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RESEARCH PAPER

Association between chronic toxoplasmosis and thyroid function hormone levels in patients with schizophrenia – A case-control study

Alla K. Mohammed[1], Sarmad N. Mageed [2]

[1] Department of Medical Microbiology, Faculty of Science and Health, Koya University, Koya KOY45, Kurdistan Region - F.R. Iraq

A B S T R A C T:

Chronic toxoplasmosis is a widespread zoonotic disease caused by a protozoan parasite, *Toxoplasma gondii* (*T. gondii*). Chronic *T. gondii* has recently been linked to the development of psychiatric disorders by interfering with thyroid hormone levels. Unfortunately, not enough research has been done on this link. Therefore, we studied the possible association between chronic toxoplasmosis and thyroid function hormones in schizophrenic patients. The study included 101 patients with schizophrenia who were hospitalized to three psychiatric hospitals in Kurdistan Region. Demographic information and 4 ml of venous blood were collected from each patient and examined for detection of anti-*Toxoplasma* IgG antibody via enzyme-linked immunosorbent assay (ELISA). Furthermore, thyroxine (T4), triiodothyronine (T3), and thyroid-stimulating hormone (TSH) levels were measured in serum by ELISA technique. Overall, 40% of patients tested positive for *T. gondii* IgG antibodies. Toxoplasmosis incidence increased significantly in the 50 to 60-year age group (OR= 6.2, p =0.05). Data analysis showed a non-significant association between chronic toxoplasmosis and TSH levels (p>0.5). In contrast, we found a strong positive association between chronic toxoplasmosis and T4 levels (p=0.01); furthermore, the seropositive group had higher T4 levels (10.2 ± 2.6) than the seronegative group (7.0 ± 1.7). Finally, chronic toxoplasmosis was positively but non-significantly associated with T3 levels (p=0.3), and T3 levels were higher in the seropositive group (1.9 ± 0.5) in comparison to the seronegative group (1.1 ± 0.4). In conclusion, chronic toxoplasmosis was significantly associated with elevation in thyroxine levels in patients with schizophrenia.

KEY WORDS: *Toxoplasma gondii*, Chronic toxoplasmosis, Thyroid function hormones, ELISA.
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1.INTRODUCTION:

Chronic or latent toxoplasmosis is a widespread, zoonotic disease caused by an obligate intracellular parasite called *Toxoplasma gondii* (*T. gondii*). The parasite can infect almost all warm-blooded animals including human and birds (Mageed, 2017). About 30% of the world's population is infected with toxoplasmosis (Egorov et al., 2021). The parasite produces infected cysts in the muscle, brain, or other body tissues, resulting in a chronic infection that lasts a lifetime. Despite the fact that chronic infections are often asymptomatic, they are connected with neurological impairments and an increased risk of neuropsychiatric disorders (Kamal et al., 2022). Furthermore, Ticks have recently been implicated as a potential vector for the spread of *T. gondii* (Ben-Harari, 2019).

Schizophrenia is a chronic central nervous system neuropsychiatric illness that affects 1% of people globally (Cheslack-Postava & Brown, 2022). While the causes of schizophrenia are poorly understood, family studies suggest that hereditary factors play a significant role in the disease's etiopathogenesis(Schlüter & Barragan, 2019). Epidemiological studies, on the other hand, have linked environmental factors such as being born in the winter season or urban area, or being exposed to infectious agents to increase the chance of having schizophrenia later on in life (Desmettre, 2020).

Among the infectious agents, *Toxoplasma gondii* has been suggested as a potential factor in the development of psychiatric disorders in certain people (Elsheikha et al., 2016). Multiple pieces of evidence suggest that the parasite may live for a long time in the brain of the infected host, where it

* **Corresponding Author:**
Alla K. Mohammed
E-mail:
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may exhibit its neurotropism and consequently influence the host's behavior (Schlüter & Barragan, 2019; Desmettre, 2020).

Thyroid Stimulating Hormone (TSH) is a glycoprotein hormone synthesized and regulated by Thyrotropin Releasing Hormone (TRH), which is secreted by the nerves in the dorsomedial hypothalamus region of the brain. Through negative feedback, TSH stimulates the release of T4 and T3 by the thyroid gland (Razvi et al., 2019). Thyroid hormones are vital for development and metabolism, and they have a substantial impact on speaking abilities, behavioral modulation, and memory due to their influence on the development of the central nervous system (Alvarado-Esquivel et al., 2019). Although *T. gondii* can infect almost any organ in the human body, it is only after entering the brain that it poses a threat to the thyroid. Once there, it can alter the morphology of the thyroid gland and significantly increase thyroid peroxidase (TPO), both of which are crucial to the production of thyroid hormones (Al-Issawi & Aysir, 2020).

Very little is known about the impact of chronic toxoplasmosis on TSH and thyroid hormones and its role in developing psychiatric disorders. Therefore, the objective of our study was to examine a potential link between chronic toxoplasmosis and thyroid function hormone levels in individuals with schizophrenia.

2. MATERIALS AND METHODS

2.1. Study population

The population of the current study consisted of 101 individuals diagnosed with schizophrenia. All of the study participants were aged between 18-60 years old, and they were hospitalized and on antipsychotics at Soz mental hospital, Shahid Salah Muhandis mental hospital in Sulaymaniyah, and Erbil mental hospital in Erbil city, located in the Kurdistan Region of Iraq, from January 1st, 2021, to March 2nd, 2022. In order to gather socio-demographic information, a questionnaire was prepared and utilized. Informed permission was acquired from each participant in this study.

2.2. Sample collection

Using the conventional venipuncture technique, 4 ml of venous blood was drawn from all patients. Sera samples were obtained by centrifuging the blood samples at 14000 rpm (round per minute) for 14 minutes. The serum samples were then transported in a cool box to the SHRC (Science and health research center) at Koya University. The samples were stored in Eppendorf tubes and kept at -80°C until examination.

2.3. Anti-*Toxoplasma* IgG antibody detection in serum

A commercially available enzyme-linked immunosorbent assay (ELISA) kit (Pishtaz Teb, Iran) was used to qualitatively measure anti-*Toxoplasma* IgG antibody levels in serum according to manufacturer's instructions, using microplate reader EXL800 (Bio Teck, USA). According to the manual, the IgG levels reater than 33IU/ml were reported as seropositive.

2.4. Thyroid hormone evaluation

A commercially available, enzyme-linked immunosorbent assay (ELISA) kit (PishtazTeb, Iran) was used to qualitatively measure triiodothyronine (T3), thyroxine (T4), as well as thyroid-stimulating hormone (TSH) levels in serum according to manufacturer's instructions, using microplate reader EXL800 (Bioteck, USA). According to the kit's manual, the normal ranges for each hormone were as follows: T3 (0.5-2.2 ng/ml), T4 (4.6- 12.6 µg/dl), and TSH (0.4-5.3 mIU/l).

2.5. Data analysis

Data analysis was carried out using Statistical Package for Social Science version 26 (SPSS, Inc., Chicago, IL, USA. The demographic characteristics of the study groups were compared using the Chi-squared test. The risk variables for *T. gondii* IgG seropositivity were evaluated using regression analysis. Furthermore, T-test was utilized to compare the continuous variables. Furthermore, the association between thyroid hormones and anti-*Toxoplasma* IgG antibody was evaluated using Pearson's correlation. All of the data analysis was conducted with 95% confidence intervals, and the attained P value ≤ 0.05 was reported as statistically significant.

3. RESULTS

3.1 Socio-demographic characteristics of the study participants

The research population consisted of a hundred and one people diagnosed with schizophrenia. The socio-demographic characteristics are presented in Table (1). Of the 101 participants whose samples were tested, 40 were found to have anti-*Toxoplasma* IgG antibodies. According to *Toxoplasma* IgG antibody detection, the study participants were separated into 2 groups; 61 (60.4%) *Toxoplasma* IgG seronegative and 40 (39.4%) *Toxoplasma* IgG seropositive. Anti-*Toxoplasma* IgG antibody levels ranged between

0.02 – 956 IU/ml, with a mean of 168.8 ± 121.1 IU/ml. The majority of the study participants were male, 70 (69.3%), and only 31 (30.7%) females. The participants aged between 18 to 60 years old averaged 41± 9.7 years.

Chi-squared analysis showed no statistically significant difference in age, gender, blood group, and marital status between the study groups. Interestingly, the most common blood group was A+ (36.6%), although the difference in the blood groups was close but could not reach a significant level (0.06).

Furthermore, logistic regression analysis for assessing the risk factors revealed that patients in the 50-60 age range had a 6-fold increased risk of developing chronic *toxoplasma* infection compared to the other age groups (OR= 6.20, *P*=0.05, CI upper 40.30 and CI lower 1.04) than the other age groups. Finally, no significant association was found between the parasite and gender, marital status, or ABO blood group (Table 2).

Table 1 Socio-demographic characteristics and *Toxoplasma* prevalence of the study population

Socio-demographic characteristics	IgG seronegative n=61		IgG seropositive n=40		Total		*P* value
	n	%	n	%	n	%	
Age, mean ± SD	39.5 ± 10.1		42 ± 8.8		41± 9.7		0.16
18-29	11	18	2	5	13	12.8	
30-49	37	60	28	70	65	64.4	
50-60	13	22	10	25	23	22.8	
Gender							
Female	23	37.7	8	20	31	30.7	0.06
Male	38	62.3	32	80	70	69.3	
Blood group							
O+	19	31.1	7	17.5	26	25.7	0.06
O-	1	1.6	1	2.5	2	2	
AB+	4	6.6	6	15	10	9.9	
AB-	1	1.6	0	0	1	1	
A+	17	27.9	20	50	37	36.7	
A-	5	8.2	1	2.5	6	5.9	
B+	12	19.7	5	12.5	17	16.8	
B-	2	3.3	0	0	2	2	
Marital status							
Married	6	9.8	8	20	14	13.9	0.14
Un-married	55	90.2	32	80	87	86.1	

n= number, SD= standard deviation, *P*= probability value, IgG= Immunoglobulin G antibody

Table 2 Regression analysis of risk factors associated with chronic toxoplasmosis in schizophrenic patients

Socio-demographic characteristics	B	OR	*P* value	95 % CI	
				Upper	Lower
Age in years					
18-29	……..	……..	……..	……..	……..
30-49	1.37	4.14	0.11	0.76	22.03
50-60	1.51	6.20	**0.05**	1.04	40.30
Gender					
Male	……..	……..	……..	……..	……..
Female	0.81	0.45	0.14	0.18	1.18
Blood Group					
A+	……..	……..	……..	……..	……..
A-	-0.12	0.94	0.90	0.13	1.01
AB+	0.20	0.81	0.84	0.10	6.64
AB-	-2.50	0.01	0.99	0.01	1.00
O+	1.63	0.20	0.11	0.03	1.61
O-	-2.40	0.01	0.90	0.02	1.00
B+	1.42	0.34	0.24	0.02	3.01
B-	-2.21	0.01	1.00	0.01	1.00
Marital status					
Married	……..	……..	……..	……..	……..
Un-married	0.91	3.22	0.15	0.73	7.20

B= beta regression coefficient, OR= Odd ratio, *P*= probability value, CI= Confidence intervals

3.2 Association between thyroid function hormones and *T. gondii* seropositivity

Independent sample t-test analysis revealed a highly significant elevation in T4 levels in IgG seropositive compared to IgG seronegative groups (p=0.001); however, the T4 levels remained within the normal range. IgG seropositive patients also showed a statistically significant elevation in T3 levels (P=0.02); however, the T3 levels were within the normal range. Finally, no significant change was observed in TSH levels in either group (*P*=0.9) (Table 3, Figure 1).

The association between the thyroid hormones and anti-*Toxoplasma* IgG antibody was evaluated by Pearson's correlation (Bivariate analysis). A statistically significant increasing trend was observed between T4 levels and anti-*Toxoplasma* IgG antibody levels (r = 0.63, p = 0.01) (Figure 2.A).

Conversely, a non-significant negative association was seen between TSH levels and anti-*Toxoplasma* IgG antibody levels (r = -0.07, p = 0.54) (Figure 2C). Finally, T3 levels were positively but non-significantly associated with anti-*Toxoplasma* IgG antibody levels (r = 0.11, p = 0.30) (Figure 2B).

Table 3 Serum level distribution of T4, T3, and TSH levels in both IgG seronegative and IgG seropositive group, with their mean ± standard deviation.

Hormones	IgG seronegative	IgG seropositive	*P* value	Reference-range (Kit)
	Mean ± SD	Mean ± SD		
T4 µg/dl	7.0 ± 1.7	10.2 ± 2.6	0.001	4.6- 12.6
T3 ng/ml	1.1 ± 0.4	1.9 ± 0.5	0.02	0.5-2.2
TSH mIU/l	2.7 ± 1.4	2.7 ± 1.9	0.9	0.4-5.3

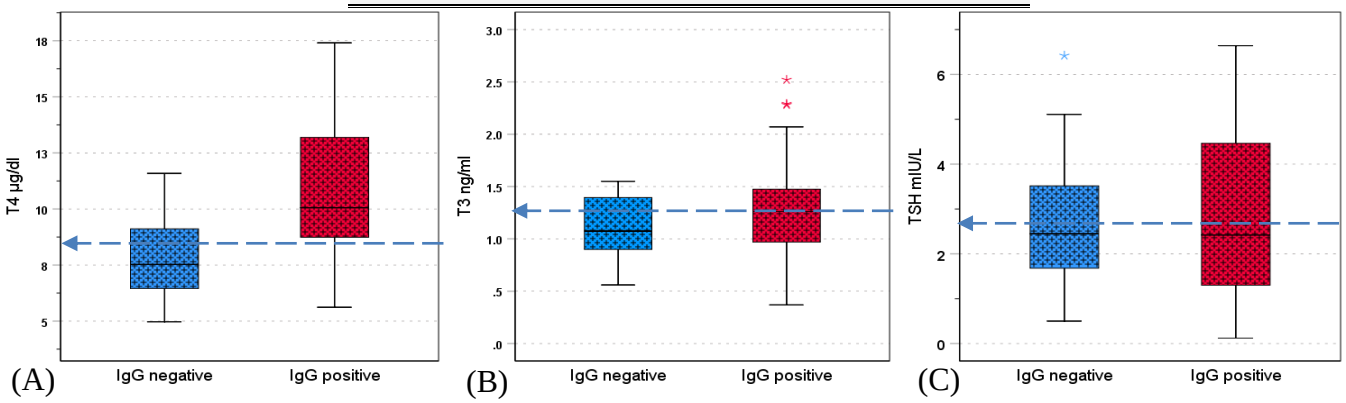

Figure 1 Box plots represent the serum levels of (A) T4, (B) T3, and (C) TSH in both IgG seropositive and IgG seronegative group. The blue dashed line represents the threshold value. The black line in the center of the box represents the mean value, while the asterisks represent the outliers.

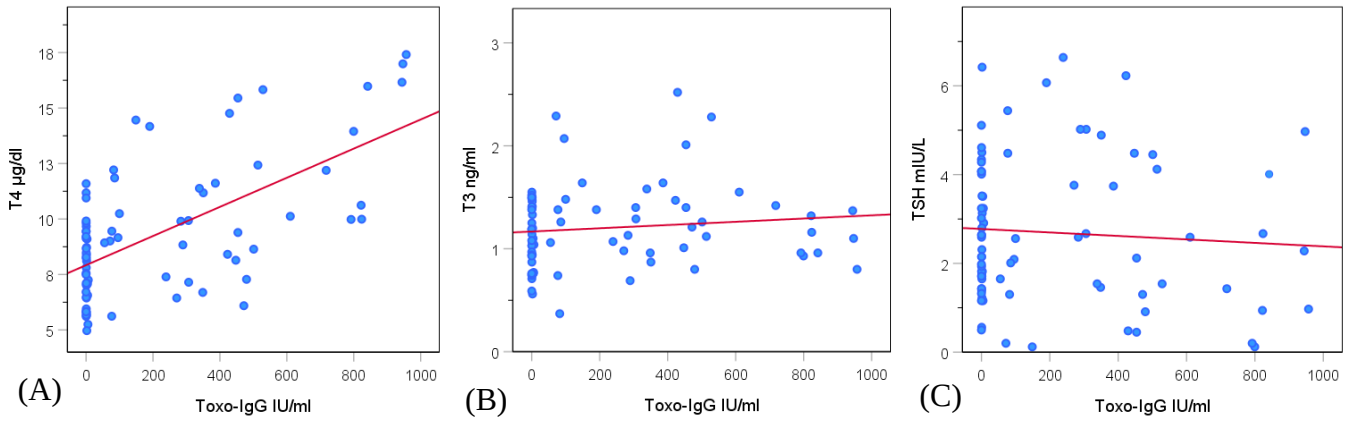

Figure 2 Scatter plots illustrate the association between (A) *Toxoplasma* IgG antibodies and T4 levels, (B) *Toxoplasma* IgG antibodies and T3 levels, and (C) *Toxoplasma* IgG antibodies and TSH levels. The red line represents the trend line for the association.

4. DISCUSSION

4.1 Association between chronic toxoplasmosis and Socio-demographic features

The main objective of this research was to examine whether or not there is a correlation between chronic toxoplasmosis and thyroid hormone levels in the sera of people diagnosed with schizophrenia. As far as we are concerned, this might be the first study of its kind in the Kurdistan region of Iraq to study the relationship between thyroid hormones, thyroid stimulating hormone, and chronic toxoplasmosis in individuals with schizophrenia.

Toxoplasma seroprevalence was high among schizophrenic patients, considering the small sample size of the study, 40/101 (39.6%) tested positive for toxoplasmosis. Our results are in line with those of Bakre et al. (2015) in Erbil, Omer (2022) in Sulaymaniyah, AL-Maamuri et al. (2014) in Baghdad. They reported *Toxoplasma* seropositivity rates of 32.3%, 62%, and 79.7%, respectively.

There are several factors that could have contributed to this high levels of *Toxoplasma* seroprevalence, such as, poor hygienic practice, drinking water source (tape water), and the presence of stray cats in and around the hospitals.
In the present study, *Toxoplasma* seropositivity had no association with gender. Our result is in line with those of Daryani et al. (2014) in Iran, and Yuksel et al. (2010) in Turkey. On the contrary, Al-Hassnawi and his coworkers in Iraq reported a higher toxoplasmosis rate in females (31%) than in male (23%) schizophrenic patients (Al-Hassnawi et al., 2015). Furthermore, in Mexico , a higher toxoplasmosis rate was observed only in male schizophrenic individuals than in healthy controls (p=0.008) (Alvarado-Esquivel et al., 2019). The lack of a statistically significant correlation between gender and toxoplasmosis in this study could be attributed to the skewed gender distribution of the study population (most participants were male), or it could be due to factors such as physical activities, cleanliness, and immunity of each individual.

We observed a statistically significant association between toxoplasmosis and patients aged between 50-60 years old. In agreement with our findings, Yuksel et al. (2010) reported a significantly higher toxoplasmosis rate in schizophrenic patients who were 51 - 65 years of age in comparison to the uninfected group. In addition, in a meta-analysis and a comprehensive study conducted in Iran, Daryani and his coworkers reported a significant linear trend of increasing *Toxoplasma* seropositivity with age ($p < 0.001$) (Daryani et al., 2014). Conversely, Omar et al. (2015) and Khademvatan et al. (2014) found a non-significant link between toxoplasmosis and age. We hypothesize that older people are more susceptible to infection than the young; they are more susceptible to one of the risk factors or transmission pathways because their immune system declines over time. In addition, Omar et al. (2015) and Bouscaren et al. (2018) agree with our hypothesis.

Data analysis showed non-significant association between Toxoplasmosis seropositivity and the ABO blood group. Our findings are in agreement with those of Rodrigues et al. (2011) and Esshili et al. (2016). In contrary, Neamah & Abdullah, (2021) discovered that *T. gondii* has a significant correlation with patients with B positive blood type. They hypothesized that blood type B has two chains of carbohydrates, which may play an essential part in the parasite's adherence to the mucosa layer of the gastrointestinal tract.

4.2 Association between thyroid function hormones chronic toxoplasmosis

In the present study, we found no significant link between chronic toxoplasmosis and TSH levels. In agreement with our results, Mendy et al. (2015) studied 4485 schizophrenic patients, and they observed normal TSH levels in *T. gondii* infected and healthy schizophrenic patients.

On the other hand, Shaker et al., (2019) reported higher levels of TSH in the sera of Iraqi depressed women who were infected with toxoplasmosis than in the sera of healthy controls. The authors suggested that this elevation in TSH level may be related to autoantibodies to the thyroid-stimulating hormone respecter antibodies (TSHR-Ab), that bind to TSH-receptors in the thyroid gland, and result in elevated TSH levels in the blood. This non-significant association between *Toxoplasma* and TSH levels in our study could be interpreted as follow; it might be due to the fact that all of the participant of this study used anti-psychotic medications, namely Risperidone and Olanzapine, and these medications have been proven to interfere with TSH production and inhibit the parasite replication (Fond et al., 2014; Vedal et al., 2018). Or, it can simply be due to the failure of *T. gondii* to reach the hypothalamus in the brain to induce any alteration in TSH levels.

Regarding the association between chronic toxoplasmosis and thyroid hormones (T4 and T3), a significant increase in both hormones was recorded in IgG seropositive group only; however, both hormones remained in the normal range. In consistence with our results, Shaker et al. (2019) in Iraq recorded a significant increase in both hormones in depressed women infected with toxoplasmosis (8.03 ± 0.36, 2.79 ± 0.14) than in healthy controls (5.22 ± 0.47, 2.25 ± 0.14); however, the levels of the two hormones stayed within the normal range.

On the contrary, Raissi et al. (2021) reported no significant difference in T4 or T3 levels between hypothyroid, hyperthyroid, and healthy control groups in regards to toxoplasmosis ($P>0.05$). Finally, we observed *Toxoplasma* IgG was positively correlated with T4 levels but not with T3 levels. On the other hand, Al-Kurdy and his coworkers, found no significant association between thyroid hormones and *Toxoplasma* seropositivity in non-pregnant Iraqi women (Al-

Kurdy et al., 2015). We suggest, the parasite might have directly or indirectly caused an elevation in thyroid hormone levels. Our results put further weight on the hypothesis that suggests *T. gondii* disrupts the thyroid hormone levels and cause behavioral alteration or mental illnesses.

5. CONCLUSION

We conclude that *Toxoplasma* seropositivity is high among schizophrenic patients and it increases with age. Additionally, *Toxoplasma* seropositivity had led to a significant increase in T4 and T3 levels in the serum of schizophrenic patients. Therefore, treatment and screening measures for toxoplasmosis should be prioritized for individuals with schizophrenia.

Ethical considerations

To conduct this study, we have got the ethical approval from Koya University's Ethical Committee, Sulaymaniyah's general directorate of health, as well as Erbil's general directorate of health.

Conflict of interest

The authors of this study declared no conflict of interest.

REFERENCES

Al-Hassnawi, A. T. S., Musawy, H. S. A., Al-Murshidy, K. A. H., & Eessa, A. S. A. (2015). Prevalence of Toxoplasma gondii Infection Among Schizophrenic Patient: Probable Linked Between Toxoplasmosis and Behavior Shifting. *International Journal of Public Health Research*, 3(5), 288–291.

Al-Issawi, T. A. M., & Aysir, S. M. (2020). Effects of Infection with Toxoplasma Gondii to the Levels of Thyroid Hormones. *European Journal of Molecular and Clinical Medicine*, 7(1). https://doi.org/10.31838/ejmcm.07.01.11

Al-Kurdy, M. J., AliBdairi, T. A., Jawad, T. I., & Amana, A. M. (2015). Serological Detection of Toxoplasma Gondii Antibodies and Its Effect on Thyroid Function in Non-Pregnant Women. *International Center for Science and Technology*, 10(1), 64–68. https://doi.org/10.12816/0013029

AL-Maamuri, S. D., AL-Shanawi, F. A., & Melconian, A. K. (2014). Seroprevalence of Toxoplasma gondii in Schizophrenic Patients in Iraq using ELISA test. *Iraqi Journal of Science*, 55(3), 1243–1248.

Alvarado-Esquivel, C., Ramos-Nevarez, A., Guido-Arreola, C. A., Cerrillo-Soto, S. M., Pérez-Álamos, A. R., Estrada-Martínez, S., Gutierrez-Martinez, V. D., Sifuentes-Alvarez, A., Ramírez-Valles, E. G., & Contreras-Cisneros, E. (2019). Association between Toxoplasma gondii infection and thyroid dysfunction: A case-control seroprevalence study. *BMC Infectious Diseases*, 19(1), 826. https://doi.org/10.1186/s12879-019-4450-0

Bakre, H., Hussain, S., & Ali, S. (2015). Toxoplasma gondii infection in patients with schizophrenia. *Zanco Journal of Medical Sciences*, *19*(1), 874–879. https://doi.org/10.15218/zjms.2015.0006

Ben-Harari, R. R. (2019). Tick transmission of toxoplasmosis. *Expert Review of Anti-Infective Therapy*, 17(11), 911–917. https://doi.org/10.1080/14787210.2019.1682550

Bouscaren, N., Pilleron, S., Mbelesso, P., Ndamba-Bandzouzi, B., Dartigues, J.-F., Clément, J.-P., Preux, P.-M., Dardé, M.-L., Guerchet, M., & the EPIDEMCA Group. (2018). Prevalence of toxoplasmosis and its association with dementia in older adults in Central Africa: A result from the EPIDEMCA programme. *Tropical Medicine & International Health*, 23(12),1304–1313. https://doi.org/10.1111/tmi.13151

Cheslack-Postava, K., & Brown, A. S. (2022). Prenatal infection and schizophrenia: A decade of further progress. *Schizophrenia Research*, 247, 7–15. https://doi.org/10.1016/j.schres.2021.05.014

Daryani, A., Sarvi, S., Aarabi, M., Mizani, A., Ahmadpour, E., Shokri, A., Rahimi, M.-T., & Sharif, M. (2014). Seroprevalence of Toxoplasma gondii in the Iranian general population: A systematic review and meta-analysis. *Acta Tropica*, 137, 185–194. https://doi.org/10.1016/j.actatropica.2014.05.015

Desmettre, T. (2020). Toxoplasmosis and behavioral changes. *Journal Français d'ophtalmologie*, 43, 89–93. https://doi.org/10.1016/j.jfo.2020.01.001

Egorov, A. I., Converse, R. R., Griffin, S. M., Styles, J. N., Sams, E., Hudgens, E., & Wade, T. J. (2021). Chronic Toxoplasma gondii infections are associated with elevated biomarkers of inflammation and vascular injury. *BMC Infectious Diseases*, 21(1), 188. https://doi.org/10.1186/s12879-021-05882-6

Elsheikha, H. M., Büsselberg, D., & Zhu, X.-Q. (2016). The known and missing links between Toxoplasma gondii and schizophrenia. *Metabolic Brain Disease*, 31(4), 749–759. https://doi.org/10.1007/s11011-016-9822-1

Esshili, A., Thabet, S., Jemli, A., Trifa, F., Mechri, A., Zaafrane, F., Gaha, L., Juckel, G., Babba, H., & Bel Hadj Jrad, B. (2016). Toxoplasma gondii infection in schizophrenia and associated clinical features. *Psychiatry Research*, 245, 327–332. https://doi.org/10.1016/j.psychres.2016.08.056

Fond, G., Macgregor, A., Tamouza, R., Hamdani, N., Meary, A., Leboyer, M., & Dubremetz, J.-F. (2014). Comparative analysis of anti-toxoplasmic activity of antipsychotic drugs and valproate. *European Archives of Psychiatry and Clinical Neuroscience*, 264(2), 179–183. https://doi.org/10.1007/s00406-013-0413-4

Johnson, S. K., & Johnson, P. T. J. (2021). Toxoplasmosis: Recent Advances in Understanding the Link Between Infection and Host Behavior. *Annual Review of Animal Biosciences*, 9(1), 249–264. https://doi.org/10.1146/annurev-animal-081720-111125

Kamal, A. M., Kamal, A. M., Abd El-Fatah, A. S., Rizk, M. M., & Hassan, E. E. (2022). Chronic Toxoplasmosis is Associated with Depression and Suicidal Behavior. *Archives of Suicide Research*,

26(2), 819–830. https://doi.org/10.1080/13811118.2020.1838368

Khademvatan, S., Saki, J., Khajeddin, N., Izadi-Mazidi, S., Beladi, R., Shafiee, B., & Salehi, Z. (2014). Toxoplasma gondii Exposure and the Risk of Schizophrenia. *Jundishapur Journal of Microbiology*, 7(9). https://doi.org/10.5812/jjm.12776

Mageed, S. N. (2017). Seroprevalence of Toxoplasma gondii antibodies among farmers in Erbil Government by using enzyme linked immunosorbent assay (ELISA). *Journal Of Raparin University*, 4(10), 5–16.

Mendy, A., Vieira, E. R., Albatineh, A. N., & Gasana, J. (2015). Immediate rather than delayed memory impairment in older adults with chronic toxoplasmosis. *Brain, Behavior, and Immunity*, 45, 36–40. https://doi.org/10.1016/j.bbi.2014.12.006

Neamah, S. R., & Abdullah, Y. J. (2021). The Relationship between ABO and Rhesus Blood Groups with Toxoplasmosis in Thi-Qar Province, Iraq. *Journal of Chemical Health Risks*, 11(4), 367–373. https://doi.org/10.22034/jchr.2021.1916672.1227

Omar, A., Bakar, O. C., Adam, N. F., Osman, H., Osman, A., Suleiman, A. H., Manaf, M. R. A., & Selamat, M. I. (2015). Seropositivity and Serointensity of <I>Toxoplasma gondii</I> Antibodies and DNA among Patients with Schizophrenia. *The Korean Journal of Parasitology*, 53(1), 29–34. https://doi.org/10.3347/kjp.2015.53.1.29

Omer, L. (2022). Seroprevalence and correlation between Toxoplasmosis and Schizophrenic patients in Sulaimania city, Iraq. *Diyala Journal for Pure Science*, 18(2), 17–27. https://doi.org/10.24237/djps.1802.574A

raissi, vahid, Ibrahim, A., Bayat, F., akhlaghi, elham, Getso, M., raiesi, O., Abdollahi, A., Alizadeh, G., Akbari, sakineh, Navi, Z., & etemadi, soudabeh. (2021). Association between T3, T4, and TSH hormones proportion and Toxoplasma gondii anti-IgG seroprevalence in patients suffering from clinical and drug-controlled thyroid dysfunctions in southeastern Iran, 2019. *Turkish Bulletin of Hygiene and Experimental Biology*, 78(3), 299–306. https://doi.org/10.5505/TurkHijyen.2021.95825

Razvi, S., Bhana, S., & Mrabeti, S. (2019). Challenges in Interpreting Thyroid Stimulating Hormone Results in the Diagnosis of Thyroid Dysfunction. *Journal of Thyroid Research*, 20(19), 4106816. https://doi.org/10.1155/2019/4106816

Rodrigues, A. C. F., Uezato, S., Vono, M. B., Pandossio, T., Spegiorin, L., Oliani, A. H., Vaz Oliani, D. C. M., Brandão de Mattos, C. C., & de Mattos, L. C. (2011). Non-association between anti-Toxoplasma gondii antibodies and ABO blood group system. *Journal of Venomous Animals and Toxins Including Tropical Diseases*, 17(2), 184–189. https://doi.org/10.1590/S1678-91992011000200009

Schlüter, D., & Barragan, A. (2019). Advances and Challenges in Understanding Cerebral Toxoplasmosis. *Frontiers in Immunology*, 10, 13. https://doi.org/10.3389/fimmu.2019.00242

Shaker, M. M., Hamied A. Rahman, S. A., & AL-Abassi, H. (2019). ASSESSMENT LEVEL OF TSH, T4, T3 AND TESTOSTERONE IN IRAQI DEPRESSED WOMEN WITH CHRONIC TOXOPLASMOSIS INFECTION. *Biochem. Cell. Arch*, 19, 2721–2724. https://doi.org/10.35124/bca.2019.19.S1.2721

Vedal, T. S. J., Steen, N. E., Birkeland, K. I., Dieset, I., Reponen, E. J., Laskemoen, J. F., Rødevand, L., Melle, I., Andreassen, O. A., Molden, E., & Jönsson, E. G. (2018). Free thyroxine and thyroid-stimulating hormone in severe mental disorders: A naturalistic study with focus on antipsychotic medication. *Journal of Psychiatric Research*, 106, 74–81. https://doi.org/10.1016/j.jpsychires.2018.09.014

Yuksel, P., Alpay, N., Babur, C., Bayar, R., Saribas, S., Karakose, A. R., Aksoy, C., Aslan, M., Mehmetali, S., Kilic, S., Balcioglu, I., Hamanca, O., Dirican, A., Kucukbasmaci, O., Oner, A., Torun, M. M., & Kocazeybek, B. (2010). The role of chronic toxoplasmosis in the aetiopathogenesis of schizophrenia—The risk factor or an indication of a contact with cat? *Folia Parasitologica*, *57*(2), 121–128. https://doi.org/10.14411/fp.2010.015