

Article

Toxoplasma gondii Seroprevalence Among Community-Based Adults in Kuwait

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Abstract

Background: Toxoplasmosis is a globally prevalent zoonotic infection caused by *Toxoplasma gondii*, with potentially severe consequences for pregnant women, fetuses, and immunocompromised individuals. Despite its public health importance, epidemiological data on *T. gondii* infection in Kuwait remain limited and restricted to selected population groups. This study assessed the seroprevalence of *T. gondii* among community-based adult participants in Kuwait and examined potentially associated risk factors. **Methods:** A cross-sectional study was conducted in September 2024 in Kuwait City and Jahra governorates. Serum samples from a convenience sample of 200 adults attending governmental polyclinics were screened for *T. gondii* IgM and IgG antibodies using VIDAS ELISA assays, with IgG-positive samples further analysed for IgG avidity. Demographic and exposure data were collected using structured questionnaires. Univariable and multivariable associations between demographic and exposure-related factors and IgG seropositivity were statistically evaluated. **Results:** The overall IgG seroprevalence was 11.5% (23/200), with no significant difference between governorates. All samples were IgM-negative, and all IgG-positive and equivocal samples showed high avidity. Age >40 years was associated with seropositivity in univariable analysis, but this association was not significant after adjustment (aOR = 2.21, 95% CI: 0.88–5.89; $p = 0.092$). No significant associations were observed with sex, nationality, educational level, travel history, cat ownership, or contact with stray cats. **Conclusions:** Among the participating community-based adults in Kuwait, *T. gondii* seroprevalence was lower than that reported in several regional studies, with serological findings consistent with past rather than recent infection. No demographic or exposure-related factor was independently associated with seropositivity. Larger population-based studies specifically powered to investigate risk factors and incorporating dietary, occupational, environmental, and migration-related exposures are needed to better characterise transmission pathways and inform targeted One Health surveillance and prevention strategies.



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conditions of the [Creative Commons](https://creativecommons.org/licenses/by/4.0/)[Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.**Keywords:** *Toxoplasma gondii*; Kuwait; Epidemiology; public health; environmental hygiene; zoonotic infection

1. Introduction

Toxoplasmosis is a neglected parasitic disease caused by the apicomplexan protozoan *Toxoplasma gondii*, which infects approximately one-third of the world's population. Cats (and other felids) are the primary reservoirs for the parasite, and almost all warm-blooded mammals and avians can act as intermediate hosts [1,2]. Transmission of the parasite to humans can involve ingesting *T. gondii* oocysts in contaminated soil, food, water, and utensils,

or by contact with cats' faeces. Ingestion of food contaminated with tissue cysts can also lead to transmission of the parasite [1]. Toxoplasmosis mainly affects immunocompromised individuals and fetuses of infected pregnant women, particularly in their first trimester. In the latter, congenital toxoplasmosis can result in growth and developmental retardation, miscarriage, and stillbirth. It can also lead to ocular toxoplasmosis at a later age, where the parasite reaches the eyes, damages the nerves, and may potentially lead to blindness. In case of immunosuppression, cerebral toxoplasmosis can lead to severe inflammation and tissue destruction in the central nervous system, where the parasite encysts, leading to neurological symptoms such as headaches, fever, seizures, and possibly fatality. Latent toxoplasmosis may cause behavioural changes, psychological illnesses, and neurodegenerative disorders in immunocompetent individuals due to its chronic encystation in the central nervous system [1,2].

The seroprevalence of *T. gondii* was recorded as the highest in Africa (61.4%), followed by Oceania (39%), South America (32%), Europe (30%), and North America (18%), with the lowest rates reported in Asia (16.4%) [3]. These variations in prevalence were commonly linked to factors such as low income, climatic influences, and the widespread presence of cats [3]. A global systematic review examining *T. gondii* infections in pregnant women estimated an overall IgG seropositivity rate of 33%, with the highest levels observed in the Americas [4]. The Eastern Mediterranean region had the highest IgM seropositivity rate (4%), indicating more recent infections [4]. A more recent systematic review and meta-analysis focused specifically on the World Health Organisation (WHO) Eastern Mediterranean region (EMRO) further supported these findings, reporting an IgG seroprevalence of 34% and an IgM seropositivity rate of 4% among pregnant women. The study identified significant associations between *T. gondii* seropositivity and risk factors, including consumption of unpasteurised milk, contact with cats, ingestion of contaminated vegetables, and consumption of undercooked or contaminated meat [5,6].

There is a clear lack of documentation regarding *T. gondii* infections in Kuwait, and no recent general population surveys have been conducted. A 2021 study involving 280 pregnant women in Kuwait found that 13% were IgG seropositive, while 2% tested positive for IgM antibodies [7]. In parallel, the population of stray cats and dogs has been steadily increasing in Kuwait [8,9]. In 2013, approximately 20% of stray cats in Kuwait were found to be seropositive for *T. gondii* [10]. To date, no official governmental regulations have been implemented to address the potential public health risks associated with zoonotic transmission of *T. gondii*. Occupational exposure also represents a growing concern. A recent study among waste workers in Kuwait, a potentially high-risk occupational group because of frequent exposure to contaminated waste and environments, reported *T. gondii* IgG seropositivity in 21% of participants. Among the seropositive workers, approximately half exhibited low IgG avidity. In contrast, around one quarter had high IgG avidity, indicating past exposure that likely occurred within the past 9 months [8]. Although low avidity may be compatible with relatively recent exposure, it does not confirm the precise timing of infection. Nevertheless, the proportion of low-avidity results raises the possibility of ongoing or relatively recent transmission and supports the need for larger population-based studies in Kuwait.

Building upon these observations, the study investigated the seroprevalence of *T. gondii* among community-based adult participants in Kuwait recruited from two major governorates: Kuwait City (the Capital) and Jahra. Seroprevalence was measured using enzyme-linked immunosorbent assays (ELISA) to assess IgG, IgM, and IgG avidity, alongside analysis of available demographic data from the sampled population. By investigating the extent of infection at the community level, the study provides baseline epidemiological evidence that may contribute to a broader One Health understanding of *T. gondii* transmis-

sion in Kuwait, particularly in relation to vulnerable groups such as pregnant women and immunocompromised individuals. Understanding local patterns of *T. gondii* exposure may help inform context-specific prevention messages addressing food hygiene, environmental exposure, and safe practices, thereby contributing to efforts to reduce the public health burden associated with toxoplasmosis.

2. Material and Method

2.1. Study Design and Study Areas

The seroprevalence of *T. gondii* was assessed through a cross-sectional study conducted in September 2024 among the adult population in Kuwait. Two governorates were selected: Kuwait City and Jahra. Kuwait City, the capital, is centrally located along the Arabian Gulf and is characterised by its urban landscape. In contrast, Jahra, the largest governorate, lies in the northwest and is generally considered less urban than the capital region (Figure 1). These regions were chosen to capture potential variations in parasite prevalence due to their distinct demographic and environmental characteristics [11]. As per the Ministry of Health (Kuwait) ethical considerations, blood samples were only collected within governmental polyclinics in selected areas. Three polyclinics were randomly selected from a list of all governmental clinics in each governorate (Figure 1). Participants were randomly selected from individuals attending the selected polyclinics. To ensure inclusion of a broader community representation, a social media announcement was circulated prior to sample collection, inviting healthy volunteers to participate. Recruitment, therefore, included patients, accompanying visitors, polyclinic staff, and volunteers who responded to the social media post.

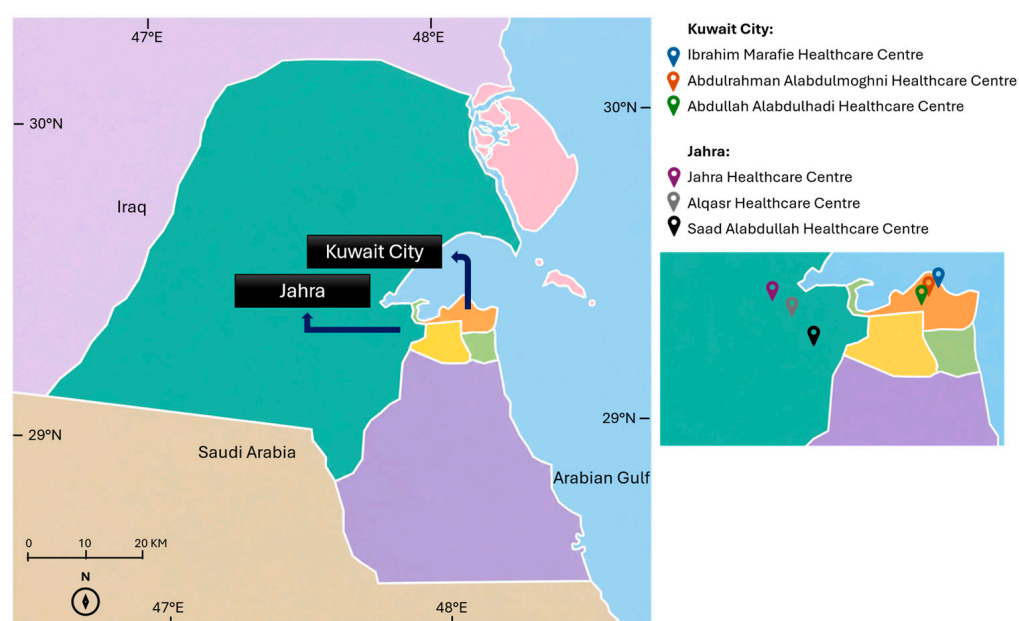


Figure 1. Geographic distribution of selected study sites in Kuwait. Map of the State of Kuwait showing the two selected governorates, Kuwait City (in orange) and Jahra (in dark green). The selected polyclinic sampling sites are indicated within each governorate and labelled using their official names.

2.2. Sample Size

To estimate the required sample size for assessing the prevalence of *T. gondii* infection in the general adult population, a 95% confidence level and a 5% margin of error were assumed. In the absence of population-based data for adults in Kuwait, the sample size calculation was based on findings from a recent study conducted among pregnant women

in Kuwait, which reported a seroprevalence of 12.5% [7]. Based on this estimate, the minimum required sample size was calculated to be 169 participants.

2.3. Sample Collection

Blood samples (~5 mL) were collected by a registered nurse assigned to the study, with the assistance of phlebotomists at the participating polyclinics. A total of 200 samples were obtained, with 100 samples collected from each governorate. All blood tubes were transported in a temperature-regulated container to the Parasitology laboratory at the College of Allied Health Sciences, Kuwait University. Upon arrival, samples were centrifuged for serum separation and stored at -20°C for serological analysis.

2.4. Demographic and Exposure Data Collection

All participants were requested to complete a questionnaire in either English or Arabic before sample collection. Information gathered included sex, age, nationality, recent travel history, and history of recent pet contact. The term “recent” was defined for participants as a period of six months or less. Age was categorised into two groups (≤ 40 years and >40 years) to reflect differences in cumulative exposure to *T. gondii* over time. This threshold was also selected to achieve a near-median distribution of the study population ($n = 110$ vs. 90), allowing a more balanced comparison between younger and older participants for detecting age-related differences in seroprevalence. Nationality was categorised as Kuwaiti and non-Kuwaiti. Recent travel history and pet contact were recorded as binary variables (yes/no).

2.5. Inclusion and Exclusion Criteria

The inclusion criteria were adults aged 18 years and above residing in the selected areas of Kuwait City or Jahra Governorate. The exclusion criteria included individuals younger than 18 years of age and residents outside the selected governorates. Written informed consent was obtained from all participants before blood collection, and all individuals were given the option to decline participation. During recruitment, 11 individuals from Kuwait City and 16 from Jahra refused to participate.

2.6. Ethical Considerations

Ethical approval for the study was obtained from the Ethics Committee of Kuwait University (Project No. NM01/23) and the Ministry of Health of Kuwait (Ref No. 2023/2500).

2.7. Enzyme-Linked Immunosorbent Assay (ELISA): IgM, IgG, and IgG Avidity

The serum samples were tested for *T. gondii* IgM and IgG antibodies using the VIDAS Toxo IgM and IgG II assays (bioMérieux, SA, Lyon, France), as per the manufacturer’s instructions. All IgG seropositive samples were further analysed for *Toxoplasma* IgG avidity using the VIDAS Toxo IgG Avidity kit (bioMérieux, SA, Lyon, France). Samples were diluted as instructed by the manufacturer, and a dissociation reagent (urea) was applied to clear low-avidity binding IgG antibodies. The avidity index (%) was calculated as the ratio between the optical density (OD) values of the urea-treated samples (containing high avidity antibodies) and the OD values of untreated samples (containing total IgG antibodies).

All ELISA procedures were performed using the VIDAS automated system at the Parasitology Laboratory, College of Medicine, Kuwait University, according to the manufacturer’s instructions. For the VIDAS Toxo IgM assay, results were interpreted as negative when <0.55 IU/mL, indeterminate when $0.55\text{--}0.65$ IU/mL, and positive when ≥ 0.65 IU/mL. For the VIDAS Toxo IgG assay, results were interpreted as negative when <4 IU/mL, indeterminate when $4\text{--}7.9$ IU/mL, and positive when ≥ 8 IU/mL. IgG avidity was interpreted

as low when the avidity index was <20%, indeterminate when 20–29.9%, and high when $\geq 30\%$, according to the VIDAS Toxo assays (bioMérieux SA, Lyon, France).

2.8. Statistical Data Analysis

Descriptive and univariable statistical analyses were performed using GraphPad Prism software (version 11.0.2). Seroprevalence estimates were reported as proportions with 95% confidence intervals calculated using the modified Wald (Agresti–Coull) method. Associations between demographic and exposure variables and *T. gondii* IgG seropositivity were evaluated using two-sided Fisher’s exact tests. Odds ratios (ORs) and 95% confidence intervals were calculated from 2×2 contingency tables using the Baptista–Pike method.

Given the limited number of IgG-seropositive outcomes, a parsimonious multivariable model was constructed to minimise overfitting and unstable effect estimates. The model included age group (>40 versus ≤ 40 years), nationality (non-Kuwaiti versus Kuwaiti), and recent travel history (no travel versus travel outside Kuwait during the preceding six months), as these variables were considered epidemiologically relevant and showed the strongest associations in the univariable analyses. Adjusted odds ratios (aORs), 95% profile penalised-likelihood confidence intervals, and penalised likelihood-ratio *p*-values were reported. The two participants with equivocal IgG results were excluded from the univariable and multivariable risk-factor analyses. A two-tailed *p*-value of ≤ 0.05 was considered statistically significant.

3. Results

3.1. Demographic Data

A total of 200 adults participated in this study, with equal representation from Kuwait City ($n = 100$) and Jahra ($n = 100$). The majority of participants were females ($n = 129$), accounting for 63% in Kuwait City and 66% in Jahra. Kuwaiti nationals constituted the majority ($n = 145$), comprising 66% of Kuwait City and 79% of Jahra participants. Among the non-Kuwaiti participants, Southeast Asians formed the largest group ($n = 32$), followed by Arab nationals ($n = 23$). The Southeast Asian group included individuals from India ($n = 21$), Sri Lanka ($n = 5$), the Philippines ($n = 4$), and Bangladesh ($n = 2$). Arab participants included nationals from Egypt ($n = 6$), Saudi Arabia ($n = 6$), Stateless individuals “Bedoon” ($n = 4$), Bahrain ($n = 2$), Jordan ($n = 2$), Tunisia ($n = 1$), Iraq ($n = 1$), and Syria ($n = 1$).

Overall, a larger proportion of participants were aged 40 years or younger ($n = 110$), compared to those older than 40 years ($n = 90$). In Kuwait City, the majority of participants were aged >40 years, whereas in Jahra, most participants were aged ≤ 40 years ($n = 68$).

Education was categorised into three groups based on the highest level attained: high school or diploma, bachelor’s degree, and postgraduate degree. The majority had completed either high school or held a diploma ($n = 114$), with 55% in Kuwait City and 59% in Jahra. A total of 75 participants held a bachelor’s degree, comprising 36% of Kuwait City and 39% of Jahra participants. Postgraduate degrees ($n = 11$) were more common among Kuwait City residents (9%) compared to those from Jahra (2%).

Most participants reported recent travel, within six months prior to blood collection ($n = 123$), with 57% from Kuwait City and 66% from Jahra. A total of 35 participants reported owning cats as pets, including 22% from Kuwait City and 13% from Jahra. Additionally, 23 participants reported direct contact with stray cats, with similar proportions from both governorates: 11% in Kuwait City and 12% in Jahra. The demographic and exposure characteristics of the study participants are presented in Table 1.

Table 1. Demographic and exposure characteristics of study participants stratified by governorate (Kuwait City and Jahra). Values for Kuwait City and Jahra are presented as numbers because each location included 100 participants; therefore, the numbers correspond directly to percentages. Total values are presented as *n* (%), based on the overall sample of 200 participants. Age was categorised into two groups (≤ 40 and >40 years). Nationality was classified as Kuwaiti nationals and non-Kuwaitis (Asian and Arab origin). Educational level was grouped as diploma or below, bachelor's degree, and postgraduate degree. Travel history was defined as travel outside Kuwait within the six months preceding blood sample collection. Animal exposure included contact with domestic cats (pet ownership) or exposure to stray cats.

Variable	Category	Kuwait City <i>n</i> = 100	Jahra <i>n</i> = 100	Total <i>n</i> (%)
Sex	Females	63	66	129 (64.5%)
	Males	37	34	71 (35.5%)
Age group (years)	≤ 40	42	68	110 (55%)
	>40	58	32	90 (45%)
Nationality	Kuwaiti	66	79	145 (72.5%)
	Arabs	9	14	23 (11.5%)
	Asians	25	7	32 (16%)
Educational level	High school/diploma	55	59	114 (57%)
	Bachelor	36	39	75 (37.5%)
	Postgraduate	9	2	11 (5.5%)
Travel history	Yes	57	66	123 (61.5%)
	No	43	34	77 (38.5%)
Cat ownership	Yes	22	13	35 (17.5%)
	No	78	87	165 (82.5%)
Stray cat exposure	Yes	11	12	23 (11.5%)
	No	89	88	177 (88.5%)

3.2. Enzyme-Linked Immunosorbent Assay (ELISA) Results for *Toxoplasma* IgM, IgG, and IgG Avidity Antibodies

3.2.1. Seroprevalence and Avidity Findings

A total of 200 serum samples were tested for *T. gondii* antibodies using ELISA. The overall seroprevalence of *Toxoplasma* IgG antibodies was 11.5% (23/200, 95% CI: 7.7–16.7%), with a higher number of seropositive cases among residents of Kuwait City (14%, 14/100, 95% CI: 8.4–22.3%) compared to those in Jahra (9%, 9/100, 95% CI: 4.6–16.4%). However, this difference was not statistically significant (OR = 1.7, 95% CI: 0.7–4; $p = 0.27$), and therefore, the results were analysed collectively for both governorates. Two equivocal IgG results were recorded, both from Kuwait City residents. None of the samples tested positive for *Toxoplasma* IgM in either governorate. All 23 IgG-positive samples were further tested for IgG avidity, and all demonstrated high avidity index values. Additionally, the two equivocal samples also exhibited high IgG avidity.

3.2.2. Univariable Analysis of Factors Associated with IgG Seropositivity

Associations between IgG seropositivity and demographic and exposure variables were evaluated after excluding the two equivocal samples ($n = 198$). The variables examined included sex, nationality, age, education level, travel history, and contact with domestic or stray cats. Although males showed a higher seropositivity than females, this difference was not statistically significant (OR = 2.1, 95% CI: 0.9–5.0; $p = 0.11$). Seropositivity was observed in 8.7% females (11/127; 95% CI: 4.8–15%) and 16.9% males (12/71; 95% CI: 9.8–27.4%). Seroprevalence was higher among non-Kuwaitis (18.9%, 10/54; 95% CI: 10.2–31%) compared to Kuwaitis (9%, 13/144; 95% CI: 5.2–14.9%); however, this difference was borderline and did not reach statistical significance (OR = 2.29, 95% CI: 0.94–5.59;

$p = 0.08$). Participants aged over 40 years had a significantly higher seroprevalence (16.9%, 15/89; 95% CI: 10.4–26.1%) compared to younger individuals (7.3%, 8/109; 95% CI: 3.6–14%) (OR = 2.6, 95% CI: 1.03–6.1, $p = 0.046$).

No significant association was observed between IgG seropositivity and educational level (OR = 0.66, 95% CI: 0.28–1.64; $p = 0.50$). Seroprevalence was 13.4% (15/112) among participants with a high school or diploma qualification, compared with 9.3% (8/86) among those with a bachelor's degree or postgraduate qualification. Similarly, travel history was not significantly associated with seropositivity (OR = 2.3, 95% CI: 0.9–5.5; $p = 0.07$); however, seroprevalence was higher among participants who had not travelled outside Kuwait in the preceding six months (16.9%, 13/77; 95% CI: 10.0–26.9%) compared to those who had (8.3%, 10/121; 95% CI: 4.4–14.7%).

No significant association was found between seropositivity and cat ownership or contact with stray cats ($p = 0.38$ and 0.48 , respectively). Among participants who reported owning cats, seroprevalence was 5.7% (2/35; 95% CI: 0.6–19.6%), compared to 12.9% (21/163; 95% CI: 8.5–19%) among those who did not. Similarly, seroprevalence was 4.3% (1/23; 95% CI: <0.01–22.7%) among those reporting contact with stray cats, compared to 12.6% (22/175; 95% CI: 8.4–18.4%) among those without such exposure. The distribution of seropositive cases and their associated demographic characteristics are presented in Table 2.

Table 2. Demographic and exposure characteristics of participants who tested seropositive for *T. gondii* IgG antibodies in Kuwait City and Jahra governorates. The table presents individual-level demographic and exposure data for each seropositive participant, including age, sex (female = F, male = M), nationality, educational level (high school/diploma = HS/Dip; bachelor's or postgraduate = Postgrad), travel history and destination, contact with stray cats, and pet ownership. Not applicable = NA.

	Nationality	Sex	Age	Education	Travel History	Travel Country	Contact with Stray Cats	Cat Ownership
1	Sri Lanka	M	41	HS/Dip	No	NA	No	No
2	India	M	43	HS/Dip	No	NA	No	No
3	India	F	52	HS/Dip	No	NA	No	No
4	Kuwait	M	49	Postgrad	Yes	UAE and Oman	No	No
5	Kuwait	M	62	HS/Dip	No	NA	No	No
6	Kuwait	M	39	Postgrad	Yes	Japan	No	No
7	Sri Lanka	F	40	HS/Dip	No	NA	No	No
8	Sri Lanka	F	54	HS/Dip	No	NA	No	No
9	Kuwait	M	61	HS/Dip	Yes	Saudi Arabia and Bosnia	No	No
10	Kuwait	F	51	Bachelor's	Yes	Saudi Arabia	No	No
11	Kuwait	F	69	HS/Dip	No	NA	No	No
12	India	M	48	HS/Dip	No	NA	No	No
13	Tunisia	F	38	HS/Dip	No	NA	No	No
14	Kuwait	F	40	Bachelor's	No	NA	Yes	Yes
15	Kuwait	F	19	HS/Dip	Yes	Oman	No	No
16	Kuwait	M	45	Postgrad	Yes	Saudi Arabia	No	No
17	Kuwait	M	18	Bachelor's	No	NA	No	No
18	India	F	43	HS/Dip	Yes	India	No	No
19	Kuwait	F	20	Bachelor's	Yes	Saudi Arabia	No	No
20	Syrian	M	54	HS/Dip	No	NA	No	No
21	Egypt	M	47	Bachelor's	Yes	Saudi Arabia	No	No
22	Kuwait	F	63	HS/Dip	Yes	UK, Turkey and Saudi Arabia	No	Yes
23	Kuwait	M	37	HS/Dip	No	NA	No	No

The association between demographic and exposure variables and *T. gondii* IgG seropositivity was further evaluated using univariable analysis. Seroprevalence within each category, along with corresponding odds ratios (ORs), 95% confidence intervals (CIs), and *p*-values, are summarised in Table 3. A statistically significant association was observed only for age, while no significant associations were identified for the other variables.

Table 3. Association between demographic and exposure variables and *T. gondii* IgG seropositivity among study participants. Values are presented as numbers (*n*) and percentages (%), with percentages calculated within each category. Odds ratios (ORs) with 95% confidence intervals (CIs) were derived from 2×2 contingency tables, and *p*-values were calculated using Fisher's exact test. Two equivocal samples were excluded from the analysis. A *p*-value of ≤ 0.05 was considered statistically significant; statistically significant results are indicated by an asterisk (*).

Variable	Category	Positive <i>n</i> (%)	Negative <i>n</i> (%)	OR (95% CI)	<i>p</i> -Value
Gender	Females	11 (8.7%)	116 (91.3%)	2.1 (0.9–5)	0.11
	Males	12 (16.9%)	59 (83.1%)		
Age	≤ 40	8 (7.3%)	101 (92.7%)	2.6 (1.0–6.1)	0.046 *
	> 40	15 (16.9%)	74 (83.1%)		
Nationality	Kuwaitis	13 (9%)	132 (91%)	2.4 (0.9–5.5)	0.08
	Non-Kuwaitis	10 (18.9%)	43 (81.1%)		
Travel history	Yes	10 (8.3%)	111 (91.7%)	2.3 (0.9–5.5)	0.07
	No	13 (16.9%)	64 (83.1%)		
Level of education	High school/diploma	15 (13.4%)	97 (86.6%)	0.7 (0.3–1.6)	0.50
	Bachelor/Postgrad	8 (9.3%)	78 (90.7%)		
Cat ownership	Yes	2 (5.7%)	33 (94.3%)	2.4 (0.6–10.9)	0.38
	No	21 (12.9%)	142 (87.1%)		
Stray cat exposure	Yes	1 (4.3%)	22 (95.7%)	3.2 (0.5–34.2)	0.48
	No	22 (12.6%)	153 (87.4%)		

3.2.3. Multivariable Logistic Regression Analysis

A multivariable logistic regression analysis was performed to evaluate the independent associations of age group, nationality, and recent travel history with *T. gondii* IgG seropositivity. The analysis included 198 participants after excluding the two equivocal IgG results. After mutual adjustment, none of the examined variables was statistically significantly associated with IgG seropositivity.

Participants aged > 40 years had higher adjusted odds of seropositivity than those aged ≤ 40 years, although this association did not reach statistical significance (adjusted odds ratio [aOR] = 2.21, 95% profile-likelihood CI: 0.88–5.89; *p* = 0.09). Non-Kuwaiti participants also had higher adjusted odds of seropositivity than Kuwaiti participants (aOR = 1.58, 95% profile-likelihood CI: 0.59–4.12; *p* = 0.36). Similarly, participants who had not travelled outside Kuwait during the preceding six months had higher adjusted odds of seropositivity than those reporting recent travel, but this association was not statistically significant (aOR = 1.87, 95% profile-likelihood CI: 0.74–4.82; *p* = 0.19). The multivariable results are presented in Table 4.

Table 4. Multivariable logistic regression analysis of factors associated with *T. gondii* IgG seropositivity among study participants. The model included age group, nationality, and recent travel history. The dependent variable was *T. gondii* IgG seropositivity, coded as positive = 1 and negative = 0. Reference categories were age ≤ 40 years, Kuwaiti nationality, and travel outside Kuwait during the preceding six months. Adjusted odds ratios (aORs), 95% profile-likelihood confidence intervals (CIs), and likelihood-ratio *p*-values are presented. The two participants with equivocal IgG results were excluded; therefore, 198 participants were included in the analysis. A two-sided *p*-value of ≤ 0.05 was considered statistically significant.

Variable	Adjusted OR	95% Profile Penalised-Likelihood CI	<i>p</i> -Value
Age			
>40 vs. ≤ 40 years	2.13	0.87–5.52	0.098
Nationality			
Non-Kuwaitis vs. Kuwaitis	1.59	0.60–4.04	0.342
Travel history			
No vs. Yes	1.84	0.74–4.63	0.019

4. Discussion

We assessed the seroprevalence of *T. gondii* infections among the adult population in Kuwait attending governmental polyclinics in two major governorates, Kuwait City and Jahra. Seropositivity rates did not differ significantly between Kuwait City and Jahra, indicating the possibility that underlying environmental conditions and behavioural patterns contributing to exposure are comparable across the two governorates. Out of 200 serum samples analysed, 11.5% tested seropositive for *Toxoplasma* IgG antibodies, which is relatively similar to the prevalence in pregnant women in Kuwait but lower than that observed in waste workers [7,8].

Serology is commonly used as the primary epidemiological tool, particularly in population-based research, as many infected individuals within the community may remain asymptomatic [12–14]. Detection of antibodies using ELISA is commonly preferred in such investigations due to its rapid turnaround, economic practicality, and reliable performance [13,15]. For *Toxoplasma* detection, we used the Vidas automated system to test for IgM, IgG, and IgG avidity antibodies. Vidas assays are among the most widely used routine diagnostic methods and are particularly effective in excluding early infections within the past four months [13,16,17].

All samples that tested positive for *Toxoplasma* IgG were negative for IgM and exhibited high IgG avidity indices. This serological profile strongly suggests past, likely acquired more than four months prior to sampling, rather than recent infection. IgM antibodies typically appear within the first week of infection and indicate early infections, while IgG antibodies emerge later and persist long-term as an immunological memory marker [13]. It is noteworthy that IgM antibodies may yield negative results during the transient phase or the early stages of infection [8,18]. Consequently, IgG avidity testing is a valuable complementary tool to accurately determine the timing of infection [19]. IgG avidity assesses the binding strength of IgG antibodies to *T. gondii* antigens in the presence and absence of a denaturing agent, such as urea [20]. A high IgG avidity index indicates strong antibody–antigen binding, thereby excluding recent infections. In contrast, low avidity reflects weaker binding, suggestive of a more recent exposure, as the antibodies have not yet matured to high-affinity forms [19]. The combined findings of IgG seropositivity with high avidity are also consistent with chronic infection, likely reflecting the long-term persistence of *T. gondii* tissue cysts within the human host [21].

We analysed several variables among the study participants, including nationality, sex, age, level of education, travel history, contact with stray animals, and pet ownership. In the

univariable analysis, age was the only demographic factor significantly associated with *T. gondii* IgG seropositivity, with higher odds observed among participants aged >40 years than among those aged ≤40 years. However, this association was attenuated and no longer statistically significant after adjustment for nationality and recent travel history in the multivariable logistic regression model (aOR = 2.21, 95% CI: 0.88–5.89; $p = 0.092$). Nevertheless, the direction and magnitude of the adjusted association suggest that increasing age may remain epidemiologically relevant, although the wide confidence interval indicates considerable uncertainty. Previous reports in the literature found that the seroprevalence of *T. gondii* increases cumulatively with age, likely due to repeated environmental exposure over time [6,12]. Furthermore, the association between IgG seropositivity and advancing age has been observed in several studies among pregnant women [22,23]. Similarly, a study from Bosnia and Herzegovina reported a 19% seroprevalence of *T. gondii* IgG antibodies in the general population and 16% among pregnant women, with positivity associated with increasing age and rural residence [24].

In the present study and after mutual adjustment, both non-Kuwaiti nationality and the absence of recent travel were associated with higher odds of seropositivity, although neither association reached statistical significance (aOR = 1.58, 95% CI: 0.59–4.12; $p = 0.356$ and aOR = 1.87, 95% CI: 0.74–4.82; $p = 0.188$, respectively). These elevated estimates suggest that potentially relevant differences cannot be excluded. The wide confidence intervals and the limited statistical power to identify modest associations, reflecting the relatively small number of seropositive participants, should be considered when interpreting these findings. Although Kuwait is characterised by a generally high socioeconomic standard, a substantial proportion of the population consists of expatriates [25] originating from regions where parasitic infections, including toxoplasmosis, are more endemic and often associated with lower socioeconomic conditions. Previous exposure prior to migration from endemic countries may therefore contribute to the observed seropositivity patterns. Moreover, travel during a six-month period may not adequately capture lifetime geographic exposure, which is more relevant to persistent IgG seropositivity and infection acquired several years previously.

Comparable regional findings have been reported in neighbouring Gulf countries. A systematic review and meta-analysis from Saudi Arabia, which reported a *T. gondii* IgG seroprevalence of 27.5% in the general population and 28% among pregnant women across various regions of the Kingdom, with a significant association with advancing age [26]. Similarly, a study from Qatar showed an age-related increase in *T. gondii* seropositivity, rising from 23% in young children to 41.2% among individuals older than 45 years [27].

In the present study, no significant association was observed between *T. gondii* IgG seropositivity and cat ownership or contact with stray cats. This finding is consistent with a previous study among pregnant women in Kuwait, which also found no significant association between *T. gondii* seropositivity and contact with stray cats or pet ownership [7]. A similar observation was also reported in a recent *Toxocara* spp. study in Kuwait, where pet ownership and recent contact with stray cats were not significantly associated with seropositivity [28]. Together, these findings suggest that self-reported recent animal contact may not fully capture cumulative or indirect environmental exposure to zoonotic parasites. Future investigations will benefit from investigating alternative transmission routes in Kuwait, such as contaminated food, water, or soil [29]. Although most seropositive participants did not report recent travel outside Kuwait, the influence of international migration and travel to highly endemic regions should also be considered a potentially important contributor to primary *T. gondii* acquisition years earlier, particularly given the long-term persistence of antibodies [30].

Although males demonstrated a higher seroprevalence of *T. gondii* infection compared with females, the association was not statistically significant. This trend may nevertheless reflect differences in occupational and environmental exposure patterns, as higher-risk occupations in Kuwait are predominantly male-dominated. We previously investigated the seroprevalence of *T. gondii* among waste collectors in Kuwait, a group characterised by occupational exposure and lower socioeconomic conditions, exhibited a higher seroprevalence of *T. gondii* (21% out of 201 participants) [8] than that observed in the present study. The findings of this study highlight the need to investigate other high-risk occupational groups in Kuwait, such as butchers, farmers, and veterinary workers, who are directly exposed to raw meat and animals. A study of 401 serum samples from occupationally exposed workers in Iran, including butchers, slaughterhouse workers, veterinarians and farmers, found that 46% tested positive for *T. gondii* IgG. This rate was significantly higher than that in the control group (31%) [31]. Another study reported that 11% of 519 individuals with occupational animal exposure were IgG positive, with the highest rates observed in those exposed to cattle, pigs, and sheep [32].

Since the global prevalence of *T. gondii* infections in 2019 was estimated to be approximately 26% [33], regional variations in seroprevalence have been widely documented. A meta-analysis from Saudi Arabia that included 20,699 individuals reported an overall IgG seroprevalence of 27.5% [26]. Approximately 30% of the 1625 individuals surveyed in Qatar were IgG seropositive for *T. gondii* [27]. Similarly, a meta-analysis from Iran reported a 33% seroprevalence in the general population based on 122,882 individuals across 31 provinces [6]. Although seroprevalence rates have declined in several developed countries in recent years, largely due to improved community awareness of hygiene practices and access to higher-quality food and water supplies [2], *Toxoplasma* infection remains a significant public health concern. A study conducted in Spain among 273 residents showed a seroprevalence of 37% for *T. gondii* IgG [34]. In England and Wales, approximately 365 cases were confirmed and reported annually [35]. Our study demonstrated comparatively lower seroprevalence than that reported in several regional and global studies, suggesting lower *Toxoplasma* exposure among the community-based adult participants included in this study. However, such differences should be interpreted cautiously, as they may reflect variations in study design, participant characteristics, sampling strategies, diagnostic methods, geographical setting, and underlying exposure patterns rather than true differences in population-level transmission. Although urbanisation, socioeconomic conditions, hygiene practices, and access to healthcare were not directly assessed, Kuwait's generally urban setting and socioeconomic development may potentially contribute to lower exposure risk [7,36]. Future studies should investigate these factors, including relevant environmental, behavioural, and socioeconomic determinants.

Given these findings, this study has several limitations. The convenience sampling approach used to recruit participants may have introduced selection bias and may not be representative of the wider adult population of Kuwait, as individuals attending healthcare facilities or volunteering through social-media advertisements may differ from the broader community in demographic characteristics, health-seeking behaviour, educational level, socioeconomic status, and exposure history. In addition, participants were recruited from only two governorates, which may limit the generalisability of the findings to other areas of Kuwait. Several established or potentially relevant risk factors were also not assessed, including dietary practices such as the consumption of raw or undercooked meat and unpasteurised milk, handwashing and other hygiene behaviours, soil exposure, underlying health conditions, and the use of immunosuppressive medications. The absence of these variables limited our ability to evaluate important dietary, behavioural, and host-related determinants of *T. gondii* seropositivity. The sample-size calculation was designed primarily

to estimate the overall prevalence of *T. gondii* IgG antibodies and was not specifically powered to detect differences between demographic or exposure variables. The risk-factor analyses were based on only 23 seropositive outcomes and may therefore have had insufficient statistical power to identify modest or moderate associations. This limitation may partly explain why several comparatively elevated crude and adjusted odds ratios did not reach statistical significance, particularly for age, nationality, and travel history. The wide confidence intervals further indicate substantial uncertainty around these estimates. Accordingly, the risk-factor findings should be regarded as exploratory, and the absence of statistical significance should not be interpreted as evidence of the absence of an association.

Further research using larger and more representative samples should investigate additional risk factors for *T. gondii* exposure that were not assessed in this study, including hygiene-related practices. Although the present findings have potential relevance for public health education and prevention of *T. gondii* infection in Kuwait, future studies should evaluate hygiene behaviours, food-preparation practices, soil contact, water sources, and environmental contamination to identify the most relevant local transmission routes and guide targeted prevention strategies.

Implementing prevention and control measures within a One Health framework, by integrating surveillance of humans, animals and environmental reservoirs, would strengthen national monitoring systems and help limit parasite transmission, particularly among high-risk groups such as fetuses and infants of pregnant women, as well as immunocompromised individuals, and patients at risk of reactivation of latent toxoplasmosis. Enhanced multidisciplinary collaboration between public health authorities, veterinary sectors, food safety agencies, and environmental services is essential for understanding parasite circulation, reducing transmission, and limiting disease burden in the region.

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