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Hematological and biochemical parameter changes among healthy individuals infected with COVID-19 according to sex and age: A hospital based study

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ABSTRACT

Background: Numerous studies have linked COVID-19 to a range of human health problems, including high blood pressure, diabetes, and heart disease. Only a few research have focused on the specific effects of COVID-19 on healthy people. Consequently, this study was designed to investigate the effects of COVID-19 on hematological and biochemical markers among healthy people infected with COVID-19 patients according to sex, and age.

Materials and methods: This study is a retrospective cross-sectional study conducted on 2,640 healthy people infected with COVID-19 in Jordan for the period from January 2021 to March 2022. Independent t-test and one-way ANOVA tests were used to compare the means of different groups.

Results: In the present study, only 271 out of 2,640 COVID-19 cases met the criteria and were assessed according to sex and age. The average age of the study population was 57.90 years. The findings of this study revealed that statistically significant increases were noticed only in the levels of WBC, K, and ferritin of males compared with females. Similarly, statistically significant increases across various age groups were observed in WBC, MCV, MCH, PT, INR, and D-dimer levels. Moreover, statistically significant increases in FBS, creatinine, AST, CPK, CK-MB, ferritin, and LDH were seen when comparing the biochemical parameters across age groups.

Conclusions: Patients infected with COVID-19 should be screened for all these studied hematological and biochemical parameters because the findings of the present study suggest that COVID-19 could lead to disturbances in, WBC, PT, APTT, d-dimer, INR, FBS, CR, urea, K, AST, ALT, ALP, LDH, CPK, CK-MB, and ferritin. We recommend clinical physicians to monitor patients' conditions immediately by evaluating all of these parameters in order to prevent patients from deteriorating into life-threatening situations.

Keywords: COVID-19, SARS-CoV-2, hematological, biochemical, kidney, liver, heart, Jordan

INTRODUCTION

A novel coronavirus or COVID-19 outbreak that first emerged in mainland Wuhan, China in December 2019, has subsequently spread to many countries, including Jordan, raising concerns for human health and posing a significant challenge for national health services [1, 2]. World Health Organization (WHO) declared COVID-19 a pandemic in March 2020 [3, 4]. This virus is similar to severe acute respiratory disease (SARS), which also caused an outbreak of SARS in 2002-2003 [5] despite the fact that COVID-19 has more cases than the SARS outbreak [6].

Additionally, COVID-19 has hampered the capabilities of the global healthcare system, making it difficult to treat patients, particularly those in intensive care units [7]. According to WHO statistics on December 2022, there have been 651,918,402 confirmed cases of COVID-19, including 6,656,601 deaths [8]. The human-to-human transmission of COVID-19 occurs by minute droplets or direct contact. Within a short period of time, COVID-19 reaches its peak and has become the most hazardous illness on the entire planet. The majority of infected people had mild to severe symptoms, and in certain circumstances, a catastrophic condition might result in death [9]. Although the respiratory system is most frequently impacted in those who acquire clinical sickness as a result of SARS-CoV-2, the virus can damage a variety of other organs [10, 11]. Through exploring of different pathological mechanisms of the COVID-19 virus, it was observed that it has the capability to bind itself to angiotensin converting enzyme-2 (ACE-2) receptors that are exposed in vascular endothelial cells, heart, brain, kidneys, colon, liver, pharynx, and other tissues causing direct injury and malfunction to these organs [10-15]. Organ dysfunctions could be occurred as a result of the virus's systemic diseases as well. Subsequently, it is critical to assess the efficacy of these organs while treating a patient [10]. Furthermore, issues with coagulation and vascular endothelium are frequent, but may not initially cause symptoms [16, 17]. In this regard, no study has been conducted

in Jordan to investigate the effects of COVID-19 on different hematological and biochemical markers to assess its effects on organ damage. Therefore, this study aimed to assess the impact of COVID-19 on hematological and biochemical parameters in healthy people with respect to sex and age.

MATERIALS AND METHODS

Data Sources

This retrospective cross-sectional study was conducted on healthy people infected with COVID-19 from January 2021 to March 2022. For this study, all determined data were collected and extracted from the system of the Ministry of Health in Jordan, through the Electronic Health Solutions Company, which includes all COVID-19 reported cases from many hospitals in different districts in Jordan. The collected data included information regarding sex, age, and laboratory findings. Charleson index was used to extract data from COVID-19 patients. It was designed to be zero to exclude those patients who could suffer from any disease, such as diabetes, blood pressure, heart diseases, cancer, kidney, or liver diseases, or others.

Hematological & Biochemical Data

Data for selected participants regarding blood tests, including white blood cells (WBCs), red blood cells (RBCs), hemoglobin (Hb), packed cell volume (PCV), mean cell volume (MCV), mean cell hemoglobin (MCH), mean cell hemoglobin concentration (MCHC), red cell distribution width coefficient variations (RDW-CV), platelets (PLT), prothrombin time (PT), activated partial thromboplastin time (APTT), international normalized ratio (INR), and d-dimer were collected and statistically analyzed. Biochemical tests included fasting blood sugar (FBS), hemoglobin A1c (HbA1C), high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride (TG), total cholesterol (TC), creatinine (CR), sodium (Na), chloride (Cl), potassium (K), calcium (Ca), magnesium (Mg), albumin (ALB), total protein (T. Prot), alkaline phosphatase (ALP), alanine transaminase (ALT), aspartate transaminase (AST), total bilirubin (T. Bili), direct bilirubin (D. Bili), creatine phosphokinase (CPK), creatine kinase MB (CKMB), ferritin, and lactate dehydrogenase (LDH).

Study Regulations

Study participants were not required to provide informed consent or answer any questions, patient confidentiality will be maintained, and we promise not to ask for any personally identifiable information (PII) for the purposes of this study.

Inclusion Criteria

1. Healthy people suffered only from for COVID-19.
2. Patients who had COVID-19 verified by RT-PCR.
3. Patients who were hospitalized or not.
4. Those who have complete data.

Exclusion Criteria

1. Patients suffered from any chronic disease.
2. Those who had some data missing from the system.

Figure 1 shows the flow of the study.

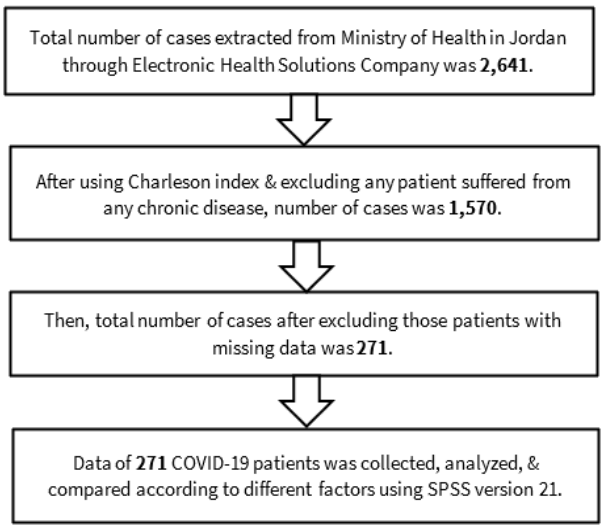

Figure 1. Flow chart of study (Source: Authors)

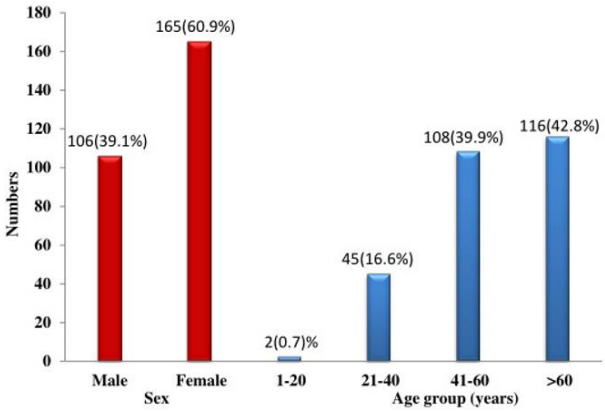

Figure 2. Distribution of COVID-19 patients according to sex & age (Source: Authors)

Data Analysis

All collected and extracted information were tabulated and presented as the mean±SD. Demographic data were collected and are presented as numbers and percentages. Statistical package for the social sciences (SPSS) version 21 for Windows was used for the analysis and comparison of the data. The results were compared and analyzed based on various parameters using one-way analysis of variance (ANOVA) and independent t-test.

RESULTS

Demographic Data

This retrospective cross-sectional study was conducted in Jordan from January 2021 to March 2022. In the current study, out of 2,640, only 271 cases had complete hematological and biochemical tests, making them appropriate for analysis of differences between these parameters depending on sex and age, as shown in **Figure 2**.

Figure 2 shows distribution of COVID-19 patients according to sex and age group. Average age of patients with COVID-19 was 57.90 years. Out of the 271 patients, females constitute about 165 (60.90%) were women and 106 (39.10%) were males. Most of admitted patients were in age group ranged

between 41-60 years 108 (39.90%) and above 60 years 116 (42.80%). While 45 (16.60%) and two (0.70%) were recorded for age group categories 21-40 and 1-20 years, respectively.

Number and Percentages of Hematological & Biochemical Tests & Their Reference Ranges

According to the results, there were high WBC counts in 126 (46.50%) of the participants, high RDW-CV in 163 (60.10%), high PT in 195 (71.96%), high APTT in 103 (38.00%), and high INR and d-dimer were observed in 151 (55.72%) and 59 (21.87%), respectively.

Additionally, high levels of PLT and MCV were detected in 60 (22.10%) and 25 (9.00%), respectively and high levels of PCV and RBC were observed only in 16 (5.90%) as shown in **Table 1**.

In contrast, the numbers of patients with low Hb and RBC levels were 166 (61.30%) and 100 (36.90%), respectively. In addition, low levels were recorded for PCV 64 (23.60%), MCV 68 (25.10%), and MCH 65 (24.00%) (**Table 1**).

Table 2 provides a detailed description about the number and percentages of normal, high, and low levels of all biochemical parameters reported in this study. High percentage of studied cases showed increased levels for LDH, ferritin and FBS tests compared to the reference values.

Comparing Results of Hematological & Biochemical Parameters of COVID-19 Patients According to Sex

For comparing the hematological tests between males and females, statistically significant differences were observed in WBCs ($p<0.05$) only and no significant differences were noticed

Table 1. Number & percentages of hematological and coagulation parameters & their reference ranges

Test	Reference range	Within reference range (n & %)	Lower than reference range (n & %)	Higher than reference range (n & %)	Reference
WBC cell×10^9/L	3.91-10.9	133 (49.1)	12 (4.4)	126 (46.5)	[21]
RBC cell×10^{12}/L	4.5-6	155 (57.2)	100 (36.9)	16 (5.9)	[21]
Hb g/dL	13.5-17.5	102 (37.6)	166 (61.3)	3 (1.1)	[21]
PCV%	36-48	191 (70.5)	64 (23.6)	16 (5.9)	[21]
MCV FL	80-96	178 (65.7)	68 (25.1)	25 (9.2)	[21]
MCH Pg	26-34	195 (72.0)	65 (24.0)	11 (4.1)	[21]
MCHC g/dL	31-37	247 (91.1)	19 (7.0)	5 (1.8)	[21]
RDW-CV%	11-16	108 (39.9)	-	163 (60.1)	[21]
PLT cell×10^9/L	150-450	195 (72.0)	16 (5.9)	60 (22.1)	[21]
PT sec	10.1-15.9	76 (28.0)	-	195 (71.9)	[21]
APTT sec	22-45	168 (61.9)	-	103 (38.0)	[21]
INR%	0.6-1.2	120 (44.9)	-	151 (55.7)	[21]
D-Dimer µg/mL	<0.5	212 (78.2)	-	59 (21.9)	[40]

Note. WBC: White blood cells; RBC: Red blood cells; Hb: Hemoglobin; PCV: Packed cell volume; MCV: Mean cell volume; MCH: Mean cell hemoglobin; MCHC: Mean cell hemoglobin concentrations; RDW-CV: Red cell distribution width coefficient variations; PLT: Platelets; PT: Prothrombin time; APTT: Activated partial thromboplastin time; & INR: International normalized ratio

Table 2. Number & percentages of biochemical parameters & their reference ranges

Test	Reference range	Within reference range (n & %)	Lower than reference range (n & %)	Higher than reference range (n & %)	Reference
FBS mg/dL	70-100	88 (32.47)	-	183 (67.5)	[41]
HbA1C %	0-6	202 (74.6)	-	69 (25.4)	[41]
HDL mg/dL	<60	25 (9.2)	246 (90.8)	--------	[42]
LDL mg/dL	<130	227 (83.7)	-	44 (16.2)	[43]
TG mg/dL	<150	205 (75.6)	-	66 (24.4)	[44]
TC mg/dL	<200	216 (79.7)	-	55 (20.3)	[43]
CR mg/dL	0.7-1.3	122 (45.0)	77 (28.4)	72 (26.6)	[45]
Urea mg/dL	15-45	182 (67.2)	-	89 (32.8)	[46]
Na mmol/L	135-145	208 (76.8)	16 (5.9)	47 (17.4)	[20, 47, 48]
Cl mmol/L	95-105	182 (67.2)	18 (6.6)	71 (26.2)	[20]
K mmol/L	3.5-5.5	236 (87.1)	6 (2.2)	29 (10.7)	[20]
Ca mg/dL	8.5-10.5	149 (55.0)	91 (33.6)	31 (11.5)	[49]
Mg (mg/dL	1.7-2.5	18 (6.6)	253 (93.4)	-	[50]
ALB g/dL	3.50-5.50	181 (66.8)	88 (32.5)	2 (0.7)	[51]
T. Prot g/dL	6.6-7.9	156 (57.6)	89 (32.8)	26 (9.6)	[52]
T. Bili mg/dL	0.2-1.2	228 (84.1)	24 (8.9)	19 (7)	[53]
D. Bili mg/dL	0-0.3	186 (69.6)	-	85 (31.4)	[53]
ALT U/L	0-35	153 (56.5)	-	118 (43.5)	[21]
AST U/L	0-50	184 (67.9)	-	87 (32.1)	[21]
ALP U/L	125	191 (70.5)	-	80 (29.5)	[36]
LDH U/L	0-248	74 (27.3)	-	197 (72.7)	[21]
CPK U/L	0-50	163 (60.1)	15 (5.5)	93 (34.3)	[54]
CKMB U/L	0-24	127 (46.9)	-	144 (35.1)	[21]
Ferritin ng/mL	22-274	75 (27.7)	8 (3.0)	188 (69.4)	[22, 55]

Note. FBS: Fasting blood sugar; HbA1C: Hemoglobin A1c; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; TG: Triglycerides; TC: Total cholesterol; CR: Creatinine; Na: Sodium; Cl: Chloride; K: Potassium; Ca: Calcium; Mg: Magnesium; ALB: Albumin; T. Prot: Total protein; ALP: Alkaline phosphatase; ALT: Alanine transaminase; AST: Aspartate transaminase; T. Bili: Total bilirubin; D. Bili: Direct bilirubin; CPK: Creatine phosphokinase; CKMB: Creatine kinase MB; & LDH: Lactate dehydrogenase

Table 3. Comparison between hematological and coagulation parameters of COVID-19 patients according to sex

Test	Males (106)	Females (165)	Sig. (2-tailed)
WBC cell×10^9/L	14.64±18.64	11.19±6.32	0.050[a]
RBC cell×10^{12}/L	4.95±87.00	4.71±75.00	0.116
Hb g/dL	13.91±1.89	12.21±1.83	0.121
PCV%	42.34±6.69	38.67±7.43	0.211
MCV FL	87.33±9.65	84.46±9.11	0.121
MCH Pg	29.16±3.45	27.28±3.50	0.071
MCHC g/dL	34.62±5.49	33.59±3.64	0.064
RDW-CV%	14.76±2.02	15.45±3.22	0.061
PLT cell×10^9/L	358.49±65.37	340.26±36.54	0.345
PT sec	15.33±3.25	14.94±2.49	0.271
APTT sec	32.19±6.54	32.73±7.31	0.542
INR%	1.28±0.55	2.40±1.63	0.432
D-dimer µg/mL	1.55±2.34	1.16±1.33	0.123

Note. WBC: White blood cells; RBC: Red blood cells; Hb: Hemoglobin; PCV: Packed cell volume; MCV: Mean cell volume; MCH: Mean cell hemoglobin; MCHC: Mean cell hemoglobin concentrations; RDW-CV: Red cell distribution width coefficient variations; PLT: Platelets; PT: Prothrombin time; APTT: Activated partial thromboplastin time; INR: International normalized ratio; Data are presented as mean±SD; Independent t-test was used to compare means of different group; & p-value was considered significant at ≤0.05, a≤0.05, b≤0.01, & C≤0.001

for the other hematological parameters (p>0.05) (**Table 3**). The average of WBCs values of males was statistically increased compared with females (p<0.05). The results of the means of RBC, Hb, PCV, MCV, MCH and MCHC were found to be slightly increased in male compared with female, but without any significant differences (p>0.05). While the RDW-CV, APTT, and INR was found to be increased in females compared with males (p≥0.05). At the same time, findings of PLTs, PT, and d-dimer were found to be slightly increased in males compared with females (p>0.05) (**Table 3**).

On comparing the results of the biochemical markers between males and females, it was found that only potassium and ferritin had statistically significant differences (p<0.001) (**Table 4**). Other parameters did not show any statistically significant differences when comparing mean values between males and females (p>0.05) (**Table 4**).

Table 4. Comparison between biochemical parameters of COVID-19 patients according to sex

Test	Males (106)	Females (165)	p-value
FBS mg/dL	224.21±42.18	212.77±52.53	0.453
HbA1C %	5.80±1.66	5.99±1.65	0.372
HDL mg/dL	45.98±13.93	46.88±13.38	0.594
LDL mg/dL	101.26±25.03	105.99±32.27	0.385
TG mg/dL	127.48±57.27	114.43±37.07	0.143
TC mg/dL	161.26±63.12	160.64±23.50	0.944
CR mg/dL	1.44±1.02	1.31±0.56	0.112
Urea mg/dL	32.71±8.75	27.42±7.032	0.082
Na mmol/L	140.90±15.29	140.80±12.41	0.955
Cl mmol/L	103.59±6.95	103.17±6.63	0.618
K mmol/L	6.89±0.82	4.15±0.72	0.001[C]
Ca mg/dL	15.34±42.75	16.04±42.08	0.895
Mg (mg/dL	0.84±0.15	0.83±0.18	0.638
ALB g/dL	3.46±0.92	3.77±1.76	0.099
T. Prot g/dL	10.32±14.30	10.15±13.88	0.920
ALP U/L	120.39±41.01	130.06±33.17	0.436
ALT U/L	77.85±19.78	75.00±24.34	0.923
AST U/L	83.37±26.48	86.06±27.70	0.930
T. Bili mg/dL	0.60±0.24	0.60±0.77	0.979
D. Bili mg/dL	0.30±0.23	0.34±0.71	0.572
CPK U/L	428.95±90.97	319.67±67.29	0.298
CKMB U/L	38.44±18.43	30.68±15.41	0.146
Ferritin ng/mL	627.95±77.93	436.51±73.22	0.001[C]
LDH U/L	366.42±91.95	362.68±85.74	0.873

Note. FBS: Fasting blood sugar; HbA1C: Hemoglobin A1c; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; TG: Triglycerides; TC: Total cholesterol; CR: Creatinine; Na: Sodium; Cl: Chloride; K: Potassium; Ca: Calcium; Mg: Magnesium; ALB: Albumin; T. Prot: Total protein; ALP: Alkaline phosphatase; ALT: Alanine transaminase; AST: Aspartate transaminase; T. Bili: Total bilirubin; D. Bili: Direct bilirubin; CPK: Creatine phosphokinase; CKMB: Creatine kinase MB; LDH: Lactate dehydrogenase; Data are presented as mean±SD; Independent t-test was used to compare means of different group; & p-value was considered significant at ≤0.05, a≤0.05, b≤0.01, & C≤0.001

Variation Between Results of Hematological, Coagulation & Biochemical Parameters of COVID-19 Patients According to Age Group Classification

Comparison of hematological tests of COVID-19 patients according to different age groups revealed statistically significant differences in WBC (p<0.05), MCV (p<0.01), MCH (p<0.001), PT (p<0.013), INR (p<0.01), and d-dimer levels (p<0.001). Other hematological parameters such as RBC, Hb, PCV, MCHC, PLT, and APTT, did not show any statistically significant differences between different age groups (**Table 5**).

On the other hand, comparing the differences in the means of the biochemical parameters among different age groups showed that statistically significant increases were detected between the means of FBS (p<0.002), CR (p<0.01), AST (p<0.036), CPK (p<0.012), CKMB (p<0.05), ferritin (p=0.001),

Table 5. Comparison between hematological and coagulation parameters of COVID-19 patients according to age group classification

Test	1-20 (2): Mean±SD	21-40 (45): Mean±SD	41-60 (108): Mean±SD	>60 (116): Mean ± SD)	p-value
WBC cell×10^9/L	6.47±1.75	8.94±3.98	11.9±7.22	14.61±17.78	0.050[a]
RBC cell×10^{12}/L	5.39±0.49	5.28±0.63	5.41±0.87	5.56±1.75	0.131
Hb g/dL	14.15±0.92	13.47±1.73	13.03±2.23	12.90±1.81	0.340
PCV%	42.50±0.71	40.75±4.64	40.01±7.88	93.84±7.81	0.869
MCV FL	79.65±8.98	81.55±7.17	82.24±9.51	88.49±8.92	0.001[C]
MCH Pg	26.80±4.52	26.94±2.64	27.11±3.90	29.30±3.23	0.001[C]
MCHC g/dL	33.25±1.63	34.58±8.24	33.88±4.42	33.88±1.65	0.810
RDW-CV%	14.95±0.35	14.79±2.43	15.79±3.62	14.77±1.94	0.069
PLT cell×10^9/L	293.50±48.02	311.89±35.12	383.93±87.97	328.59±84.25	0.081
PT sec	13.40±0.99	14.68±2.05	16.82±2.14	18.54±3.51	0.010[b]
APTT sec	31.75±0.64	31.77±4.68	31.69±7.29	44.59±7.45	0.189
INR%	1.30±0.02	1.09±0.22	1.17±0.35	3.52±1.78	0.010[b]
D-Dimer µg/mL	0.73±0.22	0.86±0.41	1.13±0.71	1.68±0.93	0.001[C]

Note. WBC: White blood cells; RBC: Red blood cells; Hb: Hemoglobin; PCV: Packed cell volume; MCV: Mean cell volume; MCH: Mean cell hemoglobin; MCHC: Mean cell hemoglobin concentrations; RDW-CV: Red cell distribution width coefficient variations; PLT: Platelets; PT: Prothrombin time; APTT: Activated partial thromboplastin time; INR: International normalized ratio; Data are presented as mean±SD; One-way ANOVA test was used to compare means of different group; & p-value was considered significant at ≤0.05, a≤0.05, b≤0.01, & C≤0.001

Table 6. Comparison between biochemical parameters of COVID-19 patients according to age group classification

Test	1-20 (2): Mean±SD	21-40 (45): Mean±SD	41-60 (108): Mean±SD	>60 (116): Mean ± SD)	p-value
FBS mg/dL	175.70±75.08	157.70±11.16	219.37±10.63	239.08±12.99	0.010[b]
HbA1C %	3.90±0.42	5.77±1.64	6.16±1.66	6.77±1.63	0.086
HDL mg/dL	60.67±8.528	45.43±13.67	46.28±13.02	46.95±14.13	0.458
LDL mg/dL	148.01±86.28	102.51±26.12	105.03±36.82	103.13±44.14	0.531
TG mg/dL	105.03±22.05	108.12±17.62	123.14±27.41	120.93±33.82	0.673
TC mg/dL	149.39±34.08	154.21±36.05	171.12±75.76	258.70±64.03	0.070
CR mg/dL	0.80±0.56	0.76±0.35	0.91±0.27	1.76±0.93	0.010[b]
Urea mg/dL	44.32±7.71	23.80±14.98	27.87±15.09	33.00±21.10	0.120
Na mmol/L	137.00±16.44	141.42±25.14	139.81±14.56	141.63±15.06	0.743
Cl mmol/L	104.25±22.05	104.12±6.55	102.01±6.33	104.26±7.10	0.074
K mmol/L	3.89±0.41	4.42±0.57	4.67±0.74	4.82±0.89	0.061
Ca mg/dL	8.39±1.64	20.16±5.02	14.77±3.45	15.11±3.81	0.890
Mg (mg/dL	0.82±0.05	0.81±0.16	0.86±0.16	0.82±0.17	0.250
ALB g/dL	4.40±0.42	3.74±0.81	3.70±0.78	3.56±2.13	0.770
T. Prot g/dL	6.63±0.60	8.04±2.96	10.47±4.45	10.89±5.29	0.681
ALP U/L	237.00±47.88	106.64±38.06	113.18±62.26	144.18±81.85	0.129
ALT U/L	24.25±10.29	46.16±16.49	48.53±19.39	114.32±35.54	0.153
AST U/L	20.50±4.24	47.04±7.08	48.29±15.52	135.03±35.79	0.050[b]
T. Bili mg/dL	0.61±0.18	0.53±0.53	0.61±0.95	0.62±0.47	0.903
D. Bili mg/dL	0.26±0.022	0.32±0.24	0.36±0.85	0.29±0.28	0.824
CPK U/L	74.50±16.26	339.55±98.24	368.39±78.94	432.92±59.88	0.010[b]
CKMB U/L	40.75±2.47	27.32±11.93	36.67±17.45	43.32±13.64	0.050[a]
Ferritin ng/mL	466.65±35.69	398.70±61.55	516.01±39.09	550.91±47.98	0.001[c]
LDH U/L	335.07±84.98	350.69±58.33	368.59±67.21	401.77±76.86	0.050[a]

Note. FBS: Fasting blood sugar; HbA1C: Hemoglobin A1c; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; TG: Triglycerides; TC: Total cholesterol; CR: Creatinine; Na: Sodium; Cl: Chloride; K: Potassium; Ca: Calcium; Mg: Magnesium; ALB: Albumin; T. Prot: Total protein; ALP: Alkaline phosphatase; ALT: Alanine transaminase; AST: Aspartate transaminase; T. Bili: Total bilirubin; D. Bili: Direct bilirubin; CPK: Creatine phosphokinase; CKMB: Creatine kinase MB; LDH: Lactate dehydrogenase; Data are presented as mean±SD; One-way ANOVA test was used to compare means of different group; & p-value was considered significant at ≤0.05, a≤0.05, b≤0.01, & C≤0.001

and LDH (p=0.05) between different age groups, as presented in showed in (**Table 6**).

Values of the means of FBS ranged from to 175-239 mg/dL, which is higher than the normal range. No statistically significant differences were observed in HbA1C, HDL, LDL, TG, TC, UREA, Na, CL, Ca, Mg, ALP, total protein, ALT, ALP, total bilirubin, and direct bilirubin among the different age groups (p>0.05) (**Table 6**).

DISCUSSION

COVID-19 is one of the most terrible pandemic diseases that have recently swept around the planet [18]. The goal of this study is to better represent any variations that may occur in blood or biochemical parameters.

Since prior disease history may affect the results of the measured variables. This is the first study carried out in Jordan to focus on healthy individuals without a history of sickness. As a result, Charleson index was adjusted to zero to eliminate any potential cases of diabetes, high blood pressure, heart disease, cancer, renal, or liver illness, among other ailments.

Charlson comorbidity index (CCI) provides for the adjustment of mortality risk in claims-based research and assists clinicians in selecting risk-based care management resources [19]. It comprised 19 different types of medical disorders that were recognizable in medical records [19].

The current study determined that the proportion of females infected with COVID-19 was 60.90%, which is greater than that of males (39.10%). It was discovered that, in both sexes, the proportion of infection rose with age. These results differ from previous results, which revealed 68.67%, 51.10% [20] and 31.33%, 48.90% for males and females, respectively [21]. The average age reported in the current research was found to be 57.90 years, which is comparable with 56.00 [21], higher than 45.15 years [20], but lower than 67.50 years [22], and 66.00 years according to what was reported in previous studies [23]. Also, mortality rate in this study was 5.90%, which is higher than 2.50% [24], but it is considered lower than 7.00%, 10.00%, and 13.18% recorded in previous studies [25-27].

In our study, it was obvious that the majority of patients (82.70%) admitted to the hospital as a result of COVID-19 infection was above the age of 40 years, which is consistent with the findings of other studies [20, 23]. These variances might be attributable to several factors such as changes in sample size, economic situation, level of health education, and presence of other factors such as chronic diseases, which could potentially influence the findings of prior research, since our investigation was centered solely on healthy patients infected with COVID-19.

The overall analysis and categorization of the data revealed that of the 271 COVID-19 patients, 126 (46.50%), 163 (60.10%), 195 (71.96%), 103 (38.00%), 151 (55.72%), and 149 (54.98%) had higher levels of WBC, RDW-CV, PT, APTT, INR, and d-dimer, respectively, when compared with referenced ranges. These results were corroborated by the findings of previous studies [20, 21, 27]. In contrast, low values were found in other parameters, including WBC, RBC, Hb, PCV, MCV, MCH, MCHC, RDW-CV, and PLT with 12(4.40%), 100 (36.90%), 166 (61.30%), 64 (23.60%), 68 (25.10%), 65 (24.00%), 19 (7.00%), and 16 (5.90%), respectively, compared to referenced ranges.

An earlier study found that 16 (14.30%) patients had higher WBC counts than normal, whereas eight (7.10%) had lower WBC counts [27] and other studies showed similar results with no significant changes in PLT, Hb, PCV, and RBC parameters [20, 28]. The number of patients with low PLT count in this

study was 16 (5.90%), which was lower than the 71 (18.68%) reported in a previous study [29].

Regarding the alterations in the biochemical tests for COVID-19 patients, it was revealed that 183 (67.53%) patients had higher FBS levels and only 88 (32.47%) had normal levels, while 202 (74.60%) patients had normal HbA1C levels and only 69 (25.40%) had higher values. Increasing the HbA1C levels of some COVID-19 patients despite the fact that they had not previously had diabetes because those patients had been followed for more than three months.

The results of this study showed that the COVID-19 virus affected the levels of blood glucose because most of the participants experienced an increase in the levels of glucose in the blood after COVID-19 infection, which could be occurred as a result of disturbances in insulin secretion. This finding needs more investigation and confirmation using a large sample size and examination of FBS, random blood sugar (RBS), and HbA1C for all participants before and after COVID-19 infection. The findings of this study are similar to those conducted by Chen and colleagues, who reported that severe COVID-19 was associated with higher blood glucose [30]. Moreover, it was concluded in a previous study that severe COVID-19 may accelerate the development of acute complications of diabetes by having a direct negative impact on cell function and worsening diabetes [31].

Lipid profiles, including TC, TG, and LDL-C, were found to be elevated in 55 (20.30%), 66 (24.40%), and 44 (16.24%) patients, respectively, while for HDL-C, 246 (90.80%) had lower levels and only 25 (9.20%) had normal levels. This issue may not be directly connected with COVID-19 infection, and abnormality usually occurs after a long time due to the experience of many habits such as unhealthy food diet and lifestyle. Some COVID-19 patients exhibit higher levels of kidney function tests such as CR 72 (26.60%), urea 89 (32.80%), Na 47 (17.40%), Cl 71 (26.20%), and K 29 (10.70%), which is similar to the first reported findings that confirmed that COVID-19 has an effect on kidney function parameters, especially urea and CR [32-34].

Approximately 91 (33.60%) and 253 (93.40%) patients experienced low levels of Ca and Mg, respectively. Assessment of liver function parameters revealed that only two (0.70%), 26 (9.60%), 19 (7.00%), and 85 (31.40%) patients had increased levels of ALB, T. Prot, T. Bili, and D. Bili, respectively.

In regard to liver enzymes such as ALT, AST, ALP, and LDH were elevated in 118 (43.50%), 87 (32.10%), 80 (29.50%), and 197 (72.70%) patients, respectively. Hypoalbuminemia and hypoproteinemia were detected in 88 (32.50%) and 89 (32.80%), respectively, which was confirmed in another study [35]. One study reported that high levels of ALT, AST, T. Bili, ALP, and GGT were recorded in 22.70%, 7.60%, 1.80%, 4.60%, and 18.50% as well as 25.30% were suffered from hypoalbuminemia [36]. Several studies have reported different degrees of abnormalities in liver function markers in patients with COVID-19, which confirmed the findings of the current study [36-38].

Regarding cardiac enzymes, increased levels of the cardiac enzymes CPK and CKMB were found in 93 (34.30%) and 144 (35.10%) patients, respectively, and approximately 188 (69.40%) patients with COVID-19 had elevated ferritin levels. Similar findings were reported in many studies that support the results of this study [20, 39]. Comparing the changes in hematological and biochemical parameters between male and females, we found that significant differences were observed in WBC count ($p<0.05$), MCV ($p<0.001$), MCHC ($p<0.001$), and RDW-CV ($p<0.01$). In addition, significant differences were detected in K and ferritin ($p<0.001$), levels.

In the present study, we classified the patients into four categories according to their age to evaluate the changes in the hematological and biochemical parameters. We found that patients aged more than sixty, they had higher levels compared with other age groups, followed by age group 40-60 years, and low levels were observed in the age group between 1-20 years. It is crucial to highlight the fact that hematological and biochemical markers showed markedly statistically significant increases in the over-60 age group, which may indicate that older people have weakened immune systems and are therefore less resistant to viruses than younger people, allowing them to catch an infection and spread it more quickly.

CONCLUSIONS

This study showed that COVID-19 could disturb the blood glucose, affects kidney, liver and heart functions. No significant changes were noticed after comparing the values of hematological and biochemical parameters between males and females except for WBC, K, and ferritin. Comparing the findings by age groups revealed that some of the analyzed hematological and biochemical variables had substantial differences. Clinical decision-making in the future may consider the hematological and biochemical markers in COVID-19 patients. These markers may help clinicians make clinical judgments to spot high mortality patients and subpar diagnoses during the first admission stage.

A comprehensive study with large sample size should be conducted taking in consideration involvement of other parameters like CRP, ESR, differential leukocyte count, glomerular filtration rate and other related markers for better reflecting full view about possible effects, which could be emerged as a result of COVID-19 infection. Also, data about clinical symptoms like temperature, blood pressure, fever, diarrhea, difficulty in breathing should be collected and evaluated.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

1. Rachman A, Iriani A, Irawan C, et al. Complete blood count derived inflammatory biomarkers and the level of anti-SARS-CoV-2 NAb and S-RBD IgG among cancer survivors receiving COVID-19 vaccines. Electron J Gen Med. 2023;20(2):em456. https://doi.org/10.29333/ejgm/12851
2. Al-Tammemi AB. The battle against COVID-19 in Jordan: An early overview of the Jordanian experience. Front Public Health. 2020;8:188. https://doi.org/10.3389/fpubh.2020.00188 PMid:32574291 PMCid:PMC7220996
3. Jimenez-Sotomayor MR, Gomez-Moreno C, Soto-Perez-de-Celis E. Coronavirus, ageism, and Twitter: An evaluation of tweets about older adults and COVID-19. J Am Geriatr Soc. 2020;68(8):1661-5. https://doi.org/10.1111/jgs.16508 PMid:32338787 PMCid:PMC7267430
4. Tomer V, Gupta S, Manwal M, Singh D. How statistics of world health index react against COVID-19. Mater Today Proc. 2021;46:11267-73. https://doi.org/10.1016/j.matpr.2021.03.486 PMid:33816130 PMCid:PMC7997708
5. Al-Nimer MS, Merza TA, Mohammed YMKY, Mohammed HA. Blood cells indices are determinants of the COVID-19 outcome: A cross-sectional study from Kurdistan Region-Iraq. Electron J Gen Med. 2021;18(5):em304. https://doi.org/10.29333/ejgm/11013
6. WHO. Coronavirus disease (COVID-2019) situation reports. World Health Organization; 2021. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports (Accessed: 1 April 2023).
7. Tummers J, Catal C, Tobi H, Tekinerdogan B, Leusink G. Coronaviruses and people with intellectual disability: An exploratory data analysis. J Intellect Disabil Res. 2020;64(7):475-81. https://doi.org/10.1111/jir.12730 PMid:32307762 PMCid:PMC7264798
8. Chavda VP, Mishra T, Vuppu S. Immunological studies to understand hybrid/recombinant variants of SARS-CoV-2. Vaccines. 2022;11(1):45. https://doi.org/10.3390/vaccines11010045 PMid:36679891 PMCid:PMC9867374
9. Bianchi F, Bianchi G, Song D. The long-term impact of the COVID-19 unemployment shock on life expectancy and mortality rates. J Econ Dyn Control. 2022;146:104581. https://doi.org/10.1016/j.jedc.2022.104581 PMid:36506795 PMCid:PMC9721190
10. Jain U. Effect of COVID-19 on the organs. Cureus. 2020;12(8):e9540. https://doi.org/10.7759/cureus.9540
11. Zaim S, Chong JH, Sankaranarayanan V, Harky A. COVID-19 and multiorgan response. Curr Probl Cardiol. 2020;45(8):100618. https://doi.org/10.1016/j.cpcardiol.2020.100618 PMid:32439197 PMCid:PMC7187881
12. Merad M, Martin JC. Pathological inflammation in patients with COVID-19: A key role for monocytes and macrophages. Nat Rev Immunol. 2020;20(6):355-62. https://doi.org/10.1038/s41577-020-0331-4 PMid:32376901 PMCid:PMC7201395
13. Varga Z, Flammer AJ, Steiger P, et al. Endothelial cell infection and endotheliitis in COVID-19. Lancet. 2020;395(10234):1417-8. https://doi.org/10.1016/S0140-6736(20)30937-5 PMid:32325026
14. Haberman R, Axelrad J, Chen A, et al. COVID-19 in immune-mediated inflammatory diseases–case series from New York. N Engl J Med. 2020;383(1):85-8. https://doi.org/10.1056/NEJMc2009567 PMid:32348641 PMCid:PMC7204427
15. Bikdeli B, Madhavan MV, Jimenez D, et al. COVID-19 and thrombotic or thromboembolic disease: Implications for prevention, antithrombotic therapy, and follow-up: JACC state-of-the-art review. J Am Coll Cardiol. 2020;75(23):2950-73. https://doi.org/10.1016/j.jacc.2020.04.031 PMid:32311448 PMCid:PMC7164881
16. Wang K, Chen W, Zhang Z, et al. CD147-spike protein is a novel route for SARS-CoV-2 infection to host cells. Signal Transduct Target Ther. 2020;5(1):283. https://doi.org/10.1038/s41392-020-00426-x PMid:33277466 PMCid:PMC7714896
17. Wang M, Xiong H, Chen H, Li Q, Ruan XZ. Renal injury by SARS-CoV-2 infection: A systematic review. Kidney Dis. 2021;7(2):100-10. https://doi.org/10.1159/000512683 PMid:33821207 PMCid:PMC7705946
18. Saghir SA, AlGabri NA, Alagawany MM, et al. Chloroquine and hydroxychloroquine for the prevention and treatment of COVID-19: A fiction, hope or hype? An updated review. Ther Clin Risk Manag. 2021;17:371. https://doi.org/10.2147/TCRM.S301817 PMid:33953559 PMCid:PMC8092643
19. Glasheen WP, Cordier T, Gumpina R, Haugh G, Davis J, Renda A. Charlson comorbidity index: ICD-9 update and ICD-10 translation. Am Health Drug Benefits. 2019;12(4):188.
20. Bairwa M, Kumar R, Beniwal K, Kalita D, Bahurupi Y. Hematological profile and biochemical markers of COVID-19 non-survivors: A retrospective analysis. Clin Epidemiol Glob Health. 2021;11:100770. https://doi.org/10.1016/j.cegh.2021.100770 PMid:33997479 PMCid:PMC8106521
21. Huyut MT, Huyut Z, Ilkbahar F, Mertoglu C. What is the impact and efficacy of routine immunological, biochemical and hematological biomarkers as predictors of COVID-19 mortality? Int Immunopharmacol. 2022;105:108542. https://doi.org/10.1016/j.intimp.2022.108542 PMid:35063753 PMCid:PMC8761578
22. Dufrusine B, Valentinuzzi S, Bibbò S, et al. Iron dyshomeostasis in COVID-19: Biomarkers reveal a functional link to 5-lipoxygenase activation. Int J Mol Sci. 2023;24(1):15. https://doi.org/10.3390/ijms24010015 PMid:36613462 PMCid:PMC9819889
23. Yuan X, Huang W, Ye B, et al. Changes of hematological and immunological parameters in COVID-19 patients. Int J Hematol. 2020;112:553-9. https://doi.org/10.1007/s12185-020-02930-w PMid:32656638 PMCid:PMC7354745
24. Kumar R, Singh V, Mohanty A, Bahurupi Y, Gupta PK. Corona health-care warriors in India: Knowledge, attitude, and practices during COVID-19 outbreak. J Educ Health Promot. 2021;10:44. https://doi.org/10.4103/jehp.jehp_524_20 PMid:34084791 PMCid:PMC8057180
25. Lu J, Hu S, Fan R, et al. ACP risk grade: A simple mortality index for patients with confirmed or suspected severe acute respiratory syndrome coronavirus 2 disease (COVID-19) during the early stage of outbreak in Wuhan, China. MedRxiv. 2020:2020.02.20.20025510. https://doi.org/10.1101/2020.02.20.20025510
26. Wajahat M, Muhammad J, Ali SS, et al. COVID-19 Impact on hematological and biochemical parameters on outcomes of admitted patients. Int J Health Sci. 2022;6(S7):6864-74. https://doi.org/10.21203/rs.3.rs-1981846/v1
27. Anani M, Amer SA, Kishk RM, Hassan A, Hassan S, Attia F. Evaluation of blood and biochemical parameters of COVID-19 patients in Suez Canal University Hospital: A retrospective study. J Infect Dev Ctries. 2022;16(04):592-9. https://doi.org/10.3855/jidc.14591 PMid:35544618

28. Liu Y, Yang Y, Zhang C, et al. Clinical and biochemical indexes from 2019-nCoV infected patients linked to viral loads and lung injury. Sci China Life Sci. 2020;63:364-74. https://doi.org/10.1007/s11427-020-1643-8 PMid:32048163 PMCid:PMC7088566
29. Liao D, Zhou F, Luo L, et al. Haematological characteristics and risk factors in the classification and prognosis evaluation of COVID-19: A retrospective cohort study. The Lancet Haematol. 2020;7(9):e671-8. https://doi.org/10.1016/S2352-3026(20)30217-9 PMid:32659214
30. Chen J, Wu C, Wang X, Yu J, Sun Z. The impact of COVID-19 on blood glucose: A systematic review and meta-analysis. Front Endocrinol. 2020;11:574541. https://doi.org/10.3389/fendo.2020.574541 PMid:33123093 PMCid:PMC7570435
31. Apicella M, Campopiano MC, Mantuano M, Mazoni L, Coppelli A, Del Prato S. COVID-19 in people with diabetes: Understanding the reasons for worse outcomes. Lancet Diabetes Endocrinol. 2020;8(9):782-92. https://doi.org/10.1016/S2213-8587(20)30238-2 PMid:32687793
32. Cheng Y, Luo R, Wang K, et al. Kidney disease is associated with in-hospital death of patients with COVID-19. Kidney Int. 2020;97(5):829-38. https://doi.org/10.1016/j.kint.2020.03.005 PMid:32247631 PMCid:PMC7110296
33. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395(10223):497-506. https://doi.org/10.1016/S0140-6736(20)30183-5 PMid:31986264
34. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: A descriptive study. Lancet. 2020;395(10223):507-13. https://doi.org/10.1016/S0140-6736(20)30211-7 PMid:32007143
35. Meduri GU, Headley S, Kohler G, et al. Persistent elevation of inflammatory cytokines predicts a poor outcome in ARDS: Plasma IL-1β and IL-6 levels are consistent and efficient predictors of outcome over time. Chest. 1995;107(4):1062-73. https://doi.org/10.1378/chest.107.4.1062 PMid:7705118
36. Lv Y, Zhao X, Wang Y, et al. Abnormal liver function tests were associated with adverse clinical outcomes: An observational cohort study of 2,912 patients with COVID-19. Front Med. 2021;8:639855. https://doi.org/10.3389/fmed.2021.639855 PMid:34179034 PMCid:PMC8219933
37. Kulkarni AV, Kumar P, Tevethia HV, et al. Systematic review with meta-analysis: Liver manifestations and outcomes in COVID-19. Aliment Pharmacol Ther. 2020;52(4):584-99. https://doi.org/10.1111/apt.15916 PMid:32638436 PMCid:PMC7361465
38. Mao R, Qiu Y, He J-S, et al. Manifestations and prognosis of gastrointestinal and liver involvement in patients with COVID-19: A systematic review and meta-analysis. Lancet Gastroenterol Hepatol. 2020;5(7):667-78. https://doi.org/10.1016/S2468-1253(20)30126-6 PMid:32405603
39. Hanif W, Ali O, Shahzad H, Younas M, Iqbal H, Afzal K. Biochemical markers in COVID-19 in Multan. J Coll Physicians Surg Pak. 2020;30(10):1026-9. https://doi.org/10.29271/jcpsp.2020.10.1026 PMid:33143821
40. Deng P, Ke Z, Ying B, Qiao B, Yuan L. The diagnostic and prognostic role of myocardial injury biomarkers in hospitalized patients with COVID-19. Clin Chim Acta. 2020;510:186-90. https://doi.org/10.1016/j.cca.2020.07.018 PMid:32681933 PMCid:PMC7363604
41. Lartey AH, Li X, Li Z, Zhang Q, Wang J. Age- and sex-specific profiles of temporal fasting plasma glucose variability in a population undergoing routine health screening. BMC Public Health. 2021;21(1):320. https://doi.org/10.1186/s12889-021-10367-x PMid:33563261 PMCid:PMC7871645
42. Rajagopal G, Suresh V, Sachan A. High-density lipoprotein cholesterol: How high. Indian J Endocrinol Metab. 2012;16(Suppl 2):S236-8.
43. LaRosa JC. At what levels of total low-or high-density lipoprotein cholesterol should diet/drug therapy be initiated? United States guidelines. Am J Cardiol. 1990;65(12):7-10. https://doi.org/10.1016/0002-9149(90)91247-4 PMid:2180270
44. Miller M, Stone NJ, Ballantyne C, et al. Triglycerides and cardiovascular disease: A scientific statement from the American Heart Association. Circulation. 2011;123(20):2292-333. https://doi.org/10.1161/CIR.0b013e3182160726 PMid:21502576
45. Bastug A, Bodur H, Erdogan S, et al. Clinical and laboratory features of COVID-19: Predictors of severe prognosis. Inter Immunopharmacol. 2020;88:106950. https://doi.org/10.1016/j.intimp.2020.106950 PMid:32919217 PMCid:PMC7480980
46. Ye B, Deng H, Zhao H, Liang J, Ke L, Li W. Association between an increase in blood urea nitrogen at 24 h and worse outcomes in COVID-19 pneumonia. Ren Fail. 2021;43(1):347-50. https://doi.org/10.21203/rs.3.rs-74258/v1
47. Spasovski G, Vanholder R, Allolio B, et al. Clinical practice guideline on diagnosis and treatment of hyponatraemia. Eur J Endocrinol. 2014;170(3):G1-47. https://doi.org/10.1530/EJE-13-1020 PMid:24569125
48. Jung WJ, Lee HJ, Park S, et al. Severity of community acquired hypernatremia is an independent predictor of mortality. Intern Emerg Med. 2017;12:935-40. https://doi.org/10.1007/s11739-017-1673-1 PMid:28474207
49. Hadi JM, Hassan SM, Saeed MM, et al. Estimation of serum calcium on the severity and mortality in COVID-19 infections in Sulaymaniyah City, Kurdistan Region of Iraq: A cross-sectional study. Clin Pract. 2022;12(6):1001-8. https://doi.org/10.3390/clinpract12060103 PMid:36547111 PMCid:PMC9777466
50. Sharma R, Heidari A, Johnson RH, Advani S, Petersen G. Serum magnesium levels in hospitalized patients with SARS-CoV-2. J Investig Med. 2022;70(2):409-14. https://doi.org/10.1136/jim-2021-001948 PMid:34580159 PMCid:PMC8478578
51. de la Rica R, Borges M, Aranda M, et al. Low albumin levels are associated with poorer outcomes in a case series of COVID-19 patients in Spain: A retrospective cohort study. Microorganisms. 2020;8(8):1106. https://doi.org/10.3390/microorganisms8081106 PMid:32722020 PMCid:PMC7463882
52. Khan AQ, Butt I, Ali S, Sohail S, Qamar MK, Tahir F. Association of serum albumin and total protein levels with lymphopenia in COVID-19 infection at a tertiary care hospital in Pakistan. Pak J Pathol. 2022;33(2):65-8. https://doi.org/10.55629/pakjpathol.v33i2.672
53. Pitamberwale A, Mahmood T, Ansari AK, et al. Biochemical parameters as prognostic markers in severely Ill COVID-19 patients. Cureus. 2022;14(8):e28594. https://doi.org/10.7759/cureus.28594 PMid:36185918 PMCid:PMC9521622

54. Xu Z, Shi L, Wang Y, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. Lancet Respir Med. 2020;8(4):420-2. https://doi.org/10.1016/s2213-2600(20)30076-x PMid:32085846

55. Suriawinata E, Mehta KJ. Iron and iron-related proteins in COVID-19. Clin Exper Med. 2022. https://doi.org/10.1007/s10238-022-00851-y PMid:35849261 PMCid:PMC9289930