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Blood Cell Indices and Morphological Abnormalities Detected Among COVID-19 Patients Receiving Care

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Abstract

Blood cell abnormalities may occur among COVID-19 patients and could be detrimental during the disease's progression. This study assessed complete blood count (CBC) parameters and determined abnormal changes in the peripheral blood of COVID-19 patients receiving care at Komfo Anokye Teaching Hospital (KATH), Ghana. This hospital-based descriptive cross-sectional study conducted at KATH, Kumasi, Ghana, recruited seventy-three (73) RT-PCR-confirmed COVID-19 participants. Venous blood was taken from participants into EDTA tubes and used for CBC analyses and the preparation of a thin blood film for blood cell morphological examination. Data obtained were analyzed with SPSS version 22.0, and $p< 0.05$ was considered statistically significant. Females were predominant (45/61.6) and had a higher COVID-19 cycle threshold (CT) value than males (p=0.027). The overall prevalence of anaemia among the study participants was 56.2% (65.5% in males and 50% in females). Geriatrics (>70 years old) had relatively lower Hb compared to other age groups in the study. Erythrocytopaenia (18/73), leucocytosis (28/73), lymphopaenia (9/73), and thrombocytopaenia (21/73) were common among the COVID-19 participants. Red cell morphological abnormalities were seen in the study participants: echinocytes (11/73), elliptocytes (6/73), stomatocytes (1/73), acanthocytes (4/73), pencil-shaped cells (5/73), schistocytes (15/73), ovalocytes (2/73) and target cells (1/73). Moreover, the acanthocytes were significantly higher in males compared to females (4 vs. 0, p=0.019). Again, reactive lymphocytes (8/73), neutrophil toxic granulation (18/73), neutrophil cytoplasmic vacuolation (42/73), smear cells (8/73), and one each of atypical lymphocyte and Dohle body were present among the COVID-19 participants. The COVID-19 CT value was lower among male participants. The overall prevalence of anaemia among COVID-19 participants was high, with males and the aged (>70 years) predominantly affected. COVID-19 patients have abnormal blood cell counts and significant morphological abnormalities in peripheral blood. Early detection of haematological abnormalities would be beneficial in the management of COVID-19 patients. Further study to assess the haematopoietic activities of COVID-19 patients is recommended.

Keywords: COVID-19; RT-PCR; Complete Blood Count; Morphological Abnormalities.

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1. Introduction

The world has experienced serious public health setbacks since the evolvement of coronavirus disease (COVID-19), infecting 752,517,552 individuals with a loss of 6,804,491 lives globally, and Ghana has recorded over 171,02 cases with 1,462 deaths [1]. This current respiratory disease caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) presents with fever, dyspnoea, dry cough, and muscle soreness, with a few patients showing atypical symptoms such as diarrhoea and vomiting [2]. The SARS-CoV-2 interaction with angiotensin-converting enzyme-2 (ACE-2) contributes to the widespread systemic infection throughout the body, causing mild to severe haematological and thrombotic complications, organ damage, and death. Fan and colleagues in 2020 found occurrences of leucopaenia, thrombocytopaenia and lymphopaenia with few reactive lymphocytes among COVID-19 patients [3].

Previous studies have observed varying findings in complete blood counts (CBC) among COVID-19 patients in Africa and Ghana. In Ghana, haematological studies among COVID-19 patients revealed a significant increase in white blood cell (WBC) and basophil count with a significant decrease in haemoglobin (HGB) and platelet concentration [4]. However, in Ethiopia, the presentation of low platelet and haemoglobin concentrations was rarely reported among COVID-19 patients [5]. COVID-19 is associated with a cytokine storm from the severe inflammatory response, and this may account for the abnormal changes in haematological parameters. Inflammatory cytokines such as interleukin-1 (IL-1) and tumour necrosis factor-α (TNF- α) interfere with the renal release of the hormone erythropoietin (EPO), leading to a reduced rate of erythrocyte progenitor cell stimulation and hence retarding erythropoiesis [6]. Again, the cytokine IL-6 has been found to increase during COVID-19 progression, and this cytokine contributes to iron dysregulation [7]. IL-6 induces hepcidin, which interacts with ferroportin, preventing the release of iron from macrophages and other storage sites for erythropoiesis. The defective erythropoiesis eventually leads to reduced peripheral blood cell counts in SARS-CoV-2-infected individuals.

Previous studies have assessed haematological parameters among COVID-19 patients to determine the changes that are likely to occur in these patients. Elderdery et al. (2022), in their study carried out in Saudi Arabia, determined that anaemia and thrombocytopaenia were common findings among COVID-19 patients. Kazancioglu et al.'s (2020) study in Turkey also explored the predictability of PLR, NLR, and other CBC parameters in the determination of the severity of COVID-19. PLR and NLR was regarded as better markers for the determination of the severity of the infection [8–11]. These studies did not determine how the cells are altered morphologically during COVID-19, since this will help paint a better picture of the parameters obtained from the CBC analysis and can determine the severity of the infection depending on the morphological aberrations detected. An earlier study examined WBC morphological abnormalities among COVID-19 patients but could not examine the changes that may occur in the red cells [12]. Hence, this study assessed CBC parameters and determined abnormal changes in peripheral blood smears in COVID-19 patients in the Middle Belt of Ghana.

Findings from this study will elucidate the effects of COVID-19 on CBC parameters and peripheral blood cell morphology and positively influence the management protocols in Ghana.

2. Research Methodology

2.1. Study Design / Site

This descriptive cross-sectional study was conducted at Komfo Anokye Teaching Hospital (KATH) in Kumasi, Ashanti Region, Ghana, from June 2020 to May 2021. KATH is a 1200-bed facility and the second-largest hospital in Ghana [13]. It serves as a referral centre for other health facilities within the northern sector of Ghana. The Internal Medicine unit serves as one of the main COVID-19 centres in the region [13]. KATH also offers other curative, preventive, rehabilitative, diagnostic, and specialized services, as well as training students from the College of Health Sciences at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The population and housing census conducted by the Ghana Statistical Service in 2021 revealed an estimated population of 3,353,850 in the urban city of Kumasi [14].

2.2. Study Population

The study involved seventy-three (73) RT-PCR-confirmed COVID-19 participants who reported to the Internal Medicine unit of KATH for management. All COVID-19 patients who consented to the study were recruited for this study.

2.3. Sample Size Determination

The sample size for the study was calculated using Cochran's sampling formula ($N = \frac{Z^2(P)\,(1-P)}{e^2}$), where 'z' is the value of the standard normal distribution (1.96 at 95% CI); 'p' is the estimated prevalence rate of COVID-19 in Africa,

(3.2%) (15); *e* is the margin of error= 5%. From the above equation, a total of 73 RT-PCR-confirmed COVID-19 participants were recruited.

2.4. COVID-19 Threshold Cycle Value Determination

The cycle threshold (CT) value is the actual number of cycles it takes for the PCR test to detect the virus. It indicates an estimate of how much virus was likely in the sample to start with, not the actual amount. If the virus is found in a low number of cycles (CT value under 30), it means that the virus was easier to find in the sample and that the sample started with a large amount of the virus. The protocol described by Bullard et al. (2020) was used for the determination of the COVID-19 threshold cycle in this study [15, 16].

2.5. Sample Collection and Laboratory Assay

Three (3) mL of venous blood was obtained from each participant under aseptic conditions and placed into a tri-potassium ethylenediaminetetraacetic acid (K_3EDTA) anticoagulated tube for laboratory measurements. The blood was adequately mixed with the anticoagulant by gently turning the tube upside down 8–10 times. The whole blood was used to determine the CBC using the XN 2000 Sysmex haematology Analyzer (Sysmex Corporation, Kobe, Japan). Blood is sampled and diluted, and it moves through a tube, thin enough that cells pass by one at a time. Characteristics of the cells are measured using lasers (fluorescence flow cytometry) or electrical impedance. Because not everything about the cells can be measured at the same time, blood is separated into a number of different channels. In the XE-2100, there are five different channels: WBC/BASO, DIFF, IMI, RET, and NRBC.

A thin blood smear was prepared by placing 2 µL of blood near the frosted end of the slide and spreading it uniformly along the length of the same slide, using the edge of a second slide to make a thin film. The thin smear was fixed in absolute methanol after the slides were air-dried. The films on each slide were then stained in a freshly filtered Leishman using a buffer of pH 7.2 for 15 minutes and then rinsed under a mild stream of water, and air-dried. Finally, the films were observed under the microscope using an X100 objective lens (Olympus CX-21 light microscope). Blood cells were described using standard haematological terminologies.

The general flowchart and Overview of the study design are presented in Figure 1.

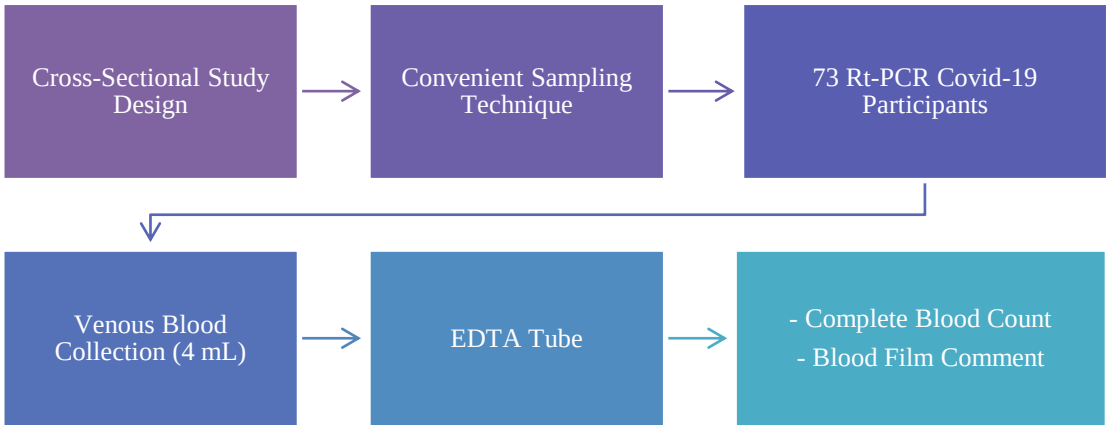


Figure 1. Overview of the study design

2.6. Statistical Analysis

The data were entered into Microsoft Excel and exported to Statistical Package for the Social Sciences (SPSS) version 22 (Armonk, NY, USA) for analysis. Data were expressed using summary and descriptive statistics such as frequencies and percentages and presented in mean and standard deviations. Normality was tested with the one-sample Kolmogorov-Smirnov test. The Chi-Square test and Fisher's exact test were used appropriately to assess the association between bivariate categorical data. Numerical data were presented in mean±SD and compared appropriately with an independent Sample Students' T-test or One-Way Analysis of Variance (ANOVA). $P < 0.05$ was considered statistically significant.

3. Results

3.1. Demographic Characteristics of the Study Participants

Table 1 shows the demographic characteristics of the study participants. Of the 73 RT-PCR-confirmed COVID-19 participants included in the study, the majority, 23 (36.5%) were above 70 years old, and only 8 (12.7%) were less than 40 years old. Females, 45 (61.6%), were more than males, 28 (38.5%), in the study (Table 1).

Table 1. Demographic Characteristics of the Study Participants

Variables	Category	Frequency (%)
Sex	Male	28 (38.4)
	Female	45 (61.6)
Age (years)	<40	8 (12.7)
	40-50	10 (15.9)
	51-60	5 (7.9)
	61-70	17 (27.0)
	>70	23 (36.5)

Data are presented in frequencies with percentages in parentheses.

3.2. COVID-19 Cycle Threshold-Value of the Study Participants Stratified by Sex and Age

The mean cycle threshold value of the male participants was significantly lower than that of the female participants (25.94±5.54 vs. 28.86±5.04, p=0.027). However, within the age groups, CT values were not statistically different (Table 2).

Table 2. COVID-19 Cycle Threshold Value of the Study Participants Stratified by Sex and Age

Variable	Category	COVID Cycle Threshold Value	*P-Value*
Sex	Male	25.94±5.54	***0.027***
	Female	28.86±5.04	
Age (years)	<40	25.60±7.72	*0.774*
	40-50	27.15±4.82	
	51-60	29.23±5.29	
	61-70	28.37±5.33	
	>70	27.52±5.39	

Sex was compared with student T test, whilst Age groups by One-Way ANOVA. p<0.05 was considered statistically significant.

3.3. Complete Blood Count Parameters of the Study Participants stratified by Age

Table 3 shows the complete blood count parameters of the participants stratified by age. HGB, RBC, and HCT were significantly different within the age groups. A posthoc analysis was done to establish the level of significance between groups. Hb [<40 against >70 and 40-50 against >70] showed significant differences between groups with *p=0.017 and 0.029,* respectively. RBC [<40 against >70, 40-50 against >70, and 61–70 against >70] showed significant differences between groups with *p=0.015, 0.004, and 0.011,* respectively (Table 3).

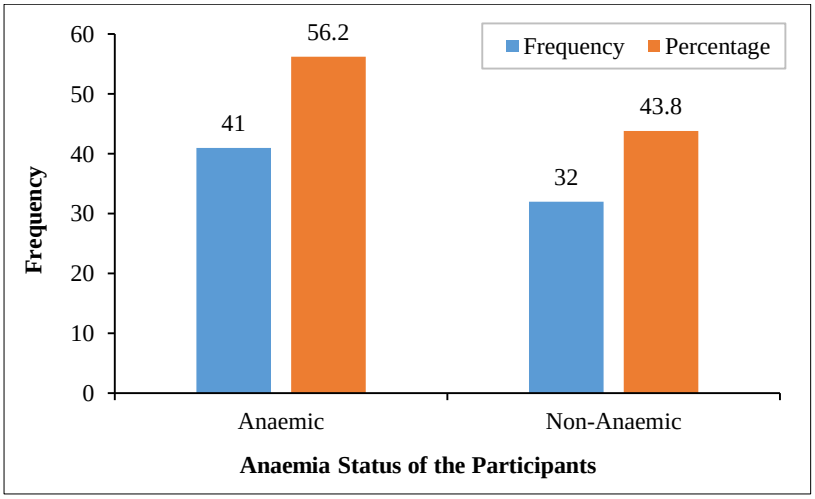
3.4. Prevalence of Anaemia among the COVID-19 Participants

The overall prevalence of anaemia among the study participants was 56.2%. Anaemia was prominent in male COVID-19 subjects compared to their female counterparts. Two-third (65.5%) of the male COVID-19 participants were anaemic whiles the prevalence of anaemia among the females was 50% (Figure 2).

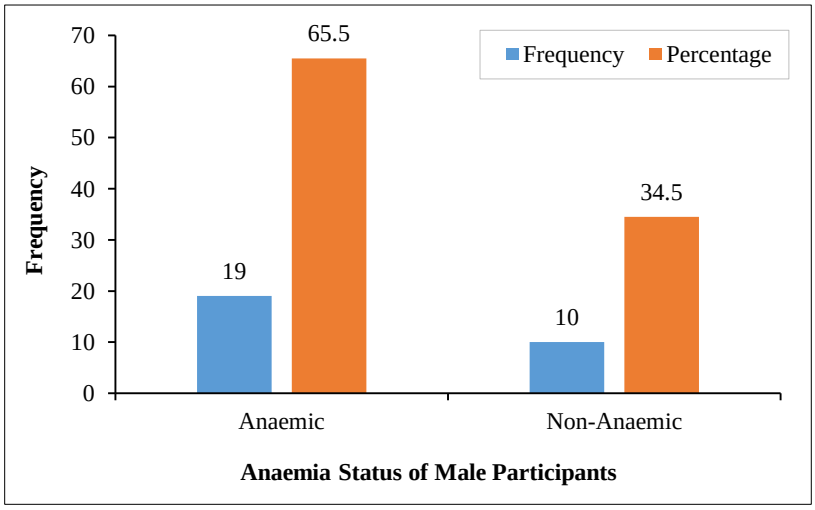
Table 3. Complete Blood Count Parameters of the Study Participants stratified by Age

FBC parameters	Age										
	<40[a]		40-50[b]		51-60[c]		61-70[d]		>70[e]		*p-value*
RBC	4.68	±0.66	4.73	±0.38	3.98	±0.73	4.50	±0.53	3.73	±0.92	***0.001*** *a&e=0.015 b&e=0.004 d&e=0.011*
HGB	13.1	±2.0	12.8	±1.1	10.9	±1.0	12.2	±1.4	10.6	±2.5	***0.004*** *a&e=0.017 b&e=0.029*
HCT	39.8	±5.4	41.3	±2.9	33.5	±1.8	39.8	±4.6	35.0	±9.2	***0.030***
MCV	85.4	±7.3	87.4	±3.2	85.8	±10.6	89.0	±9.3	93.5	±7.6	*0.051*
MCH	28.0	±2.3	26.9	±0.8	27.7	±2.8	27.2	±2.4	28.6	±1.8	*0.189*
MCHC	32.9	±2.5	30.9	±1.5	32.4	±1.5	30.7	±2.0	30.7	±2.7	*0.121*
RDW-CV	15.3	± 0.0	16.1	± 0.0	16.0	±0.0	16.6	± 0.0	16.8	±0.0	*0.519*
WBC	9.05	±3.15	13.29	±5.35	12.64	±1.46	10.45	±3.82	10.98	±5.33	*0.309*
NEUT	7	± 4	9	± 5	10	± 3	8	±4	9	± 6	*0.740*
MONO	0.53	±0.3	1.35	± 2.24	0.64	±0.54	0.86	±0.5	0.54	±0.30	*0.248*
MONO%	6.4	±3.5	5.8	±2.6	5.1	±4.3	8.5	±5.2	5.7	±3.8	*0.228*
PDW	12	± 2	14	± 3	13	±2	13	±2	14	± 3	*0.472*
P-LCR	29	± 10	33	± 7	33	±5	31	±5	34	± 8	*0.523*

Hb=Haemoglobin, HCT=Haematocrit, MCV=Mean Cell Volume, MCH=Mean Corpuscular Haemoglobin, MCHC=Mean Corpuscular Haemoglobin Concentration, RDW-CV=Red Cell Distribution Width-Coefficient of Variation, WBC=White Blood Cell #=Absolute Monocyte Count, Neut. #= Absolute Neutrophil Count, MPV=Mean Platelet Volume. Parametric data (presented in means ± standard deviation) were compared by One-Way ANOVA and p<0.05 was considered statistically significant.



(a)



(b)

(c)

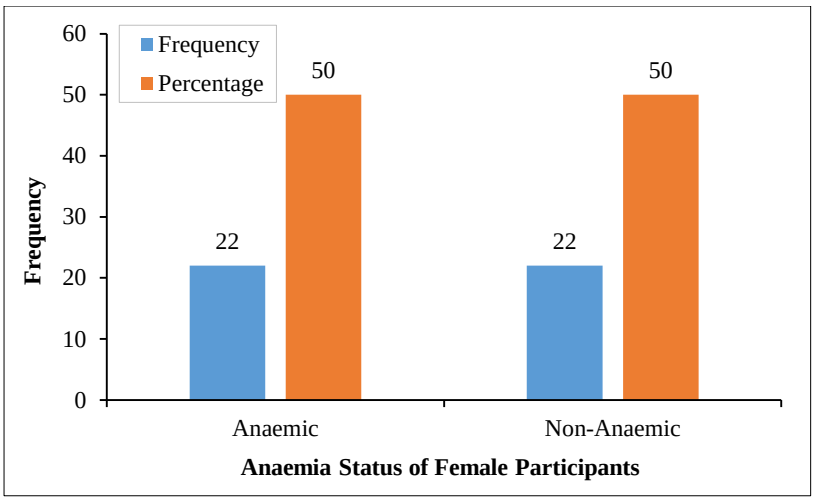


Figure 2. Prevalence of Anaemia among the COVID-19 Participants. Data are presented in frequencies and percentages

3.5. Distribution of Absolute Red Blood Cell Counts in Peripheral Smear between Males and Females

Table 4 shows the distribution of absolute red blood cell (RBC) counts between males and females. Of the seventy-three participants, 18 (24.7%) had erythrocytopaenia, 54 (73.9%) had a normal RBC count, and 1 (1.4%) had erythrocytosis. One-fifth of males had Erythrocytopaenia but no male experienced erythrocytosis. On the other hand, of the 44 female COVID-19 participants, about a quarter experienced erythropaenia and only 1.4% had erythrocytosis (Table 4).

Table 4. Distribution of Absolute Red Blood Cell Counts on Peripheral Smear between Males and Females

		Absolute RBC Count (%)			
		Decreased (Erythrocytopaenia)	**Normal**	**Increased (Erythrocytosis)**	**Total**
SEX	Male	6 (20.7)	23 (79.3)	0	29
	Female	12 (27.3)	31 (70.4)	1 (2.3)	44
Total		18 (24.7)	54 (73.9)	1 (1.4)	73

Data are represented in frequencies and percentages.

3.6. Description of Leucocytes and Platelets Counts among the COVID-19 Participants

Table 5 shows the absolute WBC, platelet, and lymphocyte counts of the participants. Of the 73 participants, 4 (5.5%) had leukopaenia, 28 (38.4%) had leukocytosis, 21 (28.8%) had thrombocytopaenia, 7 (9.6%) had thrombocytosis, 9 (12.7%) had lymphocytopaenia and 2 (2.8%) had lymphocytosis.

Table 5. Description of Leucocytes and Platelets Counts among the COVID-19 Participants

Blood Cells	Description	Count (Frequency)	Percentages (%)
White Blood Cell Counts	Decreased	4	5.5
	Normal	41	56.1
	Increased	28	38.4
Platelet Counts	Decreased	21	28.8
	Normal	45	61.6
	Increased	7	9.6
Lymphocyte Counts	Decreased	9	12.7
	Normal	60	84.5
	Increased	4	2.8

Data are represented in frequencies and percentages in parentheses.

3.7. Sex and RBC Morphological Abnormalities among the Study Participants

Table 6 shows the presence of red blood cell morphological abnormalities stratified by the sex of the participants. Echinocytes (11/73), elliptocytes (6/73), stomatocyte (1/73), acanthocytes (4/73), pencil-shaped cells (5/73), schistocytes (15/73), ovalocytes (2/73), and target cells (1/73) were observed among the study participants. Again, the acanthocytes were significantly higher in males compared to females (p=0.019) as shown in Table 6.

Table 6. Sex and RBC Morphological Abnormalities among the Study Participants

RBC Abnormalities	Outcomes	Participants' Sex		Total	*P-value*
		Males	Females		
Echinocytes	Present	4	7	11	*0.883*
	Absent	24	38	62	
	Total	28	45	73	
Elliptocytes	Present	1	5	6	*0.228*
	Absent	27	40	67	
	Total	28	45	73	
Stomatocytes	Present	0	1	1	*0.427*
	Absent	28	44	72	
	Total	28	45	73	
Acanthocytes	Present	4	0	4	***0.019***
	Absent	24	45	69	
	Total	28	45	73	
Pencil-shaped cells	Present	3	2	5	*0.365*
	Absent	25	43	68	
	Total	28	45	73	
Schistocytes	Present	4	11	15	*0.296*
	Absent	24	34	58	
	Total	28	45	73	
Ovalocytes	Present	1	1	2	*1.000*
	Absent	27	44	71	
	Total	28	45	73	
Target Cells	Present	0	1	1	*1.000*
	Absent	28	44	72	
	Total	28	45	73	

Fisher's exact test was used to test the association between RBC morphological abnormalities and sex. Data are represented in frequencies. $p<0.05$ was considered statistically significant.

3.8. Sex and Leucocytes Morphological Abnormalities among the Study Participants

Reactive lymphocytes (8/73), neutrophil toxic granulation (18/73), neutrophil cytoplasmic vacuolation (42/73), smear cells (8/73), and one each of atypical lymphocyte and dohle body were present among the COVID-19 participants. But the occurrences of the leucocyte morphological abnormalities were not associated with the sex of the participants (Table 7).

Table 7. Sex and Leucocytes Morphological Abnormalities among the Study Participants

Leucocytes Morphological Abnormalities	Outcomes	Participants' Sex		Total	P-Value
		Males	Females		
Reactive Lymphocytes	Present	5	3	8	0.136
	Absent	23	42	65	
	Total	28	45	73	
Atypical Lymphocytes	Present	0	1	1	0.616
	Absent	28	44	72	
	Total	28	45	73	
Neutrophil Toxic Granulation	Present	7	11	18	0.585
	Absent	21	34	55	
	Total	28	45	73	
Neutrophil Cytoplasmic Vacuolation	Present	17	25	42	0.426
	Absent	11	20	31	
	Total	28	45	73	
Dohle body	Present	1	0	1	0.384
	Absent	27	45	72	
	Total	28	45	73	
Smear cells	Present	2	6	8	0.340
	Absent	26	39	65	
	Total	28	45	73	

3.9. Discussion

The disturbed physiological changes during COVID-19 could significantly affect blood cell parameters and their morphological appearances in peripheral blood. This may result in adverse haematological complications, organ failure, and death. This study determined blood cell counts and morphological abnormalities among COVID-19 patients receiving management at KATH. The male COVID-19 participants had a significantly lower mean CT value than their female counterparts. Previous studies have associated lower CT values with COVID-19 severity [17–20] and can be used to predict the clinical severity of the disease [21].

The reduced erythrocyte parameters (RBC, HCT, and Hb) found in this study are similar to previous studies [22, 23]. The overall prevalence of anaemia (56.2%) recorded among the COVID-19 participants in this study is higher than the prevalence of 24.7% identified in Austria [17]. The anaemia was confirmed when Hb was <11.5 g/dL or 12.0 g/dL for females and males, respectively. The mechanism for the development of anaemia following COVID-19 infection is not fully understood but has been suggested to occur through the inflammatory dysregulation of iron metabolism, ineffective EPO expression by the kidneys, and the effects of the SARS-CoV-2 interaction with the bone marrow.

Erythrocytopaenia, leucocytosis, lymphopaenia and thrombocytopaenia were common abnormal blood cell pictures observed among the COVID-19 participants. The higher leucocyte count (leucocytosis) found among the study participants is consistent with a previous comprehensive review and meta-analysis, which found that 11.4% of COVID-19 patients had severe leucocytosis [24]. A recent study in India found lymphopaenia to be the most common haematological abnormality in COVID-19 patients, occurring in up to 85% of severe cases, and the phenomenon is associated with the disease's severity [25], which is similar to the findings obtained in this study. The lymphopaenia may result either directly from virus attachment or indirectly from immunological damage from inflammatory mediators. Furthermore, COVID-19-associated lymphopaenia may also happen when circulating lymphocytes exude into inflammatory lung tissues [7].

The decreased number of platelets (thrombocytopaenia) identified in the current study agrees with a recent study by Palladino et al. [8]. This finding is also similar to earlier findings during severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome infections, where about 60% of severe patients had thrombocytopaenia. The occurrence of thrombocytopaenia during COVID-19 infection could be related to the consumptive coagulopathy triggered by prolonged inflammation, platelet hyperactivity, and excessive platelet aggregation [26, 27].

The presence of red cell morphological abnormalities such as echinocytes, elliptocytes, stomatocytes, acanthocytes, pencil-shaped cells, schistocytes, ovalocytes, and target cells observed during active infection of COVID-19 in this study is similar to findings from different geographical locations [28, 29]. Moreover, the acanthocytes were significantly higher in males compared to females in the present study, and this is similar to earlier studies [28, 29]. It is suggested that spiculated cells develop as a result of modifications to the RBC membrane components' organization, such as disturbances in the lipid and/or protein compositions [30]. Surprisingly, the acanthocytes were more prominent among COVID-19-infected males compared to the female participants, but the difference could not be understood. Also, reactive lymphocytes, neutrophil toxic granulation, neutrophil cytoplasmic vacuolation, smear cells, atypical lymphocytes and Dohle bodies were leucocyte morphological abnormalities identified among the COVID-19 participants, and this is consistent with the findings from the study by Singh et al. [25]. The inflammatory response and viral effects on leucocytes might be responsible for these changes, which can be readily identified on peripheral blood film.

The possible blood cell changes after a successful recovery from COVID-19 could not be studied, and this was seen as a limitation to the study. Again, the study could not assess the entire haemopoietic activities of the study participants.

4. Conclusion

COVID-19 was higher in female participants and recorded the highest prevalence among participants who were 60 years and above. The overall prevalence of anaemia among COVID-19 participants was high, with males and geriatrics (>70 years) predominantly affected. Red blood cell counts (p=0.001), HGB (p=0.004), and HCT (p=0.030) showed significant variation with the ages of the participants. The majority of the participants recorded normal red blood cell counts, but Erythrocytopaenia was more pronounced in the female participants, and a few of the participants also showed erythrocytosis.

The COVID-19 CT value was higher among the female participants. COVID-19 patients have abnormal blood cell counts and significant morphological abnormalities associated with the red and white cells in their peripheral blood. The study showed a significant increase in white cells (predominantly lymphocyte count) and platelet count among the participants. Morphological red cell abnormalities determined were echinocytes, elliptocytes, stomatocytes, acanthocytes, schistocytes, and target cells. White cell abnormalities detected also include reactive and atypical lymphocytes. Also, neutrophil toxic granulation and vacuolation were seen in some participants. All of these notable changes are a result of the COVID-19 infection.

Early detection of haematological abnormalities would be beneficial in the management of COVID-19 patients and can be a vital prognostic determinant of the progress and severity of the infection. Further study to holistically assess the haemopoietic activities of COVID-19 patients is recommended.

5. Declarations

5.1. Author Contributions

Conceptualization, K.M., V.O.O., and D.S.S.; methodology, K.M., S.M., V.O.O., D.S.S.,CN and H.O-A.; software, V.K. and G.B.; validation, V.O.O., C.N., and S.K.A.; formal analysis, G.A., C.N. and V.K.; investigation, N.K., S.M., and V.O.O.; resources, D.S.S., K.M., and V.O.O.; data curation, H.A.O., V.O.O., and G.A; writing—original draft preparation, C.N., S.B.B., S.D., V.K., and S.K.A.; writing—review and editing, F.O-B., H.O.A., S.B.B., S.K.A., C.A.D., K.M., C.N. and H.A.O.; visualization, H.A.O.; supervision, K.M. and V.O.O.; project administration, D.S.S. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

5.3. Funding

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5.4. Acknowledgements

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5.5. Institutional Review Board Statement

Ethical approval was obtained from the Research and Ethics Committee of the Komfo Anokye Teaching Hospital, Kumasi, Ghana (KATH/IRB/089/20). Permission was sought from the COVID Laboratory, Department of Haematology, and the Internal medicine unit, KATH where the COVID-19 patients were managed.

5.6. Informed Consent Statement

Informed consent was obtained from the study participants.

5.7. Declaration of Competing Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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