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ORIGINAL ARTICLE

Seroprevalence of *Toxoplasma gondii* antibodies and associated risk factors among women aged 18 years and above in Duhok Governorate, Iraq

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ABSTRACT

BACKGROUND
Toxoplasma gondii is a globally distributed intracellular protozoan parasite that may cause serious complications when primary infection occurs during pregnancy. This study aimed to determine the seroprevalence of anti-*T. gondii* IgG and IgM antibodies and associated sociodemographic and behavioral factors among women aged 18 years and above in Duhok Governorate, Iraq.

METHODS
A cross-sectional study was conducted among 282 women attending Duhok Maternity Teaching Hospital from June 2024 to June 2025. Serum samples were tested for anti-*T. gondii* IgG and IgM antibodies using ELISA. Sociodemographic and behavioral data were collected using a structured questionnaire. Associations were assessed using the chi-square test and Firth penalized multivariable logistic regression.

RESULTS
Anti-*T. gondii* antibodies were detected in 25 participants (8.9%), including 12 (4.26%) with IgG and 13 (4.61%) with IgM. Age and residence were not significantly associated with seropositivity. IgM seropositivity was significantly associated with economic status (p=0.017), education level (p=0.020), and cat exposure (p=0.001). Handwashing before meals was significantly associated with both IgG and IgM seropositivity (p=0.001). In multivariable analysis, never washing hands before meals was independently associated with IgM seropositivity (aOR = 98.86, 95% CI: 13.98–1,280.43).

CONCLUSION
The study found a relatively low seroprevalence of *T. gondii* among women in Duhok. Poor hand hygiene was independently associated with seropositivity, highlighting the importance of hygiene practices. Larger multicenter studies are recommended to further investigate transmission patterns and risk factors. These findings provide local evidence for strengthening health education on hygiene and food safety, particularly among women attending maternity healthcare services in Duhok Governorate.

Keywords: *Toxoplasma gondii,* seroprevalence, IgG, IgM, risk factors, women

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INTRODUCTION

Toxoplasma gondii is an obligate intracellular protozoan parasite capable of infecting humans and a wide range of warm-blooded animals. In immunocompetent individuals, toxoplasmosis is usually asymptomatic or causes mild, nonspecific manifestations. However, infection may cause severe disease in immunocompromised individuals, while primary maternal infection during pregnancy may result in congenital transmission and adverse fetal outcomes.[1]

Toxoplasmosis is one of the most widespread parasitic infections globally, with substantial variation in seroprevalence among geographical regions and populations. A global systematic review and meta-analysis estimated that approximately one-third of the world's population has been exposed to *T. gondii*, highlighting its widespread distribution.[2] Pregnant women are a particularly important population because primary infection during pregnancy may lead to congenital transmission. A recent meta-analysis of 138 studies involving more than 135,000 pregnant women estimated a global seroprevalence of 36.6%, with considerable regional variation.[3] In the Eastern Mediterranean Region, *T. gondii* infection also shows substantial geographical variation. A systematic review of 95 studies involving 112,886 pregnant women from 18 countries reported a pooled seroprevalence of 36.5%. Country-specific estimates included 35.2% in Iran, 46.6% in Egypt, 47.5% in Jordan, and 34.4% in Iraq.[4]

The clinical consequences of toxoplasmosis are particularly important in immunocompromised individuals and congenital infection. Congenital toxoplasmosis may result in miscarriage, stillbirth, neurological abnormalities, or ocular disease.[5] The parasite has a complex life cycle in which felids serve as definitive hosts, while humans and other animals act as intermediate hosts. Cats may shed environmentally resistant oocysts in their feces, which can contaminate soil, water, vegetables, and other environmental sources.[6] Several behavioral and environmental factors have been associated with *T. gondii* infection, including contact with cats, consumption of raw or undercooked meat, exposure to contaminated soil, and consumption of inadequately washed vegetables. The importance of individual risk factors varies among populations and geographical settings.[7]

In Iraq, studies have reported considerable geographical and population-level variation in seroprevalence. In Baghdad, Fadhil et al. reported substantial serological evidence of toxoplasmosis among women with a history of abortion.[8] In Basra, Al-Sadoon et al.[9] investigated toxoplasmosis and associated risk factors among female medical students and identified soil exposure as an important factor. In Erbil, Ahmed and Khudhair [10] reported associations between seropositivity and reproductive characteristics among women with spontaneous abortion.

Studies from the Kurdistan Region have likewise demonstrated variation. In Duhok Province, Salih et al.[11] reported an overall seroprevalence of 36.3% among 792 females, with IgG detected in 35.61% and IgM in 0.76%. A cross-sectional study by Mustafa et al.[12] in Zakho district, Iraq, found other factors, such as contact with cats, occupation, marital status, history of abortion, and consumption of restaurant foods, but did not exhibit any association with IgG and IgM seropositivity among females in Zakho city. The latter study's finding contradicts another study by Mizuri and Merto [13] who found a positive association between IgM seropositivity of *T. gondii* and contact with cats. These inconsistent research results require further study to distinguish between true biological/contextual variation and methodological artifacts. Therefore, the present study aimed to determine the seroprevalence of *Toxoplasma gondii* antibodies and investigate associated sociodemographic and behavioral factors among women aged 18 years and above attending Duhok Maternity Teaching Hospital, Duhok Governorate, Iraq.

METHODS

Research design

A cross-sectional study was conducted at Duhok Maternity Teaching Hospital, Duhok Governorate, Kurdistan Region, Iraq, between June 2024 and June 2025.

Study subjects

The study population consisted of women aged ≥18 years who attended Duhok Maternity Teaching Hospital during the study period. Participants were recruited from both urban and rural areas of Duhok Governorate. Women were

eligible if they were aged ≥18 years, were residents of Duhok Governorate, attended the hospital during the study period, and voluntarily agreed to participate. Women aged <18 years, those who declined participation, and those receiving antiparasitic or antimicrobial therapy at the time of data collection were excluded. A total of 282 eligible women were consecutively recruited using a non-probability sampling technique until the required sample size was reached.

Data collection

Data were collected through face-to-face interviews using a structured questionnaire developed after reviewing previous epidemiological studies. The questionnaire included demographic characteristics such as age, residence, occupation, education, and socioeconomic status, as well as potential exposure factors including contact with cats, consumption of raw or inadequately washed vegetables, consumption of undercooked meat, and handwashing practices before meals. All interviews were conducted by one researcher to maintain consistency.

Laboratory analysis

Approximately 5 mL of venous blood was collected aseptically from each participant and transferred into sterile gel tubes. Samples were allowed to clot and were then centrifuged at 4,000 rpm for 10 minutes. The separated sera were stored at −20°C until analysis. Anti-*Toxoplasma gondii* IgG and IgM antibodies were detected using commercial ELISA kits (BT LAB, Universal Biotechnology Pvt. Ltd., India) according to the manufacturer's instructions. Optical density was measured using an ELISA microplate reader, and results were interpreted according to the manufacturer's recommended cut-off values. Positive and negative controls were included in each assay run.

Ethical approval

The study protocol was approved by the Scientific and Ethics Committee of Duhok Polytechnic University and Duhok Maternity Teaching Hospital (Approval No. 29052024-4-39; May 29, 2024). Written informed consent was obtained from all participants. Confidentiality was maintained throughout the study, and all procedures were conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

Overall seroprevalence

A total of 282 women aged ≥18 years were screened for anti-*Toxoplasma gondii* antibodies using ELISA. At least one antibody class was detected in 25 participants (8.9%). IgG antibodies were detected in 12 participants (4.26%), whereas IgM antibodies were detected in 13 participants (4.61%).

Importantly, IgM positivity was interpreted as serological evidence compatible with relatively recent exposure rather than definitive evidence of acute infection, because IgM antibodies may persist following infection.

IgG seropositivity was highest in the 38–47-year age group (7.1%), whereas IgM seropositivity was highest in the 18–27-year group (7.1%); however, age was not significantly associated with either IgG or IgM seropositivity. Residence was also not significantly associated with either antibody class (Table 1). Economic status was significantly associated with IgM seropositivity (p=0.017), with the highest proportion observed among participants in the high-income category (16.0%). Education level was significantly associated with IgM seropositivity (p=0.020), with the highest proportion observed among participants with intermediate education (17.4%). Cat exposure was significantly associated with IgM seropositivity (p=0.001), whereas the association with IgG was not significant. Handwashing before meals was significantly associated with both IgG and IgM seropositivity (p=0.001 for each). The highest proportions were observed among participants who reported never washing their hands before meals, among whom IgG and IgM positivity were 70.0% and 40.0%, respectively (Table 1).

Factors associated with *Toxoplasma gondii* IgG and IgM seropositivity

Multivariable Firth penalized logistic regression was performed separately for IgM and IgG, including all the factors shown in Table 1 (Table 2). For IgM, participants who reported never washing their hands before meals had markedly higher odds of seropositivity than those who always washed their hands (aOR=98.86, 95% CI: 13.98–1,280.43, p<0.001), and those who sometimes washed their hands also had higher odds (aOR=5.74, 95% CI: 1.12–56.56, p=0.035).

Table 1. Association of *Toxoplasma gondii* IgG and IgM seropositivity with sociodemographic and behavioral characteristics among women (n = 282)

Characteristics	IgG			IgM		
	Positive (n,%)	Negative (n,%)	p value	Positive (n,%)	Negative (n,%)	p value
Age (years)						
18-27	7 (6.2)	106 (93.8)	0.069	8 (7.1)	105 (92.9)	0.118
28-37	1 (0.9)	112 (99.1)		5 (4.4)	108 (95.6)	
38-47	4 (7.1)	52 (92.9)		0 (0.0)	56 (100.0)	
Residence						
Urban	7 (3.5)	193 (96.5)	0.446	8 (4.0)	192 (96.0)	0.326
Rural	5 (6.1)	77 (93.9)		5 (6.1)	77 (93.9)	
Economic status						
Low	7 (6.7)	98 (93.3)	0.288	4 (3.8)	101 (96.2)	**0.017**
Medium	4 (2.6)	148 (97.4)		5 (3.3)	147 (96.7)	
High	1 (4.0)	24 (96.0)		4 (16.0)	21 (84.0)	
Education						
Illiterate	2 (2.2)	88 (97.8)	0.417	6 (6.7)	84 (93.3)	**0.020**
Elementary	3 (4.0)	72 (96.0)		2 (2.7)	73 (97.3)	
Intermediate	2 (8.7)	21 (91.3)		4 (17.4)	19 (82.6)	
High school	4 (4.6)	83 (95.4)		1 (1.2)	86 (98.8)	
College+	1 (14.3)	6 (85.7)		0 (0.0)	7 (100.0)	
Occupation						
Employed	1 (4.0)	24 (96.0)	0.947	1 (4.0)	24 (96.0)	0.879
Unemployed	11 (4.3)	246 (95.7)		12 (4.7)	245 (95.3)	
Cat exposure						
Yes	4 (5.3)	71 (94.7)	0.589	3 (4.0)	72 (96.0)	**0.001**
No	8 (3.9)	199 (96.1)		10 (4.8)	197 (95.2)	
Raw vegetables						
Yes	7 (3.2)	215 (96.8)	0.078	9 (4.1)	213 (95.9)	0.392
No	5 (8.3)	55 (91.7)		4 (6.7)	56 (93.3)	
Handwashing before meals						
Always	1 (0.7)	151 (99.3)	**0.001**	2 (1.3)	150 (98.7)	
Sometimes	4 (3.3)	116 (96.7)		7 (5.8)	113 (94.2)	**0.001**
Never	7 (70.0)	3 (30.0)		4 (40.0)	6 (60.0)	

Note: Data presented as n (%)

High economic status was associated with higher odds of IgM seropositivity than low or medium status (aOR=5.75, 95% CI: 1.19–28.88, p=0.030), whereas secondary or higher education was associated with lower odds than illiteracy (aOR = 0.05, 95% CI: 0.001–0.56, p=0.011). Age, residence, occupation, cat exposure (aOR = 0.33, 95% CI: 0.05–1.44, p=0.148), and raw vegetable consumption were not independently associated with IgM seropositivity. For IgG, never washing hands before meals was again strongly associated with seropositivity (aOR=452.27, 95% CI: 45.11–11,852.70, p<0.001), whereas sometimes washing hands (aOR=3.20, p=0.216), cat exposure (aOR=2.17, p=0.344), and the other sociodemographic factors were not significantly associated. Raw vegetable consumption was associated with lower odds of IgG seropositivity (aOR=0.09, 95% CI: 0.009–0.51, p=0.006); this unexpected finding was based on few events and should be interpreted cautiously. To keep the models estimable with so few seropositive participants, economic status and education were collapsed into a single category. The confidence intervals for several estimates, particularly for hand hygiene, were very wide because of the small numbers of seropositive participants and of participants who never washed their hands; these estimates should therefore be regarded as imprecise rather than as precise measures of effect size.

Table 2. Firth penalized multivariable logistic regression analysis of factors associated with *Toxoplasma gondii* IgG and IgM seropositivity

Factors	IgM		p value	IgG		p value
	aOR	95% CI		aOR	95% CI	
Age (≥29 vs. <29 years)	0.51	0.14–1.78	0.294	0.85	0.17–3.96	0.832
Residence (urban vs. rural)	1.23	0.30–5.52	0.774	0.52	0.08–3.74	0.493
Economic status (high vs. low/medium)	5.75	1.19–28.88	0.030	0.24	0.007–3.47	0.333
Education						
Elementary/intermediate vs. illiterate	0.51	0.11–2.17	0.360	3.28	0.48–34.91	0.232
High school/college+ vs. illiterate	0.05	0.001–0.56	0.011	7.57	0.96–94.68	0.055
Occupation (unemployed vs. employed)	0.18	0.007–4.74	0.280	1.78	0.16–44.93	0.657
Cat exposure (yes vs. no)	0.33	0.05–1.44	0.148	2.17	0.42–11.22	0.344
Raw vegetables (yes vs. no)	0.43	0.11–1.77	0.233	0.09	0.009–0.51	0.006
Handwashing before meals						
Sometimes vs. always	5.74	1.12–56.56	0.035	3.20	0.52–33.73	0.216
Never vs. always	98.86	13.98–1,280.43	<0.001	452.27	45.11–11,852.70	<0.001

Note: aOR, adjusted odds ratio; CI, profile-likelihood confidence interval. Separate Firth penalized logistic regression models were fitted for IgM and IgG, each including all the factors listed. Economic status was dichotomized and education was grouped into three levels to keep the models estimable given the small number of seropositive participants. Reference categories: age <29 years; rural residence; low or medium economic status; illiterate; employed; no cat exposure; no raw-vegetable consumption; and always washing hands before meals. Estimates for hand hygiene are imprecise because only 10 participants reported never washing their hands.

DISCUSSION

The present study assessed the seroprevalence of anti-*Toxoplasma gondii* IgG and IgM antibodies and examined their relationship with selected sociodemographic and behavioral characteristics among 282 women aged 18 years and above attending Duhok Maternity Teaching Hospital. At least one anti-*T. gondii* antibody was detected in 25 participants (8.9%), including 12 (4.26%) who were IgG positive and 13 (4.61%) who were IgM positive.

The overall seroprevalence observed in this study was lower than that reported in several previous studies conducted in Duhok, Zakho, and other Iraqi populations. Differences in geographical location, demographic characteristics, environmental conditions, dietary practices, hygiene behavior, socioeconomic status, study design, and serological methods may contribute to the variation observed between studies, as reported in the epidemiological literature on *T. gondii*.[14]

The IgG prevalence in the present study was considerably lower than that reported by Mikaeel and Al-Saeed [15] among women in Duhok Province, where IgG and IgM seropositivity were 28.0% and 0.46%, respectively. Another study conducted among women in Duhok City also reported evidence of *T. gondii* exposure, although differences in the characteristics of the participants and study settings make direct comparison with the present findings difficult.[16] Differences in participant selection, healthcare settings, age distribution, exposure patterns, diagnostic methods, and study periods may partly explain these variations. The present findings should therefore be interpreted as an estimate for the women attending the study hospital rather than as a population-wide prevalence estimate for all women in Duhok Governorate.

Studies from Zakho have similarly reported different levels of seropositivity. Mizuri and Mero [13] found IgG and IgM positivity of 11.58% and 0.63%, respectively, among women of childbearing age in Zakho City and reported associations with age, educational level, cat contact, and consumption of undercooked meat. In a more recent study among women in Zakho, Ahmed and Mero [17] reported considerably higher IgG and IgM prevalences. Such differences may be related to variation in population characteristics, environmental conditions, dietary

practices, and other local factors that influence exposure to *T. gondii*.

The findings can also be considered in the broader context of toxoplasmosis in Iraq. A review of Iraqi studies showed substantial variation in seroprevalence between regions and population groups, with geographical location, age, socioeconomic characteristics, and exposure patterns identified as possible contributors to this variation.[18] Among pregnant women in Mosul, Edrees and Ibrahim [19] reported an IgG seroprevalence of 26.7%, which was higher than the prevalence observed in the current study. Similarly, Barzinij [20] reported IgG and IgM positivity of 9.05% and 3.33%, respectively, among female university students in Kirkuk and identified domestic cat ownership and exposure to soil through household gardening as associated factors. These findings further illustrate the differences in *T. gondii* exposure between Iraqi populations.

Evidence from different Iraqi populations has consistently shown heterogeneity in the distribution of *T. gondii* infection among geographical areas and risk groups.[21,22] Climate, environmental contamination, dietary habits, housing conditions, water sources, and contact with animals may all contribute to differences in exposure. Thus, the relatively low prevalence observed in the current study may be related to the particular characteristics of the women attending the study hospital rather than indicating uniformly low exposure throughout Duhok Governorate.

The interpretation of IgG and IgM results also requires caution. IgG antibodies generally indicate previous exposure to *T. gondii*, whereas IgM antibodies may be detected following a relatively recent infection. However, IgM antibodies can persist for an extended period and therefore cannot, by themselves, establish that an infection is acute. Accordingly, IgM positivity in the present study should be interpreted as serological evidence compatible with relatively recent exposure rather than definitive evidence of acute infection.

Age was not significantly associated with either IgG or IgM seropositivity in the present study. Although IgG positivity was numerically highest among women aged 38–47 years, the differences between age groups were not statistically significant. IgM positivity was highest among women aged 18–27 years, but this difference was also not statistically significant. In general, age may influence exposure because cumulative exposure can increase with time. However, the relatively small number of antibody-positive participants in the present study may have limited the ability to detect age-related differences.

Residence was also not significantly associated with either IgG or IgM positivity. Participants from rural areas showed numerically higher IgG and IgM positivity than those from urban areas, although the differences were not statistically significant. Rural residence may provide greater opportunities for contact with soil, animals, and agricultural environments. At the same time, women living in urban areas may also encounter *T. gondii* through contaminated food, soil, water, or fresh produce. Therefore, residence alone may not adequately represent the range of environmental exposures relevant to *T. gondii* transmission.

Economic status and educational level were significantly associated with IgM seropositivity in the univariable analysis. IgM positivity was highest among participants in the high-income category and among those with an intermediate educational level. After multivariable adjustment, high economic status remained associated with higher odds of IgM seropositivity, whereas secondary or higher education was associated with lower odds than illiteracy. These associations should be interpreted carefully because socioeconomic characteristics are closely related to several other factors, including dietary practices, housing conditions, sanitation, occupation, and health behavior.

Cat exposure was significantly associated with IgM seropositivity in the univariable analysis. Cats and other felids are the definitive hosts of *T. gondii* and can contribute to environmental contamination through the shedding of oocysts. These oocysts may contaminate soil, water, vegetables, and food and subsequently contribute to human exposure. [23] However, cat exposure did not remain independently associated with either IgM or IgG positivity after multivariable adjustment. This may indicate that the initial association was partly explained by other environmental or behavioral factors. Although a direct independent association with reported cat exposure was not observed after adjustment, the environmental route of transmission remains relevant. Previous research has shown that environmental and behavioral factors may contribute to *T. gondii* infection, particularly in populations with greater exposure

to rural environmental conditions. [24] *T. gondii* oocysts can survive in soil and may represent an important source of human exposure. A systematic review and meta-analysis documented contamination of public soils with *T. gondii* oocysts in different regions worldwide, supporting the potential importance of environmental exposure. [25] Therefore, the lack of an independent association with reported cat exposure should not be interpreted as evidence that environmental exposure is unimportant.

Diet is another recognized route of *T. gondii* transmission. Consumption of raw or undercooked meat has been associated with infection, and systematic evidence supports the role of foodborne transmission. [26] Exposure may also occur through contaminated fruits, vegetables, and other food products. Appropriate cooking of meat and careful washing and handling of fresh produce are consequently important preventive measures. [27,28] In the present study, consumption of raw vegetables was not significantly associated with IgM seropositivity. Unexpectedly, in the multivariable model for IgG, raw vegetable consumption was associated with lower odds of seropositivity; this finding is based on a small number of IgG-positive participants, may reflect chance or confounding, and should not be interpreted as a protective effect.

The strongest association identified after adjustment was related to handwashing before meals. Participants who reported that they never washed their hands before meals had substantially higher odds of IgM seropositivity than those who reported always washing their hands. This association is biologically plausible because inadequate hand hygiene may facilitate ingestion of *T. gondii* oocysts following contact with contaminated soil, food, vegetables, surfaces, or other environmental materials. Previous epidemiological studies have also reported poor hand hygiene as a behavioral factor associated with *T. gondii* infection.[29]

Nevertheless, the magnitude of this association should be interpreted with caution. Only 10 participants reported never washing their hands before meals, and four of these participants were IgM positive. Sparse data in a small subgroup can result in relatively large odds ratios and wide confidence intervals, even when Firth penalized regression is applied. Furthermore, the cross-sectional nature of the study does not allow determination of whether the reported handwashing behavior preceded infection. Handwashing was also self-reported and may have been influenced by recall or social-desirability bias. Thus, the observed association should be considered an epidemiological association rather than evidence of a causal relationship.

The relatively low IgG prevalence observed in this study is also relevant to women who may become pregnant in the future. Primary maternal infection during pregnancy can result in congenital transmission of *T. gondii*, making prevention of primary infection particularly important among women who remain susceptible.[30] The recognized global burden of congenital toxoplasmosis further emphasizes the importance of preventive measures.[30]

Studies from other countries have also demonstrated considerable geographical variation in *T. gondii* exposure. Research among pregnant women in Nigeria has reported substantial seroprevalence as well as differences between populations and geographical regions.[31,32] Similar variation has been reported among women of reproductive age in Saudi Arabia,[33,34] Egypt,[35] and Latin America.[36,37] Taken together, these findings are consistent with the view that local environmental conditions, dietary practices, socioeconomic characteristics, and behavioral factors can influence patterns of *T. gondii* exposure.

Studies involving women with adverse reproductive outcomes provide additional epidemiological context. Among Jordanian women who had recently experienced spontaneous abortion, Abo-Shehada et al. [38] reported IgG and IgM seroprevalences of 22.1% and 2.6%, respectively. A systematic review and meta-analysis has also examined the possible relationship between *T. gondii* infection and spontaneous abortion.[39] However, reproductive outcomes were not specifically investigated in the present study; therefore, these findings are presented as contextual evidence rather than as directly comparable results.

Felids have an important role in the life cycle of *T. gondii* because they are the definitive hosts responsible for the environmental dissemination of oocysts. A systematic review and meta-analysis demonstrated widespread *T. gondii* infection among domestic and wild felids and emphasized their epidemiological importance.[40] Human transmission, however, involves several interconnected pathways, including foodborne, environmental, animal-associated, and behavioral routes.[41] Consequently, preventive strategies

should not focus solely on direct contact with cats but should also include appropriate hand hygiene, safe food preparation, proper washing of fresh produce, and reduction of exposure to potentially contaminated environments.

Several limitations should be acknowledged. First, the cross-sectional design prevents assessment of temporality and limits conclusions regarding causality. Second, participants were recruited consecutively from a single maternity hospital using non-probability sampling; therefore, the findings cannot necessarily be generalized to all women in Duhok Governorate. Third, the relatively small number of seropositive participants, particularly within some exposure categories, resulted in imprecise estimates and wide confidence intervals. Fourth, several behavioral characteristics were self-reported and may therefore have been affected by recall or reporting bias. Finally, serological testing provides information about antibody status but cannot independently establish the precise timing or route of infection. From a clinical and public health perspective, these findings indicate that a small but relevant proportion of women attending the maternity hospital had serological evidence of exposure to *T. gondii*. Because IgM antibodies may persist for a prolonged period and cannot by themselves distinguish recent from past infection, IgM-positive results in women of childbearing age should be confirmed with complementary tests, such as IgG avidity testing or molecular methods, before clinical decisions are made.

The association between poor hand hygiene and IgM seropositivity supports the inclusion of simple, low-cost preventive counselling in routine antenatal and reproductive health education, including regular handwashing before meals, safe food preparation, and washing of fresh produce. These findings may also help guide targeted counselling and screening for women who are pregnant or planning pregnancy, in whom primary infection carries a risk of congenital transmission. However, given the cross-sectional design and the imprecise estimates, these implications should be regarded as supportive rather than conclusive.

CONCLUSION

The present study found an overall anti-*Toxoplasma gondii* antibody positivity of 8.9%, with IgG and IgM seropositivity of 4.26% and 4.61%, respectively, among women aged 18 years and above attending Duhok Maternity Teaching Hospital. Several sociodemographic and behavioral factors were associated with seropositivity in univariable analysis. After multivariable adjustment using Firth penalized logistic regression, poor handwashing remained the clearest independent correlate of IgM seropositivity, although the estimate was imprecise because of the small number of participants reporting no handwashing.

These findings support the importance of practical preventive measures, including regular handwashing before meals, appropriate preparation and cooking of food, washing of fresh produce, and reduction of environmental exposure. Further multicenter studies involving larger and more representative populations are needed to better characterize the epidemiology of *T. gondii* infection in Duhok Governorate and clarify the contribution of foodborne, environmental, and animal-associated exposure pathways.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Authors' Contributions

WMS contributed to study design, data collection, laboratory procedures, data analysis, manuscript writing, and manuscript review. MIA and JNH contributed to study supervision and final approval of the manuscript. All authors reviewed and approved the final version of the manuscript.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of AI Usage in Scientific Writing

Artificial intelligence tools were used only for language editing, improving manuscript clarity, and assisting with organization. All scientific interpretations, statistical analyses, and final decisions regarding the manuscript content were performed and approved by the authors.

REFERENCES

1. Fadel EF, El-Hady HA, Ahmed AM, Tolba MEM. Molecular diagnosis of human toxoplasmosis: the state of the art. J Parasit Dis 2024;48:201–16. doi:10.1007/s12639-024-01667-1.
2. Rostami A, Riahi SM, Gamble HR, et al. Global prevalence of latent toxoplasmosis in pregnant women: a systematic review and meta-analysis. Clin Microbiol Infect 2020;26:673–83. doi:10.1016/j.cmi.2020.01.008.
3. Salari N, Rahimi A, Zarei H, et al. Global seroprevalence of *Toxoplasma gondii* in pregnant women: a systematic review and meta-analysis. BMC Pregnancy Childbirth 2025;25:90. doi:10.1186/s12884-025-07182-2.
4. Rabaan AA, Uzairue LI, Alfaraj AH, et al. Seroprevalence, risk factors and maternal–fetal outcomes of *Toxoplasma gondii* in pregnant women from WHO Eastern Mediterranean Region: systematic review and meta-analysis. Pathogens 2023;12:1157. doi:10.3390/pathogens12091157.
5. Daher D, Shaghlil A, Sobh E, et al. Comprehensive overview of *Toxoplasma gondii*-induced and associated diseases. Pathogens 2021;10:1351. doi:10.3390/pathogens10111351.
6. Dubey JP. Toxoplasmosis of animals and humans. 3rd ed. Boca Raton: CRC Press; 2021. DOI:10.1201/9781003199373.
7. Bahadori A, Babazadeh T, Maleki CK, et al. Seroprevalence and risk factors associated with toxoplasmosis in nomadic, rural, and urban communities of northwestern Iran. Front Public Health 2025;13:1516693. doi:10.3389/fpubh.2025.1516693.
8. Fadhil AA, Ramadan GM, Hameed NA, et al. Identification of toxoplasmosis in women by serology in the Baghdad Province, Iraq. J Commun Dis 2023;55:72–5. doi:10.24321/0019.5138.202327.
9. Al-Sadoon MA, Nasir MAH, Yasir ET, Khalaf AO, Kadim SJ. Toxoplasmosis and risk factors among female students of medical colleges at Basra University, Iraq. Biomed Pharmacol J 2018;11:2117–22. doi:10.13005/bpj/1591.
10. Ahmed ZY, Khudhair AA. Seroprevalence of *Toxoplasma gondii* among aborted women admitted to Erbil maternity teaching hospital. JZS A 2023;12:460-70. DOI:10.17656/jzs.10950.
11. Salih JM, Mero WMS, Eassa SHE. Seroprevalence and some demographic factors associated with *Toxoplasma gondii* infection among female population in Duhok province, Iraq. Int J Res Med Sci 2020;8:921–6. doi:10.18203/2320-6012.ijrms20200755.
12. Mustafa KM, Mohammed AB, Mero WMS. Seroprevalence of *Toxoplasma gondii* antibodies and associated risk factors among women in Zakho City, Iraq. Cureus 2024;16:e56328. doi:10.7759/cureus.56328.
13. Mizuri SSM, Mero WMS. Seroprevalence of anti-*Toxoplasma gondii* antibodies among women of childbearing age in Zakho City, Kurdistan Region/Iraq. Zanco J Pure Appl Sci 2020;32:75–84. doi:10.21271/ZJPAS.32.3.9.
14. Thebault A, Kooh P, Cadavez V, Gonzales-Barron U, Villena I. Risk factors for sporadic toxoplasmosis: a systematic review and meta-analysis. Microb Risk Anal 2020;15:100133. doi:10.1016/j.mran.2020.100133.
15. Mikaeel FB, Al-Saeed ATM. Seroprevalence and molecular detection of *Toxoplasma gondii* among women in Duhok Province/Iraq. J Univ Duhok 2020;22:85–92. doi:10.26682/ajuod.2019.22.2.9.
16. Awad RN, Al-Mufti SA. Detection of *Toxoplasma gondii* among women in Duhok City-Kurdistan Region of Iraq. J Univ Duhok 2020;23:20–33. 10.26682/ajuod.2020.23.2.5.
17. Ahmed PB, Mero WMS. Seroprevalence of toxoplasmosis and associated risk factors among females at childbearing ages in Zakho City, Iraq. Egypt J Intern Med. 2025;37:119. doi:10.1186/s43162-025-00508-8.
18. Ismael SSIB. Epidemiology of toxoplasmosis in Iraq. In: Abbas RZ, Hassan MF, Khan A, Mohsin M, editors. Zoonosis. Faisalabad: Unique Scientific Publishers; 2023.p.178–88. doi:10.47278/book.zoon/2023.62.
19. Edrees T, Ibrahim RH. Seroprevalence of *Toxoplasma gondii* among pregnant women visiting antenatal clinic at Mosul City, Iraq. Pak J Med Health Sci 2020;14:1046–9. doi:10.53350/pjmhs20201421046.
20. Barzinij AKRA. Seroprevalence and risk factors of toxoplasmosis among University of Kirkuk female students. Ann Parasitol 2021;67:175–86. doi:10.17420/ap6702.327.
21. Al-Rubaiy KK, Al-Hadithi TS. Epidemiology of toxoplasmosis in Iraq. East Mediterr Health J 2018;24:561–8. doi:10.26719/2018.24.6.561.
22. Al-Rubaiy KK, Al-Hadithi TS. Seroprevalence of *Toxoplasma gondii* among different risk groups in Iraq. Trans R Soc Trop Med Hyg 2017;111:396–403. doi:10.1093/trstmh/trx060.
23. Shapiro K, Bahia-Oliveira L, Dixon B, et al. I. Environmental transmission of *Toxoplasma gondii*: oocysts in water, soil and food. Food

Waterborne Parasitol 2019;15:e00049. doi:10.1016/j.fawpar.2019.e00049.
24. Silva J, Santos A, Oliveira F, et al. Prevalence and risk factors for *Toxoplasma gondii* infection in rural Brazilian populations. Trop Med Int Health 2019;24:1314–22. doi:10.1111/tmi.13304.
25. Maleki B, Ahmadi N, Olfatifar M, et al. Toxoplasma oocysts in the soil of public places worldwide: a systematic review and meta-analysis. Trans R Soc Trop Med Hyg 2021;115:471–81. doi:10.1093/trstmh/traa133.
26. Ducrocq J, Simon A, Lemire M, De Serres G, Lévesque B. Exposure to *Toxoplasma gondii* through consumption of raw or undercooked meat: a systematic review and meta-analysis. Vector Borne Zoonotic Dis 2021;21:40–9. doi:10.1089/vbz.2020.2639.
27. Jones JL, Dubey JP. Foodborne toxoplasmosis. Clin Infect Dis 2012;55:845–51. doi:10.1093/cid/cis508.
28. EFSA Panel on Biological Hazards (BIOHAZ), Koutsoumanis K, Allende A, Alvarez-Ordóñez A, et al. 2018. Scientific opinion on the public health risks associated with food-borne parasites. EFSA J 2018;16:e05495. doi: 10.2903/j.efsa.2018.5495.
29. Wehbe K, Pencole L, Lhuaire M, et al. Hygiene measures as primary prevention of toxoplasmosis during pregnancy: a systematic review. J Gynecol Obstet Hum Reprod 2022;51:102300. doi:10.1016/j.jogoh.2021.102300.
30. Torgerson PR, Mastroiacovo P. The global burden of congenital toxoplasmosis: a systematic review. Bull World Health Organ 2013;91:501–8. doi:10.2471/BLT.12.111732.
31. Olaogun MO, Olatunde AO, Ilesanmi OJ, et al. Seroepidemiology of toxoplasmosis among pregnant women in Nigeria: a systematic review and meta-analysis. Pathogens 2023;12:918. doi:10.3390/pathogens12060918.
32. Adeniyi OT, Adekola SS, Oladipo OM. Seroepidemiology of toxoplasmosis among pregnant women in Osogbo, Southwestern Nigeria. J Infect Dis Immun 2018;10:8–16. doi:10.5897/JIDI2018.0175.
33. Alzaheb RA. Seroprevalence of *Toxoplasma gondii* and its associated risk factors among women of reproductive age in Saudi Arabia: a systematic review and meta-analysis. Int J Womens Health 2018;10:537–44. doi:10.2147/IJWH.S173640.
34. Moafa HN, Altemani AH, Alaklabi A, et al. The prevalence of *Toxoplasma gondii* in Saudi Arabia (1994–2023): a systematic review and meta-analysis. J Epidemiol Glob Health 2024;14:1413–52. doi:10.1007/s44197-024-00314-5.
35. Abbas IE, Villena I, Dubey JP. A review on toxoplasmosis in humans and animals from Egypt. Parasitology 2020;147:135–59. doi:10.1017/S0031182019001367.
36. Rosso F, Les JT, Agudelo A, et al. Prevalence of infection with Toxoplasma gondii among pregnant women in Cali, Colombia, South America. Am J Trop Med Hyg 2008;78:504–8. doi:10.4269/ajtmh.2008.78.504.
37. Lozano TdSP, Benitez A, Santos JC, et al. Seroprevalence of *Toxoplasma gondii* and associated risk factors in pregnant women in Araçatuba, São Paulo, Brazil: a multi-level analysis. Microorganisms 2024;12:2183. doi:10.3390/microorganisms12112183.
38. Abo-Shehada MN, Khalil R, Abu-Halaweh M, Sweis K, Amr Z, Billeh L. Seroprevalences of Toxoplasma gondii and Neospora caninum infections in Jordanian women who had a recent spontaneous abortion. Rev Bras Parasitol Vet 2021;30:e21076. doi:10.1590/S1984-29612021076.
39. Kalantari N, Gorgani-Firouzjaee T, Moulana Z, Chehrazi M, Ghaffari S. *Toxoplasma gondii* infection and spontaneous abortion: a systematic review and meta-analysis. Microb Pathog 2021;158:105070. doi:10.1016/j.micpath.2021.105070.
40. Hatam-Nahavandi K, Calero-Bernal R, Rahimi MT, et al. *Toxoplasma gondii* infection in domestic and wild felids as public health concerns: a systematic review and meta-analysis. Sci Rep 1;11:9509. doi:10.1038/s41598-021-89031-8.
41. Khairullah AR, Kurniawan SC, Widodo A, et al. A comprehensive review of toxoplasmosis: serious threat to human health. Open Public Health J 2024;17:1–15. doi:10.2174/0118749445281387240202094637.

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