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# Risk Factors and their Contributions to the Development of *Toxoplasma gondii* among Pregnant Women Attending ANC Services in Northwest Ethiopia: Structural Equation Modelling

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## Abstract

**Background:** Toxoplasmosis, caused by *Toxoplasma gondii*, is a significant health concern for pregnant women in Ethiopia due to its high prevalence and complex risk factors. Limited understanding of these factors hinders effective prevention efforts, making targeted interventions necessary. **Objectives:** This study used Structural Equation Modeling (SEM) to analyze socio-environmental risk factors associated with *T. gondii* infection in pregnant women in Northwest Ethiopia, aiming to inform preventive strategies. **Methods:** A cross-sectional study of 554 pregnant women attending antenatal care clinics used a structured questionnaire to assess latent constructs. SEM analysis was performed using AMOS version 18, with model fit evaluated through indices like $\chi^2$, RMSEA, CFI, TLI, IFI, and NFI. **Findings:** SEM analysis indicated acceptable model fit ($\chi^2$ = 131.493, df = 7, RMSEA = 0.176, CFI = 0.866, TLI = 0.139, IFI = 0.871, NFI = 0.865). Education and residence were positively associated with exposure to cat feces ($p < 0.05$), residence correlated with dust exposure, and education showed an inverse link to dog contact. Regression analysis confirmed significant relationships between residence, dust exposure, and water-related factors ($p < 0.05$). **Novelty:** This study is the first in Ethiopia to use SEM to explore indirect and mediating effects of environmental and behavioral risk factors for *T. gondii* infection in pregnant women. Findings provide critical insights for targeted educational and intervention programs to reduce maternal exposure to toxoplasmosis.

**Keywords:** *Toxoplasma gondii*; Risk factors; Structural equation model; Pregnant women; Ethiopia

## 1 Introduction

*Toxoplasma gondii* causes toxoplasmosis[1], a prevalent zoonotic disease affecting warm-blooded vertebrates, including humans and various animals[2],[3]. With a global impact on one-third of the population[4], *T. gondii* has a complex life cycle, undergoing sexual reproduction in cats and asexual replication in intermediate hosts[3],[5]. Infection occurs in two stages: acute toxoplasmosis, often asymptomatic but sometimes presenting flu-like symptoms[6],[7], and chronic infection, which poses serious risks, particularly to pregnant women and fetuses[8]. Infection during pregnancy can result in depression and is associated with psychiatric problems and adverse pregnancy outcomes, including miscarriage, fetal death, and delayed motor development. In pregnant women, infection is associated with anxiety, depression, and illnesses related to schizophrenia[9]. Congenital infection can lead to severe complications, including neurological damage, hydrocephaly, and fetal death[10],[11]. Environmental and dietary factors, including hygiene and undercooked meat consumption, influence transmission. Climate conditions can play a vital role in oocyst survival[12],[13]. Seroprevalence varies geographically, with cat exposure and meat consumption being key risk factors[14],[15]. This is because pregnant women who were not aware of the disease had a greater likelihood of becoming infected. Importantly, pregnant women are considered a high-risk group for toxoplasmosis[16]. Preventive strategies, such as improved hygiene, food safety, and public awareness, can mitigate risks[5],[17]. Structural analysis using SEM examines relationships among risk factors, confirming model validity through statistical indices[18]. This process examines how independent constructs influence dependent constructs or, in more complex models, how dependent variables influence other dependent variables by path analysis (the structural model) and measurement model analysis to ensure that the measures are valid for composite variables to form[19]. No studies on the modeling of *T. gondii* in pregnant women have been conducted in Ethiopia. This study is the first in Ethiopia to apply SEM to *T. gondii* infection in pregnant women, providing essential data for control and prevention strategies.

## 2 Methodology

### 2.1 Study area and design

A cross-sectional study was conducted in Northwest Ethiopia to analyze socio-environmental risk factors for *Toxoplasma gondii* infection among pregnant women attending antenatal care (ANC), aiming to inform control measures.

### 2.2 Study participants

The study population consisted of pregnant women attending ANC clinics in Northwest Ethiopia, including both seropositive and seronegative individuals.

### 2.3 Sample size determination and sampling technique

A sample size of 554 was selected based on Structural Equation Modeling (SEM) requirements, ensuring sufficient statistical power for analysis[20]. Considerations included effect size, required p-value, and the number of variables.

### 2.4 Sampling technique

A pragmatic sampling approach was used to select pregnant women from Northwest Gondar Public Hospitals, considering budget, accessibility, and resource constraints. The sample size and selection ensured a feasible and effective study design

### 2.5 Model Specification

Six SEM models were developed to assess risk factors and control measures for *T. gondii*. Variables such as education, job, residence, hygiene, and animal exposure were examined, using correlation and path modeling to measure their relationships.

### 2.6 Theoretical Framework

Structural Equation Modelling, a powerful multivariate statistical technique, was used to analyze causal relationships[21]. Path models explored direct and mediated effects, identifying endogenous and exogenous variables influencing toxoplasmosis risk. Model fit was evaluated using CMIN/df, CFI, and RMSEA, ensuring validity and reliability.

## 2.7 Data collection and processing

**Questionnaire survey:**

A structured questionnaire was designed to assess risk factors for toxoplasmosis. Three rating questions evaluated prevalence, exposure frequency, and control measures, using a yes/no scale to determine associations. This helped establish the relevance of risk management strategies for pregnant women.

## 2.8 Data management and analysis

Data were checked for completeness and processed using SPSS version 21. A logistic regression model examined associations between variables, while AMOS version 18 performed confirmatory factor analysis, reliability testing, Pearson correlations, and path analysis. Factor analysis (FA) was used for independent evaluation, with Cronbach's alpha measuring reliability ($p < 0.05$). Preventive measures were implemented to reduce risk factors for toxoplasmosis control in Northwest Ethiopia. Eight correlation coefficients were identified among risk factors: cat and dog presence, water type, farming dust exposure, education, job, residence, and hand washing habits. SEM examined relationships between these variables, confirming their interconnections and guiding intervention strategies.

## 2.9 Ethical considerations

The study was undertaken after receiving ethical approval from the research and ethics committee of the Institutional Review Board (IRB) at the University of Gondar. Furthermore, the researchers obtained a letter of support from the APHI and Northwest Ethiopia health offices. Before starting the actual data collection, permission was obtained from the offices of the hospital directors. Additionally, participants were asked to provide informed written consent after being informed about the study's purpose, benefits, and potential risks. This ensured that participation was voluntary.

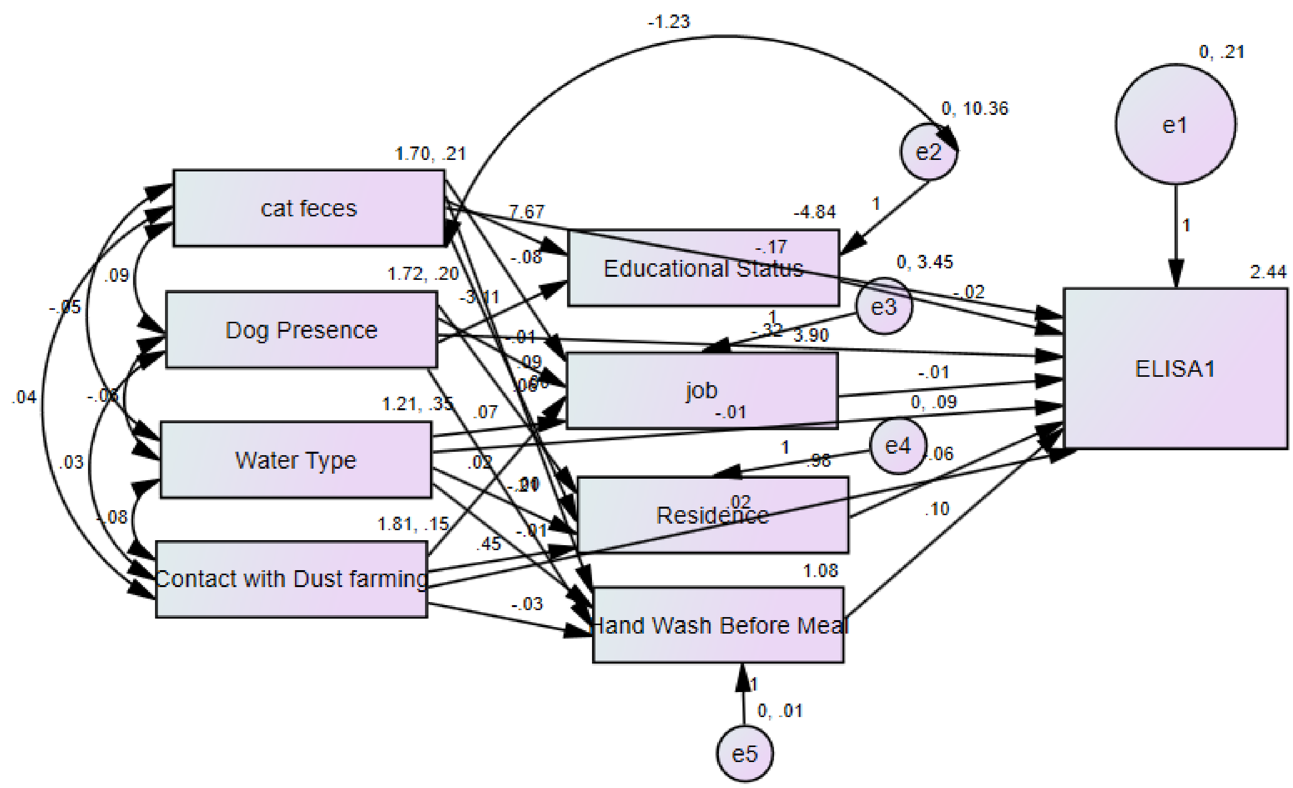


**Fig 1.** The constructs of the SEM in the presented factor analysis

# 3 Results and Discussion

## 3.1 Model of associations between risk factors and *Toxoplasma gondii* development Variable Summary

A total of 554 study participants were included, with a questionnaire designed based on the theoretical framework. The model incorporated direct and indirect relationships among variables, with education, job, residence, ELISA 1, and hand washing as endogenous variables, and cat feces, dog presence, water type, and dust exposure as exogenous variables. The study assessed 14 variables, including 9 observed and 5 unobserved variables, with 54 sample moments, 47 parameters, and 5 degrees of freedom.

## 3.2 Normality Test

The Skewness and kurtosis values were used to test data distribution and outliers. A variable was considered normally distributed if its kurtosis value was less than10 and less than 3 for skewness [22]. The SEM results confirmed normality, with components tested for reliability and consistency before analysis. Positive kurtosis indicated high peaks with few outliers (leptokurtic), while negative kurtosis represented flat distributions with many outliers (mesokurtic). Extreme kurtosis values exceeding 10 were considered problematic [21]. The study confirmed positive skewness across variables (Table 1).

**Table 1.** Assessment of normality

| Variable | min | max | skew | c.r. | kurtosis | c.r. |
|---|---|---|---|---|---|---|
| Education status | 1 | 4 | -.526 | 2.76 | -1.172 | 2.95 |
| Job | 1 | 6 | -.035 | 3.71 | -1.645 | 4.02 |
| Residence | 1 | 2 | -1.419 | 1.75 | 0.014 | 1.82 |
| Cat feces | 1 | 2 | -.868 | 1.66 | -1.252 | 1.74 |
| Dog present | 1 | 2 | -.974 | 1.68 | -1.055 | 1.76 |
| Water type | 1 | 2 | 2.725 | 1.16 | 6.191 | 1.26 |
| Contact with dust | 1 | 2 | -1.619 | 1.78 | 0.623 | 1.85 |
| ELISA 1 | 1 | 2 | -.174 | 1.50 | 1.58 | 1.58 |

## 3.3 Parameter Estimation, Model Evaluation, and Model Comparison

**Maximum likelihood estimates:**

Regression weight estimates show that education increases by 4, leading to a 7 unit increase in CatF and 3 unit increases in education, while doge decreases by 3, dust increases by 12, and residence rises by 0.4. The reduction in Doge is estimated at 0.005, with a critical ratio surpassing 12.389 ($p < 0.001$), indicating statistical significance. Dust exposure and water types were significantly associated with residence, while job correlated with CatF and doge. Education positively influenced CatF, but negatively affected doge, whereas residence showed a positive association with dust and a negative link to water.

**Covariance and Correlations:**

The covariance estimates between CatF and doge were 0.094, while doge and water showed -0.056, water and dust measured -0.080, and CatF and water had -0.055. The relationship between e2 and CatF was -1.229. Positive correlations indicate an increase in one variable leads to an increase in another, while negative correlations suggest inverse effects. Variances for CatF, doge, water, and dust ranged from 0.151 to 0.351, reflecting variable dispersion within the dataset. Correlations, standardized between -1 and 1, showed values like 0.455, -0.210, -0.347, and 0.196, with a 0.455 correlation between CatF and doge, indicating a strong positive linear relationship.

**Matrix factor score weights estimates:**

Matrix factor score weights represent the relationships between latent factors (Dust, Water, Doge, CatF) and observed variables (HandW, Residence, Job, Education). Weight estimates indicate strength and direction of these relationships, with HandW linked to Dust at -0.029, Residence to Dust at 0.449, and Education to Doge at -3.111. Direct effects measure impacts of latent factors on observed variables (dust on education = 7.675). Indirect effects occur through intermediate variables, such as dust affecting education through ELISA1 at -0.018. Total effects combine direct and indirect impacts, yielding dust on education at 7.657, confirming positive relationships between variables.

**Model fit summary:**

Risk factors analyzed in SEM (education, job, residence, ELISA 1, hygiene, cat feces, dog presence, water type, dust exposure) showed reasonable model fit (Table 2). Fit indices (CFI = 0.866, TLI = 0.139, IFI = 0.871, NFI = 0.865) indicate adequate fit. Degrees of freedom (DM = 7, SM = 1.000) show model imperfections but better performance than the Independence Model (IM = 135.205). Fit indices help evaluate overall model alignment with data, ensuring robust analysis [19].

**Table 2.** SEM of the model fit summary for all variables

| Model | DF | P | CMIN/DF | CFI | TIL | IF | NFI | RMSEA |
|---|---|---|---|---|---|---|---|---|
| DM | 7 | .000 | 18.785 | .866 | .139 | .871 | .865 | .176 |
| SM | 0 | | .000 | 1.000 | | 1.000 | 1.000 | |
| I'M | 45 | .000 | 135.205 | .000 | .000 | .000 | .000 | .189 |

## 4 Discussion

Toxoplasmosis, caused by *Toxoplasma gondii,* is a significant public health concern that particularly affects the immune system of pregnant women. People with compromised immune systems are more likely to develop life-threatening complications. Individuals with compromised immune systems are at increased risk of developing life-threatening complications. Pregnant women can transmit the parasite to their fetuses, making it critical to understand the transmission pathways and risk factors. Toxoplasmosis primarily occurs through contact with cat feces or the ingestion of contaminated food and affects nearly one-third of the global population. In this study, AMOS software was used to generate coefficient estimates and significance tests, with critical values of 1.96 indicating statistical significance ($p < 0.05$). Mardia's coefficient, often statistically significant in large SEM-based samples, confirmed normal distribution, as indicated by kurtosis values under 3.00 [23]. Historically, model fit criteria included CFI > 0.90 [19] and RMSEA < 0.10, though recent studies propose RMSEA < 0.06 as a stricter threshold [24]. Results confirmed reasonable fit ($\chi^2$ = 131.493, RMSEA = 0.176, CFI = 0.866, TLI = 0.139). Cronbach's alpha was calculated to assess parameter reliability [25]. The correlation analysis showed relationships among risk factors, including CatF and Doge (0.094), Doge and water (-0.056), water and dust (-0.080), CatF and water (-0.055), and e2 and CatF (-1.229). Negative correlations indicated inverse relationships, while positive correlations suggested linked risk factors. Overall, the model provided a strong foundation for toxoplasmosis management, offering baseline data for prevention strategies and advancing public health interventions to reduce *T. gondii* infection rates among pregnant women.

## 5 Conclusion

The model demonstrates a reasonable fit, with strong CFI and IFI values, though TLI and NFI require improvement. It underscores the importance of addressing key risk factors, including ingestion of oocyst from soil, water, or cat feces, and tissue cysts in undercooked food. Effective mitigation strategies involve awareness campaigns, hygiene promotion, proper food preparation, and safe water consumption. Additionally, policy advocacy for improved sanitation and cat feces disposal is crucial. These targeted interventions can significantly reduce *T. gondii* infection risks among pregnant women.

### 5.1 Acknowledgements

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### 5.2 Availability of data and materials

For the sake of maintaining patient confidentiality, the raw data will not be shared. Data supporting this research article are available from the corresponding author or first author upon reasonable request.

### 5.3 Abbreviations

AGFI: Adjusted Goodness of fit Index; ANC: Anti-Natal Care; AMOS: Analysis of Moment Structures; CFA: Confirmatory Factor Analysis; CMIN: chi-square; CT: Congenital Toxoplasmosis; DF: Degree of Freedom; GFI: Goodness of Fit Index; CFI: Comparative Fix Index; ELISA: Enzyme-Linked Immunosorbent Assay; FAT: Immuno Fluorescence Assay Test; IFI: Incremental fit Index; IgE: Immunoglobulin A; IgE: Immunoglobulin G; IgM: Immunoglobulin M; LAT: Latex Agglutination

Test; NFI: Normed fit Index; RDT: Rapid Diagnostic Test; RMSEA: Root Mean Square Error of Approximation; SEM: Structural Equation Modeling; TLI: Tucker-Lewis Index.

### 5.4 Funding

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### 5.5 Contributions of Authors

EW wrote the proposal in addition to contributing to data curation, data collection (investigation), data analysis, validation, resources, software, and manuscript drafting. NB, MB, MM, DFT, and MD were involved in the conceptualization proposal's design, data gathering, methodology, supervision, and analysis. EW took part in the data preparation and analysis. Each writer reviewed and edited the finished work and also gave their approval.

### 5.6 Conflict of interests

The authors declare that they have no conflicting interests

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