

# Objective and subjective knowledge of toxoplasmosis among women of childbearing age in the Apulia region of Southern Italy

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## ABSTRACT

Toxoplasmosis, caused by *Toxoplasma gondii*, is a widespread zoonotic disease with potentially serious consequences to the fetus if acquired during pregnancy. This study aimed to evaluate objective and subjective knowledge of toxoplasmosis and its modes of transmission in women of reproductive age living in an Italian southeastern region (i.e., Apulia region) and to identify homogeneous segments of women based on their level of knowledge of toxoplasmosis. Data were collected in a web-based survey sample of 568 women, and analyzed via a two-step cluster analysis.

The results showed that 69.4 % of respondents claimed awareness of toxoplasmosis. Specifically, knowledge about infection risk factors, such as consumption of undercooked meat and raw unwashed fruits and vegetables (95.8 %) and pregnancy-related risks (94.5 %), was high. However, only 52.8 % knew that *T. gondii* is a parasitic protozoan, and 40.5 % were aware of soil as a transmission route. Cluster analysis identified three segments: women with knowledge (40.2 %), partial knowledge (39.6 %), and no knowledge (20.2 %). Women with higher education and employed showed greater awareness, whereas students and individuals with lower education levels were overrepresented among those with limited knowledge.

These findings highlight a knowledge gap in certain transmission aspects and underscore the importance of targeted health education, particularly regarding the role of soil and the nature of *T. gondii* as a parasite.

Implementing effective, accessible educational programs is crucial for reducing the burden of *T. gondii* infection, especially in regions with limited health literacy. Establishing regional reference centers could enhance monitoring, prevention, and support for at-risk populations.

## 1. Introduction

Toxoplasmosis is one of the most widespread zoonoses in the world. The infection is caused by *Toxoplasma gondii* (Apicomplexa: Sarcocystidae), an intracellular obligate protist with three infectious stages: the oocyst, highly resistant form excreted into the environment in the feces of felids, which are the definitive hosts; tachyzoite, the rapidly proliferating stage; and bradyzoite, quiescent form found inside tissue cysts located mostly in the central nervous system and muscles. Humans and animals (including cats) are the

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intermediate hosts and harbor the last two stages (Webster and Dubey, 2010).

In immunocompetent individuals, the infection is generally mild and self-limiting, inducing an adaptive immune response and lifelong immunity. However, there can be a reactivation in immunocompromised individuals (e.g., patients with AIDS, cancer patients, transplant recipients) (Montoya and Liesenfeld, 2004). If primary infection occurs during pregnancy, *T. gondii* may cross the placenta and infect the fetus. The risk of transmission increases with gestational age, while disease severity decreases as gestational age increases. Infection acquired at an early stage of pregnancy may be associated with severe congenital toxoplasmosis (CT) ranging from spontaneous abortion or stillbirth to severe mostly neurological manifestations including the classic triad of CT characterized by hydrocephalus, retinochoroiditis and intracranial calcifications. If fetal infection occurs later in pregnancy, the majority of newborns have a subclinical infection, but these infants are at risk of delayed complications involving mostly ocular or neurological disorders (Tenter et al., 2000; Montoya and Liesenfeld, 2004).

Humans, including pregnant women, can be infected by i) eating raw or undercooked meat containing tissue cysts; ii) eating unwashed fruit or raw vegetables or drinking unfiltered water, or iii) gardening or cleaning cat litter boxes contaminated with oocysts; iv) blood transfusion or organ transplantation, by direct transmission of tachyzoites from an acutely infected donor to a seronegative recipient; v) quite rarely, drinking milk containing tachyzoites.

It is estimated that one third of the world's population is infected with *T. gondii* (Montoya and Liesenfeld, 2004), with seroprevalence reaching peaks of up to 80 % in developing countries e.g., in Africa and Asia (Molan et al., 2019), and a clearly demonstrated decline over the past five decades in industrialized countries, in the US and Europe (Pappas et al., 2009; Milne et al., 2023).

In Italy, a recent multicentric study on TORCH complex pathogens in women of childbearing age from the north, center, south, and islands, involved 111,580 subjects tested for toxoplasmosis (Pavia et al., 2024). The results showed that the infection was more prevalent in immigrant than in native Italian women, and most prevalent in the 36–45 age group compared to other age groups.

Data on CT, only available for the Campania region, showed that among the 1556 mother-child pairs who completed the follow-up, 92 cases were identified, indicating a transmission rate of 5.9 %. The overall prevalence of primary *T. gondii* infection during pregnancy was 2.46 per 1000 live births, while the prevalence of definite CT was 1.38 per 10,000 live births (Stagni et al., 2009).

Coupled with the absence of a vaccine, these data indicate that it is imperative that the female population, particularly of childbearing age, is informed about the general aspects about *T. gondii* infection. Additionally, since the infection is usually asymptomatic, educating women of childbearing age on how to prevent the infection is critical to reducing the infection rate (Martini et al., 2020). Therefore, it is crucial to evaluate the knowledge of Italian women about toxoplasmosis, modes of transmission, and prevention.

The philosopher Karl Popper discussed a traditional theory of knowledge known as the “bucket theory of the mind”, making a clear distinction between subjective and objective knowledge. Subjective knowledge refers to individuals' perceptions of their own understanding, while objective knowledge pertains to the accurate information individuals possess (Popper, 1972; Neill, 1982). Popper's Theory of Knowledge has been widely applied in various fields, including clinical studies (Stenback, 1964; Hou, 2004) and consumer research (Carlson et al., 2009; Pieniak et al., 2010). Although there have been studies examining individuals' awareness of the risks associated with toxoplasmosis (Andiappan et al., 2014; Eroglu and Asgin, 2021), no study has specifically analyzed the relationship between subjective and objective knowledge of toxoplasmosis.

Thus, the present study aims to investigate the knowledge of toxoplasmosis and its modes of transmission in a convenience sample of women of reproductive age living in an Italian southeastern region (i.e., Apulia region) by distinguishing between objective and subjective knowledge, and to identify homogeneous segments of women based on their level of knowledge of toxoplasmosis.

## 2. Materials and methods

### 2.1. Data collection and description

A web-based survey was administered between February and July 2023, seeking to collect responses from women of childbearing age (18–50 years of age), residing in the Apulia region, southern Italy. Data were managed according to the “Italian Personal Data Protection Code” (Legislative Decree No. 196/2003, subsequently updated by Legislative Decree No. 101/2018, in compliance with GDPR, EU Regulation No. 679/2016). Thus, all subjects who decided to participate in the study gave their informed consent, and all data were collected anonymously.

### 2.2. Questionnaire

The questionnaire, created on the Google Forms platform, included 18 closed multiple-choice questions divided into four sections (Supplementary data), described as follows.

The first section of the questionnaire contained three dichotomous questions (Yes/No), used as exclusion/inclusion criteria for the study, as follows: “Are you between 18 and 50 years old?”, “Are you female?”, “Do you reside in the Apulia region?”

The second section of the survey was dedicated to eliciting the respondents' level of knowledge about toxoplasmosis. A dichotomous question (Yes/No) was used to measure the self-reported knowledge of toxoplasmosis, also known as subjective knowledge, as follows: “Do you have knowledge of toxoplasmosis?”. Furthermore, a list of six multiple-choice questions was given to the participants to assess their objective knowledge of toxoplasmosis. One was on the etiology of toxoplasmosis, as follows: “What is toxoplasmosis caused by?”; six possible answers were given, where “protozoan parasite” was the correct one. The next three were multiple-choice questions (Yes/No/I don't know), with correct “Yes” answers, related to the risk factors of toxoplasmosis, as follows: “Can toxoplasmosis be contracted from consuming raw or undercooked food?”, “Can toxoplasmosis be transmitted from animals (e.g., cats) to humans?”, and “Can

toxoplasmosis be acquired via contact with soil, e.g., gardening?”. Finally, two questions assessed the objective knowledge of toxoplasmosis in relation to pregnancy: “Is it harmful to acquire toxoplasmosis during pregnancy?” and “What test is performed for toxoplasmosis in pregnant women?”. For the above questions the correct answers were “Yes” and “Blood test”, respectively.

The third section of the questionnaire included questions aimed at exploring participants’ experience with toxoplasmosis, either through indirect experience (i.e., friends and/or relatives who had toxoplasmosis) or direct experience (i.e., having been tested for toxoplasmosis). Additionally, this section aimed to assess the perceived importance of health education programs for this infection. The questions included were: “Do you have friends and/or relatives who had toxoplasmosis?”, “Have you ever been tested for toxoplasmosis?”, and “Do you think it is appropriate to implement health education programs?”

The fourth and last section of the survey examined sociodemographic characteristics, specifically education, occupation, family monthly income, province and area of residence.

### 2.3. Data analysis

After conducting an explorative analysis of the characteristics of the sample, a two-step cluster analysis was performed to identify homogeneous groups of women of childbearing age according to their level of subjective and objective knowledge about toxoplasmosis. Cluster analysis is a statistical procedure that aims to classify an initial set of  $n$  observations into  $k$  groups (Duncan et al., 2015). The discriminant variables used to identify homogeneous groups were those measuring the objective and subjective knowledge of toxoplasmosis, as shown in Table 1. The number of clusters or segments was determined using Bayesian information criterion (BIC) and likelihood (LL) as a measure of distance. The goodness-of-fit of the model was measured by the silhouette measure of cohesion and separation, i.e., based on the average distances between clusters that can vary between  $-1$  and  $+1$  (Kitunen et al., 2022). To understand how much each individual variable contributed to the variation within each cluster, the predictor importance level was measured. The segments of the participating women were further profiled using sociodemographic characteristics (i.e., education, occupation, and income) and other illustrative variables, such as indirect experience, direct experience, and the importance of implementing health education programs. Segments were profiled using cross-tabulations, and Chi-square tests were performed to examine differences between segments (Kitunen et al., 2022; Ravn, 2023). All analyses were performed using IBM SPSS Statistics version 20 IBM Corp, Armonk, N. Y., USA.

## 3. Results

### 3.1. Exploratory data analysis

The total number of respondents to the questionnaire was 695, of which a total of 568 fulfilled the inclusion criteria, i.e., women aged between 18 and 50 years and living in one of the six provinces of the Apulia region (minimum-maximum number: 88–119 per province). The sociodemographic characteristics of this series of 568 women are presented in Table 2. Of these, 69.4 % stated that they were aware of toxoplasmosis. In terms of objective knowledge, 95.8 % and 94.5 % knew that the infection may be contracted by consuming raw or undercooked food, and during pregnancy, respectively; 81.7 % were aware that toxoplasmosis can be transmitted from animals to humans; and 75.5 % were familiar with the type of test used to detect the infection. Finally, 52.8 % of the respondents knew that the etiological agent of toxoplasmosis was a protozoan parasite, and 40.5 % that it can also be acquired via contact with soil (e.g., gardening). Table 3 displays the findings on the objective knowledge of Apulian women of reproductive age.

### 3.2. Cluster analysis

The results of the quantitative analysis for the segmentation of Apulian women of childbearing age according to their level of general knowledge about toxoplasmosis showed the existence of three segments or clusters, composed of 40.2 % (cluster 1), 39.6 % (cluster 2) and 20.2 % (cluster 3) of the respondents in the population.

The goodness-of-fit of the model, as determined by the silhouette measure of cohesion and separation, was equal to 0.3, indicating acceptable quality.

**Table 1**

Segmentation variables and their related questions included in the questionnaire. The key variables used to assess the respondents’ knowledge of toxoplasmosis, covering its causes, transmission routes (food, animals, soil contact), whether it can be acquired during pregnancy, and the diagnostic test performed in pregnant women are presented. The questions were designed to identify knowledge gaps and address targeted educational efforts.

Segmentation variable	Related question
Subjective knowledge	Do you have knowledge about toxoplasmosis?
Etiology	What is toxoplasmosis caused by?
Transmission by foods	Can toxoplasmosis be contracted from consuming raw or undercooked food?
Transmission by animals	Can toxoplasmosis be transmitted from animals (e.g., cats) to humans?
Transmission via contact with soil	Can toxoplasmosis be acquired via contact with soil, e.g. gardening?
Pregnancy	Can it be harmful to acquire toxoplasmosis during pregnancy?
Diagnostic test	What test is performed for toxoplasmosis in pregnant women?

**Table 2**

Sociodemographic characteristics of respondents ( $n = 568$ ). This table summarizes the participants' education level, occupation, family income, area of residence (urban, suburban, rural), and province within the Apulia region. These factors provide context for understanding variations in knowledge and awareness of toxoplasmosis among different demographic groups.

Sociodemographic characteristics	Sample	
	N.	%
<i>Education</i>		
None	2	0.4
Primary school	6	1.0
Middle school	37	6.5
High school	162	28.5
Bachelor's degree and/or master's degree and/or postgraduate education's level (e.g., Ph.D., master)	361	63.6
<i>Occupation</i>		
Not employed or housewife	91	16.0
Retired	4	0.8
Student	120	21.1
Employed	353	62.1
<i>Family monthly income</i>		
Up to €1000	62	10.9
€1001–2000	261	46.0
€2001–3000	136	23.9
Over €3001	109	19.2
<i>Area of residence*</i>		
Rural	25	4.4
Suburban	47	8.3
Urban	495	87.3
<i>Province of residence</i>		
Bari	88	15.5
Barletta-Andria-Trani	91	16.0
Brindisi	89	15.7
Foggia	119	21.0
Lecce	90	15.8
Taranto	91	16.0

\* Urban: Areas with high population density, developed infrastructure, typically encompassing cities and towns. Suburban: Areas with moderate population density on the outskirts of urban centers, characterized by residential housing and green spaces. Rural: Areas with low population density, often including villages and natural landscapes, with limited infrastructure (ISTAT (Italian National Institute of Statistics), 2020).

**Table 3**

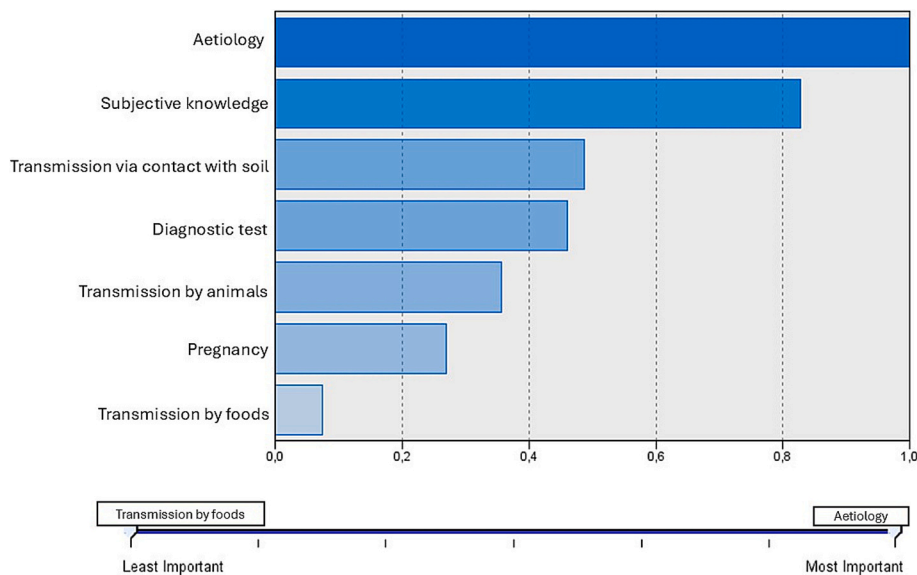
Percentage of correct, incorrect, and “I don't know” answers on the objective knowledge questions. The questions cover key aspects of toxoplasmosis such as its cause, transmission routes (via food, animals, and soil), potential risks during pregnancy, and diagnostic testing. The percentage of correct answers indicates the level of objective knowledge among respondents, while the percentage of incorrect and “I don't know” responses highlights the knowledge gaps.

Objective knowledge questions	Correct response	% Correct answer	% Incorrect answer	% “I don't know” answer
What is toxoplasmosis caused by?	Parasite	52.8	34.7	12.5
Can toxoplasmosis be contracted from consuming raw or undercooked foods?	Yes	95.8	3.3	0.9
Can toxoplasmosis be transmitted from animals (e.g., cats) to humans?	Yes	81.7	3.3	15.0
Can toxoplasmosis be acquired via contact with soil, e.g. gardening?	Yes	40.5	22.7	36.8
Can it be harmful to acquire toxoplasmosis during pregnancy?	Yes	94.5	0.2	5.3
What test is performed for toxoplasmosis in pregnant women?	Blood test	75.5	12.7	11.8

The levels of predictive importance of each segmentation variable were greater than zero, meaning that each individual variable contributed to some variation within the clusters. The results showed that the most important variable in determining the three segments was “etiology” with a value of 1.0, followed by “subjective knowledge” with a value of 0.83, and then by “transmission via contact with soil” (0.49), “diagnostic test” (0.46), “transmission by animals” (0.36), “pregnancy” (0.27), and “transmission by foods” (0.07) (Fig. 1).

Significant differences between the segments, examined through the Pearson Chi-square test, were confirmed for all the segment variables used. Table 4 shows the results of the two-step cluster analysis used to determine the segments of Apulian women of childbearing age based on their general knowledge about toxoplasmosis.

Cluster 1, which accounted for 40.2 % of the total sample, consisted of respondents who claimed to be informed about toxoplasmosis. They provided correct answers for all segmentation variables, except for “transmission via contact with soil” as a risk factor, which only 58.3 % of the respondents were aware of. Based on the answers, cluster 1 was called “women of childbearing age with knowledge of toxoplasmosis”.



**Fig. 1.** Predictor importance levels of segmentation variables in assessing knowledge of toxoplasmosis among women of childbearing age. The horizontal bar chart displays the relative importance of different variables, ranging from 0.0 (least important) to 1.0 (most important). The lower section of the figure provides a visual representation of the ranking, illustrating the progression from the least important factor (transmission by foods) to the most important (etiology).

**Table 4**

Three segments solution of Apulian women of childbearing age based on their subjective and objective knowledge of toxoplasmosis. This table presents the segmentation of participants into three clusters based on their level of knowledge - women with knowledge, partial knowledge, and no knowledge - and highlights the distribution of participants across these categories, providing insight into the extent of knowledge gaps and areas where targeted educational interventions may be necessary.

Segmentation variables	Women with knowledge <i>n</i> = 228 (40.2 %)	Women with partial knowledge <i>n</i> = 225 (39.6 %)	Women with no knowledge <i>n</i> = 115 (20.2 %)	
	Frequency %	Frequency %	Frequency %	<i>p</i>
<i>Subjective knowledge*</i>				0.000
No	0.0 %	28.4 %	95.7 %	
Yes	100 %	71.6 %	4.3 %	
<i>Etiology*</i>				0.000
Incorrect	0.0 %	61.8 %	50.4 %	
Correct	100 %	28.0 %	7.8 %	
I do not know	0.0 %	10.2 %	41.8 %	
<i>Foods*</i>				0.000
Incorrect	0.0 %	6.7 %	3.5 %	
Correct	100 %	93.3 %	92.2 %	
I don't know	0.0 %	0.0 %	4.3 %	
<i>Cats*</i>				0.000
Incorrect	0.0 %	7.6 %	1.7 %	
Correct	100 %	78.2 %	52.2 %	
I don't know	0.0 %	14.2 %	46.1 %	
<i>Soil*</i>				0.000
Incorrect	14.9 %	36.9 %	10.4 %	
Correct	58.3 %	42.7 %	0.9 %	
I don't know	26.8 %	20.4 %	88.7 %	
<i>Pregnancy*</i>				0.000
Incorrect	0.0 %	0.4 %	0.0 %	
Correct	100 %	99.2 %	74.8 %	
I don't know	0.0 %	0.4 %	25.2 %	
<i>Diagnostic test*</i>				0.000
Incorrect	0.0 %	15.1 %	33.0 %	
Correct	100 %	72.9 %	32.2 %	
I don't know	0.0 %	12.0 %	34.8 %	

\* *p* < 0.001.

Cluster 2 comprised 39.6 % of the sample and consisted of respondents who showed certain gaps in their knowledge: 71.6 % did not know that the causative agent of toxoplasmosis is a protozoan parasite and 36.9 % were not aware that it can be transmitted via contact with soil. Also, women belonging to cluster 2 were not aware of the “diagnostic test” (15.1 %), “transmission by cats” (7.6 %), “transmission by foods” (6.7 %) and “risk during pregnancy” (0.4 %). Based on the results cluster 2 was called “*women of childbearing age with partial knowledge of toxoplasmosis*”.

Cluster 3 included respondents who were uninformed about toxoplasmosis (95.7 %) which accounted for 20.2 % of the total sample. Specifically, the women belonging to this cluster did not know about “transmission via contact with soil” (88.7 %), “transmission by cats” (46.1 %), “etiology” (41.8 %), “diagnostic test” (34.8 %), “pregnancy” (25.2 %) and “transmission by foods” (4.3 %). Cluster 3 was called “*women of childbearing age with no knowledge of toxoplasmosis*”.

The segments of childbearing-age women were further profiled using sociodemographic characteristics (i.e. education, occupation, income, area and province of residence) and other illustrative variables, such as their level of engagement with toxoplasmosis (i.e., indirect and direct experience) and the importance of implementing health education programs. Pearson Chi-square test revealed that all the analyzed sociodemographic variables differed significantly among clusters, except for “area of residence” ( $p = 0.390$ ). These results are summarized in Table 5 and Table 6.

The obtained responses show that most women in cluster 1 (women with knowledge of toxoplasmosis) had the highest level of education (i.e., bachelor’s and/or master’s degree and/or postgraduate education’s level) (67.9 %), were employed (65.3 %), and had a family monthly income between €1001 and €2000 (45.2 %). However, this cluster included the highest percentage of respondents with a family monthly income between €2001 and €3000 (27.2 %) compared to the other two groups. Finally, most of the participants included in this cluster resided in the province of Foggia (24.6 %) (Table 5).

Regarding cluster 2 (women with partial knowledge of toxoplasmosis), the majority had a high school education (64 %) and were employed (66.2 %), while 40.4 % had a family monthly income between €1001 and €2000. Interestingly, this cluster had the highest percentage of respondents with a family monthly income over €3001 (21.8 %). Finally, the majority of participants that belong to this cluster resided in the province of Foggia (20 %) (Table 5).

**Table 5**

Sociodemographic characteristics of the three clusters of women based on their knowledge of toxoplasmosis. This table presents the distribution of participants according to their education level, occupation, family monthly income, area of residence (urban, suburban, rural), and province of residence. The three clusters represent women with correct knowledge, partial knowledge, and no knowledge of toxoplasmosis. Statistical significance ( $p$  values) is provided to highlight differences between groups in terms of their demographic and socioeconomic characteristics.

Sociodemographic variables	Women with knowledge $n = 228$ (40.2 %)	Women with partial knowledge $n = 225$ (39.6 %)	Women with no knowledge $n = 115$ (20.2 %)	
	Frequency %	Frequency %	Frequency %	$p$
<b>Education*</b>				0.000
No one education’s level	0.0 %	0.0 %	0.9 %	
Primary school	0.0 %	0.4 %	5.2 %	
Middle school	3.2 %	8.4 %	9.6 %	
High school	28.9 %	27.2 %	30.4 %	
Bachelor’s and/or master’s degree	67.9 %	64 %	53.9 %	
and/or postgraduate education’s level (e. g., p.H.D., master)				
<b>Occupation**</b>				0.003
Not employed or housewife	12.3 %	16.0 %	23.5 %	
Retired	0.0 %	1.8 %	0.0 %	
Student	22.4 %	16.0 %	28.7 %	
Employed	65.3 %	66.2 %	47.8 %	
<b>Family monthly income**</b>				0.029
Up to €1000	8.8 %	12.4 %	12.2 %	
€1001–2000	45.2 %	40.4 %	58.2 %	
€2001–3000	27.2 %	25.4 %	14.8 %	
Over €3001	18.8 %	21.8 %	14.8 %	
<b>Area of residence***</b>				0.390
Rural	3.9 %	6.2 %	1.7 %	
Suburban	7.9 %	8.9 %	7.8 %	
Urban	88.2 %	84.9 %	90.4 %	
<b>Province of residence**</b>				0.010
Bari	16.7 %	17.8 %	8.7 %	
Barletta-Andria-Trani	15.4 %	16.4 %	16.5 %	
Brindisi	17.1 %	13.8 %	16.5 %	
Foggia	24.6 %	20.0 %	15.7 %	
Lecce	9.2 %	17.3 %	26.1 %	
Taranto	17.1 %	14.7 %	16.5 %	

\* $p < 0.001$ ; \*\* $p < 0.05$  for significant differences between segments; \*\*\*Urban: Areas with high population density, developed infrastructure, typically encompassing cities and towns. Suburban: Areas with moderate population density on the outskirts of urban centers, characterized by residential housing and green spaces. Rural: Areas with low population density, often including villages and natural landscapes, with limited infrastructure (ISTAT (Italian National Institute of Statistics), 2020).



**Table 6**

Percentage of direct experience, indirect experience, and interest in educational programs across the three clusters. The distribution of participants based on their personal experience with toxoplasmosis, whether direct (having been personally affected) or indirect (knowing someone affected), and their interest in educational programs on the topic is presented. The three clusters represent women with knowledge, partial knowledge, and no knowledge of toxoplasmosis. The percentage of participants in each category is reported, along with statistical significance (*p* values) highlighting differences between groups.

Other variables	Women with knowledge 40.2 % n = 228	Women with partial knowledge 39.6 % n = 225	Women with no knowledge 20.2 % n = 115	
	Frequency %	Frequency %	Frequency %	<i>p</i>
<i>Direct experience*</i>				0.000
No	49.1 %	52.9 %	91.3 %	
Yes	50.9 %	47.1 %	8.7 %	
<i>Indirect experience*</i>				0.000
No	68.1 %	75.6 %	92.2 %	
Yes	31.9 %	24.4 %	7.8 %	
<i>Educational programs*</i>				0.000
No	0.4 %	0.0 %	2.6 %	
Yes	98.7 %	98.7 %	90.4 %	
I don't know	0.9 %	1.3 %	7.0 %	

\* *p* < 0.001.

Concerning women in cluster 3 (no knowledge of toxoplasmosis), most had a high school education (53.9 %). However, this cluster included the highest percentage of respondents with no education (0.9 %) or low education (i.e., primary school) (5.2 %). Furthermore, although about one half of women belonging to this group were employed (47.8 %), this cluster showed the highest percentage of participants who were unemployed (23.5 %) or students (28.7 %). Finally, most of the women belonging to this cluster had a family monthly income between €1001 and €2000 (58.2 %) and resided in the province of Lecce (26.1 %) (Table 5).

In terms of respondents' experience with toxoplasmosis, one half (50.9 %) of the women with knowledge of toxoplasmosis had previously been tested for the disease, and the majority (68.1 %) reported no indirect experience. Among women with partial knowledge of toxoplasmosis, one half (52.9 %) indicated that they had no direct experience with toxoplasmosis, and a substantial majority (75.6 %) reported no indirect experience either. However, among women with no knowledge of toxoplasmosis even 91.3 % and the 92.2 % have never had any direct and indirect experience with toxoplasmosis, respectively. Finally, while almost all (98.7 %) women with knowledge or partial knowledge would welcome the implementation of health education initiatives, this percentage dropped to 90.4 % among women with no knowledge. Also, 7 % of women with no knowledge were uncertain whether they would welcome educational programs on toxoplasmosis, compared to only 0.9 % of those with knowledge and 1.3 % of those with partial knowledge. The highest percentage of "No" answers was registered among the women with no knowledge (2.6 %) compared to the other two clusters (Table 6).

#### 4. Discussion

This is the first study conducted using an web-based survey to evaluate the knowledge of *T. gondii* and toxoplasmosis among women of childbearing age in the Apulia region, Southern Italy.

Web-based survey is an investigative tool that uses online surveys to collect data, commonly employed in regions with high internet usage. We here chose this method over traditional approaches (such as personal interviews) for its several advantages: quicker data collection, real-time data monitoring and analysis, cost-efficiency, reduced intrusiveness resulting in more spontaneous responses, and the ability to effectively reach specific target groups (Fricker and Schonlau, 2002).

In the present study, 69.4 % of participants reported having prior awareness and knowledge of toxoplasmosis. This figure is lower compared to the results obtained by other studies carried out in Europe. In a cross-sectional survey carried out in the Netherlands in 2010, out of 1097 interviewed pregnant women, 75.3 % had heard, read or seen information about toxoplasmosis (Pereboom et al., 2013). In another cross-sectional study aimed at assessing awareness of cytomegalovirus infection among pregnant women in Geneva, Switzerland, data about other congenital diseases were collected and 87 % of the respondents knew about toxoplasmosis (Willame et al., 2015). The highest percentage of women who reported having knowledge of toxoplasmosis was recorded in Poland where out of 465 women who participated in the survey, 439 (94.4 %) were aware of toxoplasmosis (Smereka et al., 2018). However, it should be emphasized that the target population in the above studies consisted of pregnant women, whereas the present study surveyed a broader group of women of childbearing age. The higher levels of knowledge observed among pregnant women may be attributed to the information provided by their gynecologists or their proactive efforts to seek information due to their pregnancy status.

In Italy, only one study was conducted to evaluate the knowledge of women and, out of 808 participants, 84 % reported to have heard about toxoplasmosis (Martini et al., 2020).

It should be noted that in all these studies, although women declared that they had heard of and were aware of toxoplasmosis, their knowledge was often superficial and incomplete (Pereboom et al., 2013; Willame et al., 2015; Smereka et al., 2018; Martini et al., 2020). In contrast, the present study suggests that the Italian women included in this survey may have underestimated their understanding of toxoplasmosis. Specifically, while only 69.4 % reported being aware of toxoplasmosis, the cluster of women of childbearing

age with knowledge or partial knowledge of toxoplasmosis, included 79.8 % of the respondents, indicating their actual awareness of the issue. This finding highlights the potential gap between self-reported knowledge and actual understanding of health-related topics. Nevertheless, a total of 20.2 % participants lacked any knowledge. This underscores the importance of implementing enhanced health education interventions targeting specific populations, as highlighted by previous research (Eroglu and Asgin, 2021; Jones and Taylor, 2021).

In the present survey, respondents demonstrated high levels of knowledge of certain aspects of *T. gondii* infection: 95.8 % correctly identified the role of raw or undercooked food in infection transmission, 94.5 % were aware that toxoplasmosis poses risks during pregnancy, 81.7 % knew about the role of animals (cats) in the transmission, and a substantial percentage (75.5 %) knew what type of test for toxoplasmosis should be conducted during pregnancy. Significantly lower and concerning percentages were observed regarding respondents' knowledge of the causative agent and the role of contact with soil in transmission of the parasite.

For the general public a lack of understanding about *T. gondii* being a parasite rather than a bacterium or a virus can impact both personal health practices and public health awareness. A person mistaking *T. gondii* as a bacterium or virus might erroneously believe that simple hygiene practices, like handwashing or antibacterial treatments, are sufficient to prevent infection, overlooking the critical need to avoid undercooked meat or take extra precautions when handling cat litter. This misunderstanding can hinder effective prevention and perpetuate exposure risks. Building scientific knowledge within society promotes responsible citizenship and informed decision-making.

Another key finding is the lack of awareness of the role of contact with soil (e.g., through gardening) in the transmission of toxoplasmosis. In fact, only 40.5 % of respondents gave the correct answer regarding contact with soil as a transmission route. Even in the cluster of women with knowledge of toxoplasmosis, 14.9 % answered incorrectly, and 26.8 % declared not knowing the answer. While data on soil as a transmission vehicle for *T. gondii* are limited in Europe, a European multicenter case-control study (Cook et al., 2000) involving Naples, Lausanne, Copenhagen, Oslo, Brussels, and Milan, showed that 30 % to 63 % of infections were associated with consumption of undercooked or cured meats, but also, that between 6 % and 17 % of infections could be attributed to contact with soil. Although in our study the area where the respondents live was not a significant variable, data available in the literature suggest that rural areas, where contact with soil is more frequent (e.g., through agriculture practices or gardening), are associated with a higher risk of *T. gondii* exposure and thus an increased probability of infection (Bobić et al., 1998; Thaller et al., 2020). The risk, however, is not limited to rural residents. A recent study highlights that soil in public places can be contaminated with *T. gondii* oocysts, posing a threat even to city inhabitants (Maleki et al., 2021). These findings underline the need for public health campaigns to raise awareness about the role of soil in *T. gondii* transmission, not just in rural areas but also in urban settings.

Our results indicate that women of childbearing age with knowledge of toxoplasmosis predominantly possess higher education levels, with 67.9 % holding a bachelor's, master's, or postgraduate degree. These findings are in line with the published data, which suggests a correlation between educational level and knowledge of toxoplasmosis (Pereboom et al., 2013; Smereka et al., 2018; Martini et al., 2020). This trend appears to have practical implications. In fact, in a study conducted by Hung et al. (2015), the relationship between knowledge of toxoplasmosis and seroprevalence was explored. The results showed that seroprevalence of toxoplasmosis was significantly higher among pregnant women with lower educational levels compared to those with a bachelor's degree or higher. Consequently, pregnant women with advanced educational backgrounds seem to have a more accurate understanding of this protozoan infection, which is crucial for its prevention (Hung et al., 2015). This emphasizes the importance of targeted health education initiatives that address the specific knowledge gaps in lower-educated populations.

In contrast with the data collected by Martini et al. (2020), the results of the present study indicate that employed women have a better understanding of toxoplasmosis compared to unemployed women, retirees, and students. This finding is particularly encouraging, as working women - especially those in specific occupational sectors such as those in contact with animals (e.g., farmers, veterinarians, animal handlers), individuals who handle food on a daily basis (e.g., cooks, butchers), women involved in gardening and land management (e.g., gardeners), and laboratory workers - are at a higher risk of exposure to *T. gondii* (Almeida et al., 2022; CCOHS, 2023). Consequently, their increased awareness may help mitigate the risk of contracting the infection. On the other hand, it is important to note that most unemployed women, who exhibit significantly lower awareness of the issue, are often responsible for daily food preparation within their households and, especially in rural areas, for gardening. Therefore greater attention should be directed toward addressing knowledge gaps among the unemployed women who remain unaware of the issue. Moreover, the fact that the majority of the students belonged to the cluster of women with no knowledge of toxoplasmosis is worrisome. Health literacy is known to be an important determinant of health, especially in young people. Italy ranks low in health literacy compared to other European countries. Indeed, a recent survey carried out in Italian students living in Lombardy (Northern Italy) showed that only 6.8 % of the students interviewed had a high level of health literacy (Velasco et al., 2021). The situation may be even worse in the south of Italy, where the percentage of individuals with a university degree is significantly lower compared to the north and the dropout rates are generally higher, with many students leaving school before completing their secondary education (ISTAT (Italian National Institute of Statistics), 2023).

Regarding the income variable, it is noteworthy that among women with the highest family monthly income (> €3001), 21.8 % were categorized as women with partial knowledge of toxoplasmosis. In contrast, women with a family income ranging between €2001 and €3001 predominantly demonstrated full knowledge of toxoplasmosis. This data suggests that economic well-being does not always coincide with a high level of education.

Health education initiatives aimed at pregnant women have proven effective in increasing awareness of the disease and its risk factors, contributing to the prevention of toxoplasmosis. A recent cross-sectional descriptive KAP (Knowledge, Attitude, and Practice)-type study conducted by Velasco-Velázquez et al. (2024) between 2021 and 2022 in Colombia, provided valuable insights into the impact of health education on the prevention of gestational toxoplasmosis. Among the 73 seronegative women who participated in the



educational intervention, a significant improvement in knowledge and a better understanding of risk factors, such as handling raw meat and soil, and the adoption of safer behaviors, including cooking meat thoroughly and avoiding unwashed fruits and vegetables, was observed (Velasco-Velázquez et al., 2024). Similarly, an educational campaign carried out in Poznań, Poland on 2710 pregnant women resulted in a significant increase in awareness and behavioral changes, with 89 % of participants improving their food safety practices and 77 % enhancing their hand hygiene after handling raw food (Pawłowski et al., 2001). These findings highlight that well-structured educational programs are essential for reducing the risk of toxoplasmosis during pregnancy, ultimately lowering the incidence of congenital infection and its associated health risks.

The current study comes with some limitations as we did not include time monitoring to determine whether respondents consulted external sources while answering the online survey questions. Moreover, it is possible that the questionnaire failed to reach less-educated segments of the population in the region, potentially due to their lower cultural inclination to participate in such surveys. A further limitation is the inability to infer age class differences among women of reproductive age due to the lack of age distribution data from respondents. Finally, we did not gather information on whether the respondents had children or had been pregnant in the past. Therefore, it was not possible to segment the participating women by the level of knowledge according to their obstetric history.

## 5. Conclusions

In conclusion, the findings of this study indicate a limited awareness of *T. gondii* and toxoplasmosis among Apulian women of childbearing age and underscore the need to implement effective education and training and education programs.

In Italy, the San Matteo Hospital in Pavia (Northern Italy) is the sole reference center for infections in pregnancy. Establishing a reference center in Southern Italy is highly recommended to monitor the evolution of *T. gondii* infection seroprevalence, collect data on infants born to mothers with gestational toxoplasmosis, and conduct research to assess the impact of congenital diseases in the area. These efforts should be complemented by extensive information campaigns to raise awareness of this serious health issue, which, as the results of this study showed, would be welcomed by all women of childbearing age, even though women with no knowledge were less likely to support such initiatives compared to those with at least partial knowledge.

Promotion of public understanding and health prevention programs should be viewed as investments for the country which would result in a measurable reduction in the burden of CT, thereby contributing to an improvement in overall national health and by consequence, in significant financial benefits.

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## CRediT authorship contribution statement

**Antonella Cammarelle:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Alessandra Barlaam:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition. **Ylenia De Santis:** Investigation. **Annunziata Giangaspero:** Writing – review & editing, Project administration, Conceptualization. **Biagia De Devitiis:** Writing – review & editing, Project administration, Methodology, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.fawpar.2025.e00259>.

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