ORIGINAL ARTICLE

Seroprevalence of *Toxoplasma Gondii* and the Association Between the Chronic Infection and Hemogram Parameters in Iraqi Female University Students

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ABSTRACT

Introduction: Toxoplasmosis is a disease affecting approximately one-third of the world's population. This study aimed to evaluate the seroprevalence of toxoplasmosis and assess the impact of chronic Toxoplasma gondii infection on the hematological profiles of female university students in Diyala Province, Iraq. **Materials and Methods:** Blood samples were collected from 243 participants for serological analysis and complete blood count (CBC) testing. The presence of anti-*T. gondii* IgG antibodies was detected using enzyme-linked immunosorbent assay (ELISA). **Results:** Out of the 243 female students, 44 (18.1%) were seropositive for anti-*T. gondii* IgG antibodies, while 199 (81.9%) were seronegative. An odds ratio (OR) of 1.85 was observed, indicating that female students studying health sciences were 1.85 times more likely to be seropositive than those studying Islamic studies. Lymphocyte and neutrophil counts significantly decreased ($P < 0.05$) in seropositive students compared to seronegative individuals. Monocyte, eosinophil, and platelet counts showed significant increases ($P < 0.05$) in seropositive individuals. The levels of red cell distribution width (RDW), platelet distribution width-coefficient of variation (PDW-CV), mean platelet volume (MPV), and procalcitonin were significantly higher ($P < 0.05$) in the seropositive group. Additionally, the monocyte-to-lymphocyte ratio (MLR) and platelet-to-lymphocyte ratio (PLR) were significantly associated with toxoplasmosis seropositivity, however, the neutrophil-to-lymphocyte ratio (NLR) was not. **Conclusion:** This study is the first to demonstrate that chronic *T. gondii* infection significantly alters various hematological parameters in female university students. However, further research is needed to confirm the clinical utility of these simple and cost-effective hematological markers in diagnosing toxoplasmosis.
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INTRODUCTION

Toxoplasmosis, a globally endemic zoonotic parasitic disease caused by Toxoplasma gondii, infects approximately one-third of the world's population. It is primarily transmitted through the consumption of food or water contaminated with the oocysts of the parasite, the ingestion of raw or undercooked meat containing bradyzoites (the slow-dividing stage), contact with infected domestic pets, or improper hygiene practices, such as inadequate handwashing after handling raw meat, vegetables, or fruits (1, 2).

Infection during pregnancy can result in severe complications, including abortion, stillbirth, intrauterine death, preterm delivery, or congenital toxoplasmosis, and that untreated toxoplasmosis may lead to significant clinical manifestations during childhood or early adulthood (4). Additionally, gestational *T. gondii* infection has been linked to substantial adverse effects on developing foetuses, newborns, and mothers. For instance, a longitudinal study by Parvin et al. (5) in rural Bangladesh revealed a significant association between *T. gondii* seropositivity and low birth weight in infants, further confirming the link between maternal infection and adverse neonatal outcomes.

In immunocompromised individuals, *T. gondii* reactivation can cause systemic manifestations in the nervous system, such as encephalitis, meningitis, and brain abscesses, and these conditions result from the transformation of bradyzoites into tachyzoites and can lead to significant morbidity or even high mortality rate if left untreated (6). Furthermore, *T. gondii* has been associated with autoimmune diseases. For example, a systematic review and meta-analysis by Bassett et al. (7) found that individuals with systemic lupus erythematosus had 2.34 times higher odds of *T. gondii* seropositivity compared to healthy controls.

While PCT is primarily associated with bacterial infections (8), studies have explored its role in parasitic diseases such as malaria and babesiosis (9, 10). Research indicates that PCT levels correlate with the severity of Plasmodium falciparum malaria. A study involving 66 patients found that pre-treatment PCT concentrations were closely linked to parasitemia levels, suggesting its potential as a marker for disease severity (10). Emerging evidence suggests that PCT may serve as a biomarker in parasitic infection-driven sepsis, such as in human babesiosis. Elevated PCT levels have been observed in patients with this condition, indicating its potential utility in diagnosis and monitoring (9). Several serological and molecular assays, such as the Sabin–Feldman dye test, indirect hemagglutination assay, enzyme-linked immunosorbent assay, and polymerase chain reaction (PCR), are available for detecting anti-*T. gondii* antibodies (11). IgM antibodies are typically produced during the early stages of infection and can indicate recent exposure to T. gondii, and their strength lies in the fact that it is useful for identifying acute infections and highly sensitive in early-stage infection. In contrast, their weaknesses lie in the fact that persistence of these antibodies for months or even years can lead to false positives (2). IgG antibodies develop after the acute phase and persist for life, indicating past or chronic infection. Although they are reliable for confirming past exposure and useful for epidemiological studies, they cannot distinguish between recent and past infections and requires additional testing, such as IgG avidity, for more precise timing (11). IgG avidity testing measures the binding strength of IgG antibodies to *T. gondii* antigens and low-avidity IgG suggests a recent infection, while high-avidity IgG indicates an older infection (12). Although it helps differentiate between acute and chronic infections which is particularly important in pregnancy and immunocompromised patients, avidity maturation can vary among individuals, making interpretation challenging in some cases, not useful for very early infections, as IgG may not yet be detectable and requires specialized laboratory facilities and trained personnel (13).

Complete blood count (CBC) is the most commonly used laboratory test worldwide, with over 4 billion tests performed annually. It aids healthcare providers in detecting a wide range of disorders and assessing medication side effects (14). Given its accessibility and cost-effectiveness, utilizing CBC and related hematological parameters to indicate toxoplasmosis can provide an economical alternative to more specialized tests.

While numerous studies have investigated the seroprevalence of *T. gondii* infection in Iraq (2, 15-20), none have specifically examined its impact on hematological profiles, particularly among female university students. This study seeks to fill this gap by evaluating the effects of *T. gondii* infection on various hematological indices, including monocyte-to-lymphocyte ratio (MLR), neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), red cell distribution width (RDW), platelet distribution width (PDW), mean platelet volume (MPV), and PCT levels. Additionally, the study explores the feasibility of diagnosing toxoplasmosis using complete blood count (CBC) parameters and other hematological tests.

By assessing these parameters, the study seeks to provide insights into the potential hematological alterations caused by chronic *T. gondii* infection, offering a basis for more cost-effective and accessible diagnostic approaches.

MATERIALS AND METHODS

Study design and sample collection

A total of 243 blood samples were collected from female university students enrolled in three faculties at Al-Rafidain University, Diyala Province, located in the middle of Iraq. The samples were distributed as follows: 80 from the College of Medicine, 83 from the College of Medical Sciences and Technology, and 80 from the College of Islamic Studies. For analytical purposes, data from the College of Medicine and the College of Medical Sciences and Technology were combined under the category "College of Medicine and Health Sciences (MHS)," resulting in a total of 163 samples, as students from both colleges are involved in health sciences studies.

In order to achieve the required sample size for our study, a structured and proportionate recruitment approach was adopted. The selection process began with final-year female university students, as they were more accessible and available during the data collection period, and if the desired number from the final years was not obtained, recruitment proceeded to students in the lower academic years. This process continued until the proportionate number of participants from each college was achieved. This method ensured balanced representation across different academic levels while facilitating efficient data collection within the study timeline. Each participant was anonymized using a specific ID number which enabled tracking of individuals throughout the study period.

The registered nurses working at Diyala Teaching Hospital (Diyala Province, Iraq) collected the blood samples into sterile Vacutainer glass tubes and the sera were separated by centrifugation, stored at -20°C until being used. The sera were tested for anti-*T. gondii* specific antibodies using the enzyme linked immunosorbent assay (ELISA) (Acon, San Diego, CA, USA), and the procedure was conducted according to the instructions of the manufacturer. The study was conducted between June and November 2022 in Diyala Province. Participants were informed about the study

objectives, and written consent was obtained. Ethical approval for the study was granted by the Research Ethical Committee of the Faculty of Sciences, Diyala University (Protocol 2/2022).

Measurement of hemogram parameters and hemogram index parameters

Two blood samples were obtained from each participant. The first sample (approximately 2.5 mL) was collected into sterile ethylenediaminetetraacetic acid (EDTA) tubes to avoid clotting. The samples were mixed and processed within 30 minutes using a BS-120 fully automated haematology analyser (Mindray, China). The following hematological parameters were measured: total counts of hematological cells (red blood cells, white blood cells, and platelets), Leukocyte differential counts (neutrophils, lymphocytes, monocytes, basophils, and eosinophils), haemoglobin concentration and haematocrit (HCT) were measured. Some hemogram index parameters such as Neutrophil-to-Lymphocyte Ratio (NLR) (absolute neutrophil count divided by absolute lymphocyte count), Monocyte-to-Lymphocyte Ratio (MLR) (absolute monocyte count divided by absolute lymphocyte count), and Platelet-to-Lymphocyte Ratio (PLR) (platelet count divided by absolute lymphocyte count) were calculated. Additional parameters obtained from the complete blood count (CBC) included red cell distribution width (RDW), platelet distribution width (PDW), mean platelet volume (MPV), and procalcitonin levels.

Serum samples for measuring anti-*T. gondii* IgG antibodies

Another sample (approximately 2.5 mL) of blood was collected into tubes without EDTA and left at room temperature for 30 minutes to clot. Clotted blood was centrifuged at 1,000–2,000 x g for 10 minutes in a refrigerated centrifuge. The resulting serum was transferred into clean polypropylene tubes using a Pasteur pipette, aliquoted into 0.5 mL portions, and stored at –20°C until analysis. Serum samples were used to measure anti-*T. gondii* IgG antibodies via enzyme-linked immunosorbent assay (ELISA), following the manufacturer's instructions.

Statistical analysis

Data were expressed as mean ± standard error (SE) and analyzed using Microsoft excel worksheet version 2019. A chi-square test was used to determine if there is a significant association between the different sociodemographic characteristics. The Independent (Unpaired) T-test was used to compare between the means of seropositive group and seronegative group. P value of < 0.05 was considered significant. The odds ratio (OR) was calculated using: Med Calc Software Ltd. Odds ratio calculator. https://www.medcalc.org/calc/odds_ratio.php (Version 20.013; accessed May 18, 2023).

RESULTS

A total of 243 female students participated in this study, including 163 from the College of Medicine and Health Sciences (MHS) and 80 from the College of Islamic Studies (IS) at Al-Rafidain University, located in Diyala Province, central Iraq. The average age of healthy students (*T. gondii*-seronegative) in the control group was 21.3 ± 0.16 years, while that of students infected with *T. gondii* (T. gondii-seropositive) was 22.4 ± 0.57 years (Table I).

Table I: Socio-demographic variables of the Toxoplasma gondii-seropositive female university students in comparison with T. gondii-seronegative females

Variables	Numbers (%)	
	Seropositive group N= 44	Seronegative group N= 199
Age groups (years)		
Under 20	15 (34.1)	85 (42.7)
20-25	22 (50.0)	100 (50.3)
25 +	7 (15.9)_	14 (7.1)
P-value	0.126	
Mean age ± SE	22.4 ± 0.57	21.3 ± 0.16
Marital status		
Single	38 (86.4)	156 (78.4)
Married	6 (13.6)	43 (21.6)
P-value	0.195	
Residence		
Rural	18 (40.9)	103 (51.8)
Urban	26 (59.1)	96 (48.2)
P-value	0.002	

The study found that 18.1% (44 out of 243) of the female university students were seropositive for *T. gondii* IgG antibodies, as determined by ELISA. The seropositivity rate varied based on marital status and residency. Among the 44 seropositive students, 26 out of 44 (59.1%) resided in urban areas, while 18 out of 44 (40.9%) lived in rural areas. However, this difference was not statistically significant (P = 0.129). Additionally, 38 (86.4%) of the seropositive females were single, whereas only 6 (13.6%) were married. This indicates that single females had a significantly higher risk of infection compared to their married counterparts (P = 0.002) (Table I).

Regarding the academic discipline, the seropositivity rate was higher among students from the College of Medicine and Health Sciences (MHS) at 20.9% compared to 12.5% among students from the College of Islamic Studies (IS) (Table II). However, this difference was not statistically significant (P = 0.1155). The analysis further revealed that the odds of *T. gondii* seropositivity were 1.85 times higher for students in health sciences compared to those in Islamic studies.

Table II: Seropositivity and seronegativity for anti- *Toxoplasma gondii* IgG antibodies among female university students living in Diyala Province, Iraq.

Colleges	No. examined	No. seronegative	No. seropositive	% seropositivity	Odds ratio	P-value
Islamic Studies (IS)	80	70	10	12.5		
Medicine and Health Sciences (MHS)	163	129	34	20.9	1.85	0.1155
Total	243	199	44	18.1		

Table III presents a comparison of leukocyte parameters between T. gondii-seropositive female students and the seronegative control group. The results revealed that the following parameters were significantly higher in T. gondii-seropositive female students; white blood cells counts (P= 0.0368), monocyte counts (P= 0.0317) and eosinophil counts (P= 0.0192), while lymphocyte counts (P< 0.0001) and neutrophil counts (P= 0.0128) were significantly lower in comparison to T. gondii-seronegative female students. No significant differences were observed in basophil counts between the two groups.

Table III: Leukocyte parameters of the *Toxoplasma gondii*-seropositive female university students in comparison with the *T. gondii*-seronegative females

Leukocyte parameterS	Serostatus	Mean ± SE	P-value
1. White Blood Cells (10^3 /µL)	Seronegative	7.36 ± 0.128	0.0368
	Seropositive	7.83 ± 0.266	
2. Lymphocytes (10^3 /µL)	Seronegative	2.52 ± 0.058	< 0.0001
	Seropositive	2.20 ± 0.057	
3. Monocytes (10^3 /µL)	Seronegative	0.35 ± 0.009	0.0317
	Seropositive	0.57 ± 0.117	
4. Neutrophils (10^3 /µL)	Seronegative	5.22 ± 0.131	0.0128
	Seropositive	4.69 ± 0.192	
5. Basophils (10^3 /µL)	Seronegative	0.01 ± 0.001	0.0603
	Seropositive	0.01 ± 0.007	
6. Eosinophils (10^3 /µL)	Seronegative	0.080 ± 0.006	0.0192
	Seropositive	0.148 ± 0.031	

Table IV shows a comparison between T. gondii-seronegative and T. gondii-seropositive university students regarding the erythrocyte parameters and the results revealed that the following parameters were significantly lower in T. gondii-seropositive female students; mean corpuscular haemoglobin (MCH) (P= 0.0239) and mean corpuscular volume (MCV) (P= 0.0413), while the percentage of red blood cell distribution width (RDW-CV) (P< 0.0001) was significantly higher in seropositive in comparison to seronegative female students. No significant differences were detected in the numbers of red blood cells (RBC), haemoglobin concentration (Hb), % haematocrit (HCT), mean corpuscular haemoglobin concentration (MCHC) and red blood cell distribution width RDW-SD between the two groups.

Table IV. Levels of erythrocyte parameters of the *Toxoplasma gondii*-seropositive female university students in comparison with the *T. gondii*-seronegative females

Erythrocyte parameters	Serostatus	Mean ± SE	P-value
1. Red blood cells (10^3 /µL)	Seronegative	4.557 ± 0.03	0.1704
	Seropositive	4.625 ± 0.07	
2. Haemoglobin (g/dl) (HGB)	Seronegative	12.396 ± 0.09	0.4171
	Seropositive	12.444 ± 0.36	
3. Haematocrit (HCT) %	Seronegative	39.878 ± 0.36	0.1824
	Seropositive	39. 220 ± 0.63	
4. Mean corpuscular haemoglobin (pg) (MCH)	Seronegative	27.757 ± 0.25	0.0239
	Seropositive	26.563 ± 0.79	
5. Mean corpuscular haemoglobin concentration (MCHC) (g/dL)	Seronegative	31.248 ± 0.09	0.4292
	Seropositive	31.20 ± 1.02	
6. Mean corpuscular volume (MCV)	Seronegative	88.27 ± 0.52	0.0413
	Seropositive	85.32 ± 1.56	
7. Red blood cell distribution width (RDW-CV) (%)	Seronegative	12.93 ± 0.18	< 0.0001
	Seropositive	14.59 ± 0.41	
8. Red blood cell distribution width RDW-SD (femtoliters)	Seronegative	46.24 ± 0.41	0.1028
	Seropositive	45.49 ± 1.12	

Table V shows a comparison between T. gondii-seropositive and T. gondii-seronegative female university students regarding the platelet parameters. The results revealed that the following parameters were significantly higher in T. gondii-seropositive females; platelet count (P= 0.0412), mean platelet volume (MPV) (P= 0.0222), platelet distribution width (PDW) (P= 0.0187) in comparison to seronegative females.

Table V: Platelet parameters of the *Toxoplasma gondii*-seropositive female university students in comparison with the *T. gondii*-seronegative females

Platelet parameters	Serostatus	Mean ± SE	P-value
1. Platelet count (10^3 / µL)	Seronegative	290.01 ± 4.74	0.0412
	Seropositive	308.84 ± 10.67	
2. Mean platelet volume (MPV) (fL)	Seronegative	10.57 ± 0.08	0.0222
	Seropositive	10.95 ± 0.29	
3. Platelet distribution width (PDW)	Seronegative	12.85 ± 0.17	0.0187
	Seropositive	13.53 ± 0.27	

It can be seen from Table VI that the level of procalcitonin (PCT) is significantly higher (P= 0.0001) in the blood of T. gondii-seropositive university students than in the blood of seronegative females.

Table VI: Neutrophil-lymphocyte ratio (NLR), Monocyte-lymphocyte ratio (MLR) and Platelet-lymphocyte ratio (PLR) of the Toxoplasma gondii-seropositive female university students in comparison with the T. gondii-seronegative females

Haematological parameters	Serostatus	Mean ± SE	P-value
1. Neutrophil-lymphocyte ratio (NLR)	Seronegative	2.29 ± 0.08	0.1867
	Seropositive	2.18 ± 0.09	
2. Monocyte-lymphocyte ratio (MLR)	Seronegative	0.15 ± 0.004	0.0130
	Seropositive	0.25 ± 0.044	
3. Platelet-lymphocyte ratio (PLR)	Seronegative	128.72 ± 3.63	0.0485
	Seropositive	141.13 ± 6.38	

Table VII shows a comparison between T. gondii-seropositive university students and their counterparts seronegative females regarding the neutrophil-lymphocyte ratio (NLR), monocyte-lymphocyte ratio (MLR) and platelet-lymphocyte ratio (PLR). The results revealed that the MLR (P= 0.0130) and the PLR (P= 0.0485) were significantly higher in T. gondii-seropositive university students in comparison to T. gondii-seronegative female students. No significant difference in the value of NLR was detected between the two groups.

Table VII. Neutrophil-lymphocyte ratio (NLR), Monocyte-lymphocyte ratio (MLR) and Platelet-lymphocyte ratio (PLR) of the Toxoplasma gondii-seropositive female university students in comparison with the *T. gondii*-seronegative females

Haematological parameters	Serostatus	Mean ± SE	P-value
1. Neutrophil-lymphocyte ratio (NLR)	Seronegative	2.29 ± 0.08	0.1867
	Seropositive	2.18 ± 0.09	
2. Monocyte-lymphocyte ratio (MLR)	Seronegative	0.15 ± 0.004	0.0130
	Seropositive	0.25 ± 0.044	
3. Platelet-lymphocyte ratio (PLR)	Seronegative	128.72 ± 3.63	0.0485
	Seropositive	141.13 ± 6.38	

DISCUSSION

The present study revealed that 18.1% (44 out of 243) of female university students were seropositive for anti-Toxoplasma gondii (T. gondii) IgG antibodies. The seropositivity rate of *T. gondii* IgG antibodies in female university students varies widely across studies conducted in Iraq and neighbouring countries.

In Iraq, Al-Mosawi et al. (17) reported a seropositivity rate of 14.42% among female students at ThiQar University in southern Iraq. Similarly, Obaid (18) found an 11% seropositivity rate among students at Kirkuk University. Amin and Merdaw (19) reported that 21.5% of female students at the College of Pharmacy, University of Baghdad, tested positive for *T. gondii* IgG antibodies. More recently, Barzinji (20) found a 9.1% seropositivity rate among female students at Kirkuk University. The observed differences in these studies may be attributed to variations in diagnostic methods, environmental factors, and hygiene standards.

In a neighbouring country, Iran, Ali-Asghari et al. (21) reported a 20.4% seropositivity rate in female university students in Bojnurd City (North Khorasan Province). At the Jordan University of Science and Technology, Obaidat et al. (22) found a significantly higher seropositivity rate of 66.5% among female students aged 18–23 years. Meanwhile, Jafari-Modrek et al. (23)

conducted a cross-sectional study in Zahedan, Iran, reporting a seropositivity rate of 10% among female students.

In Saudi Arabia, Alzaheb and Al-Amer (24) reported a 9.4% seropositivity rate among female undergraduate students. In Brazil, Rodrigues et al. (25) conducted a seroepidemiological analysis of college students, finding a 24.1% seroprevalence using ELISA screening for *T. gondii* IgG antibodies.

In this study, 59.1% of seropositive females resided in urban areas, compared to 40.9% in rural areas, indicating a 2.1-fold higher risk of infection in urban settings. This result may be due to the increased prevalence of domestic cats in urban settings. Similarly, Morais et al. (26) reported higher seropositivity rates in urban areas (81.9%) compared to rural areas (62.6%) in the Brazilian Amazon, with urban residents being 2.7 times more likely to be infected. Conversely, Munoz-Zanzi et al. (27) found no significant differences in seropositivity between rural and urban communities in Chile. Differences in seroprevalence across countries and regions may be influenced by environmental, geographical, and hygiene-related factors (3). Pappas et al. (28) noted that variations in *T. gondii* prevalence during pregnancy are linked to geo-climatic diversity, environmental distinctiveness, and maternal hygiene practices.

A key objective of this study was to explore whether hematological indicators in the complete blood count (CBC) could serve as an alternative to ELISA or other diagnostic tests for detecting *T. gondii* infection. Significant differences were observed between the CBC profiles of T. gondii-seropositive and seronegative female students. To our knowledge, this is the first study to evaluate the association between chronic *T. gondii* infection and CBC parameters in female university students.

In the absence of comparable studies, we referenced research involving pregnant women. Agordzo et al. (29) found that seropositive non-pregnant women exhibited decreased lymphocyte and neutrophil counts, while pregnant women showed increased counts. Additionally, the study observed a significant increase in mean corpuscular volume (MCV) in seropositive non-pregnant women compared to seronegative individuals, whereas no significant differences were noted in pregnant women.

Our study similarly revealed a significant reduction in lymphocyte and neutrophil counts in seropositive female students, aligning with the findings of Agordzo et al. (29) in Ghana. These changes may be linked to impaired T-cell immunity during chronic *T. gondii* infection, which can lead to reactivation of the parasite [30, 31]. Biswas et al. [32] reported that neutrophil depletion during *T. gondii* infection reduces IFN-γ production, increasing parasite burden in the central nervous system.

Additionally, our study noted a significant increase in monocyte and total white blood cell (WBC) counts in seropositive females. Increased monocyte levels are often associated with parasitic, bacterial, or viral infections (33), while elevated WBC counts are a common immune response to protozoal infections (34). Interestingly, eosinophil counts were higher in seronegative individuals, a finding typically linked to parasitic infections (35).

Our results showed a significant decrease in MCV and mean corpuscular haemoglobin (MCH) values in seropositive students, consistent with findings from Ghana (29) and other studies. Reduced MCV and MCH levels are associated with microcytic anaemia, suggesting a potential link between *T. gondii* infection and impaired haemoglobin synthesis (36). Conversely, we observed a significant increase in mean platelet volume (MPV) and platelet count in seropositive students. Elevated MPV indicates larger-than-average platelets, often linked to increased platelet production during chronic *T. gondii* infection (36, 37).

Our study found significantly elevated procalcitonin levels in the blood of seropositive students, suggesting its potential as a biomarker for toxoplasmosis. Previous research has demonstrated a similar relationship between procalcitonin levels and parasitic infections such as malaria (Plasmodium falciparum) (10) and babesiosis (Babesia microti) (9). This study is the first to propose procalcitonin as a marker for *T. gondii* infection, supporting its role in monitoring parasitemia in apicomplexan infections.

Understanding these hematological changes is critical for clinicians, as they can aid in the early suspicion and diagnosis of toxoplasmosis, especially in high-risk groups. Hematological parameters may also help monitor disease progression and response to treatment. Integrating hematological findings with serological and molecular diagnostic techniques enhances the overall accuracy of toxoplasmosis diagnosis.

Our study has some limitations. First, the sample sizes were not equal between the two colleges, which may have affected the generalizability of our findings. Second, the study should have examined both IgG and IgM anti-Toxoplasma gondii antibodies to assess both chronic and acute infections, rather than focusing solely on IgG antibodies.

CONCLUSION

Chronic *T. gondii* infection in female university students was found to have adverse effects on hematological

profiles. Our findings revealed, for the first time, that levels of red cell distribution width (RDW), platelet distribution width-coefficient of variation (PDW-CV), mean platelet volume (MPV), and procalcitonin were significantly higher in T. gondii-seropositive females compared to their seronegative counterparts. Additionally, the monocyte-to-lymphocyte ratio (MLR) and platelet-to-lymphocyte ratio (PLR) were significantly associated with the presence of toxoplasmosis, whereas the neutrophil-to-lymphocyte ratio (NLR) showed no significant association. Further studies are needed to explore the potential clinical utility of these simple and cost-effective hematological markers in diagnosing toxoplasmosis.

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