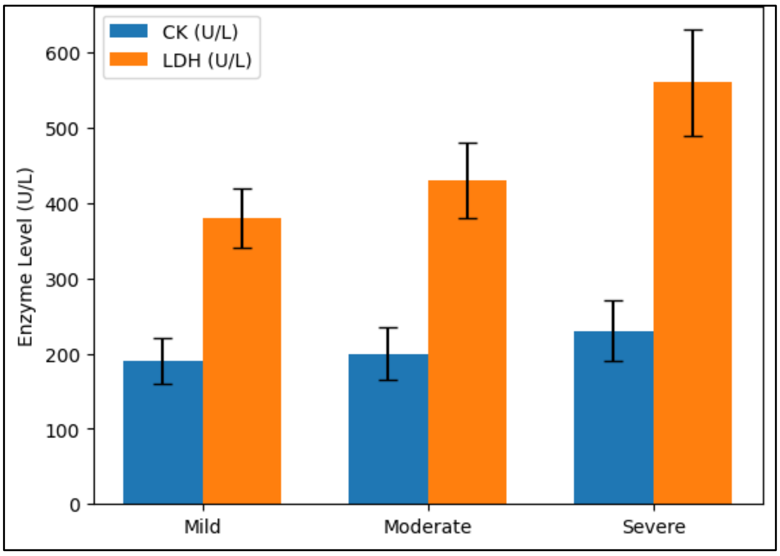

Figure 3 Increase in CK and LDH levels with increasing infection severity

3.4. Effect of Age and Gender on Enzyme Levels

CK and LDH levels tended to increase with age, particularly in individuals ≥60 years, while gender showed no significant effect.

Table 4 CK and LDH Levels by Age Group

Age Group	CK (U/L) Mean ± SD	LDH (U/L) Mean ± SD
18–39	200 ± 35	430 ± 60
40–59	215 ± 40	480 ± 70
≥60	225 ± 45	520 ± 80

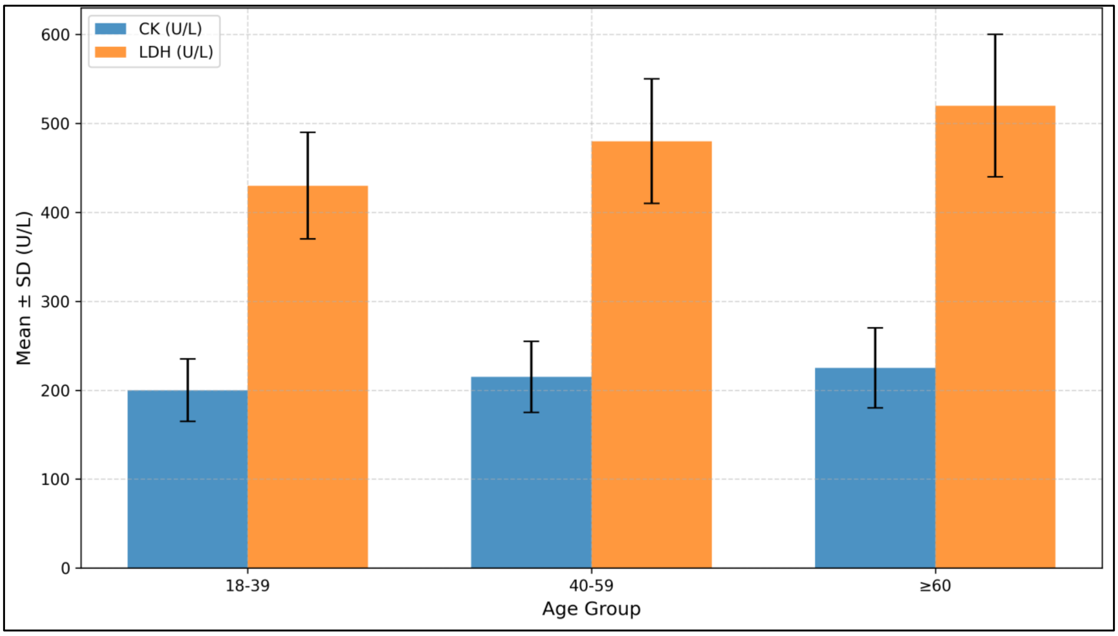

Figure 4 Effect of age on CK and LDH levels

3.5. Enzyme Follow-Up After Treatment

After one week of antibiotic therapy, CK and LDH values gradually decreased, which correlated with clinical improvement and reduced cellular damage. LDH values decreased from 480 ± 90 to 320 ± 60 units/L, and CK values decreased from 210 ± 45 to 160 ± 35 units/L.

Table 5 CK and LDH Levels Before and After Treatment

Enzyme	Before Treatment	After 1 Week of Treatment
CK (U/L)	210 ± 45	160 ± 35
LDH (U/L)	480 ± 90	320 ± 60

4. Discussion

This study showed the significance of the increase in the level of CK and LDH in the sera of patients with bacterial infections compared to healthy controls. This is because bacterial infections directly affect the tissues and cells. LDH is used as a marker for cellular damage, while CK is used as a marker for damage to the skeletal muscles [20;21]. These results were similar to those in previous studies, such as [22], which showed elevated levels of LDH and CK in severe sepsis, confirming the role of these enzymes as markers for cellular damage and effective tools for evaluating the treatment response.

Analysis of the levels of enzymes in different infections revealed that the highest levels of CK and LDH were found in sepsis infections, while the lowest levels of these enzymes were found in urinary infections. This reveals that the level of cellular damage varies in different infections. Sepsis infections have the highest level of cellular damage because of the inflammatory response in these infections, unlike other infections. This is in agreement with other studies [23], that found that LDH levels are higher in systemic infections or severe pneumonia compared to mild infections.

Regarding the severity of infection, the levels of both CK and LDH were found to have a positive correlation with the severity of the infection [24]. Among these two, LDH is found to be more sensitive in measuring the overall cellular damage [25]. The presence of LDH is seen in many tissues such as the liver, heart, muscles, and kidneys. Therefore, an increase in the level of LDH is seen in cases of extensive cellular damage [26]. CK is found primarily in the muscles and heart and is elevated in cases of direct muscle damage and severe infections. [27].

Age was found to have a slight modifying effect, with enzyme levels rising in older people, particularly those aged 60 years and above, whereas gender was not found to affect enzyme levels significantly. This could be because, as people age, they become more susceptible to complications arising from infections, and their ability to heal at a cellular level is impaired [28], a finding that is also consistent with that of [29], who found that higher levels of LDH were seen in elderly patients suffering from bacterial infections.

Levels of CK and LDH after a week of antibiotic therapy have shown a gradual decrease, which indicates improvement and less cellular damage [30]. Such enzymes could serve as supplementary tools for monitoring the treatment process along with traditional clinical parameters such as body temperature and levels of CRP and WBC [31;32].

The association between the level of CK and LDH with the type and severity of the infection helps in the quick assessment of the severity of the disease and the outcome of the patient's condition [33;34]. For example, an increased level of LDH with an increased level of CK indicates severe infection or tissue damage, which requires close monitoring and intensive care; an increased level of LDH with moderate CK indicates limited systemic infection or less muscle involvement [35;36;37].

5. Conclusion

CK and LDH enzymes are important biochemical markers in the assessment of tissue damage and the evaluation of the course of bacterial infections. LDH is considered a sensitive marker for the assessment of general cellular damage, whereas CK is important in the assessment of muscular damage. The dynamic changes in the activity of these enzymes correlate with the type, severity, and age of the patient with bacterial infections. These findings support the routine assessment of CK and LDH enzymes in the clinical evaluation of bacterial infections.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] Pieniążek, J. M., Padkowska, A., Dobosz, M., Arciszewska, K., Buczkowski, J., Miazga, M., ... and Mataczyńska, A. (2024). Overview Of The Main Bacterial Infections In Humans. Quality in Sport, 23, 54786-54786. https://doi.org/10.12775/QS.2024.23.54786

[2] Timsit, J. F., Ling, L., de Montmollin, E., Bracht, H., Conway-Morris, A., De Bus, L., ... and Lipman, J. (2025). Antibiotic therapy for severe bacterial infections. Intensive Care Medicine, 51(10), 1867-1885. https://doi.org/10.1007/s00134-025-08063-0

[3] Anju, V. T., Busi, S., Mohan, M. S., and Dyavaiah, M. (2023). Bacterial infections: types and pathophysiology. In Antibiotics-Therapeutic Spectrum and Limitations (pp. 21-38). Academic Press. https://doi.org/10.1016/B978-0-323-95388-7.00004-8

[4] Sah, A. K. (2025). Prognostic biomarkers: predicting disease outcomes. In The Potential of Cancer Biomarkers (pp. 211-238). Elsevier. https://doi.org/10.1016/B978-0-443-29279-8.00010-7

[5] Pathan, S. U., Kharwar, A., Ibrahim, M. A., Singh, S. B., and Bajaj, P. (2024). Enzymes as indispensable markers in disease diagnosis. Bioanalysis, 16(10), 485-497. https://doi.org/10.4155/bio-2023-0207

[6] Schwiete, C., Roth, C., Mester, J., Broich, H., and Behringer, M. (2025). Overlaps of skeletal muscle fatigue and skeletal muscle damage: the muscle injury continuum. Sports Medicine-Open, 11(1),73. https://doi.org/10.1186/s40798-025-00876-z

[7] Barrak, M. H., Dawood, F. A., Abed Shubar, S. N., and Al-Fahham, A. A. (2024). Pathophysiology, The Biochemical and Clinical Significance of Lactate Dehydrogenase. International Journal of Health and Medical Research, 3(07), 440-3. https://doi.org/10.58806/ijhmr.2024.v3i07n02

[8] Holmes, R. S., and Goldberg, E. (2009). Computational analyses of mammalian lactate dehydrogenases: human, mouse, opossum and platypus LDHs. Computational biology and chemistry, 33(5), 379–385. https://doi.org/10.1016/j.compbiolchem.2009.07.006

[9] Wilder-Smith, A., Chiew, C. J., and Lee, V. J. (2020). Can we contain the COVID-19 outbreak with the same measures as for SARS?. The lancet infectious diseases, 20(5), e102-e107. https://doi.org/10.1016/S1473-3099(20)30129-8

[10] Jones, R. W., and Kierzkowski, H. (2018). The role of services in production and international trade: A theoretical framework. World Scientific Book Chapters, 233-253. https://doi.org/10.1142/9789813200678_0014

[11] Fan, Z., Liu, Y., Ye, Y., and Liao, Y. (2024). Functional probes for the diagnosis and treatment of infectious diseases. Aggregate, 5(6), e620. https://doi.org/10.1002/agt2.620

[12] Farhan, F., Hussein, F., Abbas, H., and Al-Hayawi, A. (2026). Simultaneous detection of arpA, chuA, TspE4C2, and yjaA genes in UTI-associated Escherichia coli using multiplex PCR. Microbes and Infectious Diseases, 7(2), 1223-1232. https://doi.org/10.21608/mid.2025.430289.3295

[13] Cao, H., Oghenemaro, E. F., Latypova, A., Abosaoda, M. K., Zaman, G. S., and Devi, A. (2025). Advancing clinical biochemistry: addressing gaps and driving future innovations. Frontiers in Medicine, 12, 1521126. https://doi.org/10.3389/fmed.2025.1521126

[14] Zhang, M., Liu, D., Song, Y., and Zhao, J. (2026). Correlation between Interleukin-6, C-reactive protein, and lactate dehydrogenase levels and macrolide-resistant severe mycoplasma pneumoniae infection in children. BMC Infectious Diseases, 26(1), 62. https://doi.org/10.1186/s12879-025-11859-6

[15] Al-Jndeel, H. A., Mohsin, H. S., Hasan, A. A., and Mohsin, H. A. (2025). Microbial Biomarkers in Clinical Chemistry, Diagnostic and Prognostic Application: A Review. Karbala Journal of Pharmaceutical Sciences, 16(27), 318-327. https://doi.org/10.62472/kjps.v16.i27.318-327

[16] Hennø, L. T., Storjord, E., Christiansen, D., Bergseth, G., Ludviksen, J. K., Fure, H., ... and Brekke, O. L. (2017). Effect of the anticoagulant, storage time and temperature of blood samples on the concentrations of 27 multiplex assayed cytokines–consequences for defining reference values in healthy humans. Cytokine, 97, 86-95. https://doi.org/10.1016/j.cyto.2017.05.014

[17] Yasser, H., Raghda W. Khalid, Farhan, K. H.(2024) Molecular Study of K1, K2, MagA genes in High Virulent Kebsiella pneumonia in Kirkuk City, Iraq. South Asian Res J Bio Appl Biosci, 6(6), 242-245. https://doi.org/10.36346/sarjbab.2024.v06i06.006

[18] Shu, N., Lorentzen, L. G., and Davies, M. J. (2019). Reaction of quinones with proteins: Kinetics of adduct formation, effects on enzymatic activity and protein structure, and potential reversibility of modifications. Free Radical Biology and Medicine, 137, 169-180. https://doi.org/10.1016/j.freeradbiomed.2019.04.026

[19] Głowacka, J., Wiśniewska, A., Koncki, R., and Strzelak, K. (2023). Photometric flow system for the determination of serum lactate dehydrogenase activity. Talanta, 265, 124817. https://doi.org/10.1016/j.talanta.2023.124817

[20] Tu, H., and Li, Y. L. (2023). Inflammation balance in skeletal muscle damage and repair. Frontiers in immunology, 14, 1133355. https://doi.org/10.3389/fimmu.2023.1133355

[21] Salman, H. A., Hussein, F. K., and Abdulrahman, S. J. (2024). A Comparison of Glutathione and Malondialdehyde Concentrations in Athletes Engaged in Certain Sports. Thamar University Journal of Natural and Applied Sciences, 9(1), 39-42. https://doi.org/10.59167/tujnas.v9i1.2053

[22] Wang, S., Jiang, Z., Li, X., Sun, C., Zhang, Y., and Xiao, Z. (2023). Diagnostic value of serum LDH in children with refractory Mycoplasma pneumoniae pneumoniae: A systematic review and meta-analysis. Frontiers in Pediatrics, 11, 1094118. https://doi.org/10.3389/fped.2023.1094118

[23] Lu, J., Wei, Z., Jiang, H., Cheng, L., Chen, Q., Chen, M., ... and Sun, Z. (2018). Lactate dehydrogenase is associated with 28-day mortality in patients with sepsis: a retrospective observational study. Journal of Surgical Research, 228, 314-321. https://doi.org/10.1016/j.jss.2018.03.035

[24] Nedeva, C. (2021). Inflammation and cell death of the innate and adaptive immune system during sepsis. Biomolecules, 11(7), 1011. https://doi.org/10.3390/biom11071011

[25] Ulmeanu, A. I., Ciuparu, G. E., and Matran, E. R. (2025). Characteristics of Mycoplasma pneumoniae pneumonia in Romanian children. Microorganisms, 13(4), 883. https://doi.org/10.3390/microorganisms13040883

[26] Wei, Y., Liu, X., Lian, G., Han, N., Chen, Y., Zhang, Y., ... and Zhao, M. (2026). Correlation of Blood Leukocytes, CRP, LDH, and Cytokine Levels with Disease Severity in Children with Adenovirus Pneumonia. Viruses, 18(3), 364. https://doi.org/10.3390/v18030364

[27] Pan, W., Tao, C., Wu, Y., and Jiang, F. (2025). A medicinal chemistry perspective on lactate dehydrogenase: current status and future directions. Journal of Medicinal Chemistry, 68(16), 16869-16900. https://doi.org/10.1021/acs.jmedchem.5c00182

[28] Wang, X. H., Mitch, W. E., and Price, S. R. (2022). Pathophysiological mechanisms leading to muscle loss in chronic kidney disease. Nature Reviews Nephrology, 18(3), 138-152. https://doi.org/10.1038/s41581-021-00498-0

[29] Lippi, G., Schena, F., and Ceriotti, F. (2018). Diagnostic biomarkers of muscle injury and exertional rhabdomyolysis. Clinical Chemistry and Laboratory Medicine (CCLM), 57(2), 175-182. https://doi.org/10.1515/cclm-2018-0656

[30] Li, Y., Wang, C., and Peng, M. (2021). Aging immune system and its correlation with liability to severe lung complications. Frontiers in public health, 9, 735151. https://doi.org/10.3389/fpubh.2021.735151

[31] Li, C., Ye, J., Chen, Q., Hu, W., Wang, L., Fan, Y., ... and Lu, H. (2020). Elevated lactate dehydrogenase (LDH) level as an independent risk factor for the severity and mortality of COVID-19. Aging (Albany NY), 12(15), 15670. https://doi.org/10.18632/aging.103770

[32] Ali, R. H., Hussein, F. K., Nasar, D. M., and Abd Al salam Salem, A. (2025). The relevance of mitochondrial DNA mutation in human diseases and forensic sciences. Al-Nahrain Journal of Science, 28(1), 96-106. https://dx.doi.org/10.22401/ANJS.28.1.11

[33] Zheng, H., Ni, Y., Wang, S., Geng, M., Cao, H., Song, W., ... and Liu, K. (2023). Associations between antibiotic exposure and abnormal cardiac enzyme profiles in older Chinese adults. Environmental Science and Pollution Research, 30(59), 123679-123693. https://doi.org/10.1007/s11356-023-31082-7

[34] De La Fuente, M., Lombardero, L., Gómez-González, A., Solari, C., Angulo-Barturen, I., Acera, A., ... and Barreda-Gómez, G. (2021). Enzyme therapy: current challenges and future perspectives. International Journal of Molecular Sciences, 22(17), 9181. https://doi.org/10.3390/ijms22179181

[35] Ebrahimi, P., Pakdaman, K., Amri, P., Shirafkan, H., and Abedi, S. H. (2025). Prognostic values of elevated lactate dehydrogenase and creatine phosphokinase for disease severity and mortality in COVID-19 patients: a retrospective cohort study. Coronaviruses, 6(3), E26667975309434. https://doi.org/10.2174/0126667975309434240806074716

[36] Ghorbaninezhad, F., Bakhshivand, M., Saeedi, H., and Alizadeh, N. (2022). The association of elevated levels of LDH and CK-MB with cardiac injury and mortality in COVID-19 patients. ImmunoAnalysis, 2(1), 8-8. https://doi.org/10.34172/ia.2022.08