



Original Article

Impact of education on knowledge, attitudes, and practices for gestational toxoplasmosis



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ABSTRACT

Background: Toxoplasmosis is potentially avoidable, treatable, and curable by simple and direct preventive measures. Knowledge, attitudes, and practices (KAP) assessments concerning gestational toxoplasmosis were evaluated in a cohort of pregnant women from Armenia-Quindío (Colombia, South America).

Methods: This cross-sectional descriptive KAP-type study was performed with informed consent between October 2021 and March 2022. The intervention involved a ten-minute talk administered by prenatal clinic nurses to pregnant women. This took place in the public health clinic RedSalud and the private clinic Happy Maternity with a post-KAP survey after pregnancy.

Results: The findings of the initial KAP survey revealed that approximately 42.8 % of the 250 mothers surveyed had IgG anti-*T. gondii* antibodies present. A strong correlation was observed between a lower frequency of antibodies and a higher level of education. Following an educational intervention, 73 seronegative women demonstrated a significant improvement in their knowledge and behavior. Among the 111 mothers who received the intervention, 42 (37 %) were followed until delivery. Unfortunately, their level of compliance with prenatal serological follow-up was lower compared to previous historical records of cohort of mothers in the same health center during pre-pandemic periods. No seroconversion occurred, although the small number of cases makes the outcome inconclusive with respect to statistical significance. **Conclusions:** Education plays a crucial role in imparting valuable knowledge and fostering effective practices. It holds significant potential to prevent toxoplasmosis in pregnant seronegative mothers. Prenatal check-ups have proven to be a critical determinant in leveraging the benefits of education for seronegative mothers. Reporting and observed behaviors differed, identifying areas for improvement.

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Introduction

Toxoplasma gondii is classified as an obligate intracellular protozoan parasite, which displays a complicated life cycle comprising various stages [1]. The clinical outcomes that result from

transmission to humans can differ significantly based on various factors, including genetics, immunological status, gestational conditions, and nutritional factors specific to each individual host [2]. Congenital toxoplasmosis has a considerable impact on global morbidity, as it is estimated that approximately 190,000 cases occur each year [3]. Prenatal transmission occurs as a result of an acute primary infection during pregnancy or in the vicinity of conception [1]. It is crucial to diagnose and treat acute infections promptly to prevent damage from congenital *Toxoplasma* infection [1]. In

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Colombia, approximately 60 % of women are exposed to *T. gondii* and have anti-*Toxoplasma* antibodies, which serve as indicators of previous exposure [4]. Studies conducted in various regions have shown that the risk of a mother acquiring the infection during pregnancy varies between 0.6 % and 3 % [4]. Recent studies conducted in Colombia [5] suggest that the risk of acquiring *T. gondii* infection has remained constant, despite European reports [6] to the contrary. This indicates that the factors influencing transmission have persisted throughout the country [5].

Preventing toxoplasmosis is a key objective of prenatal care [7]. However, evaluating the effectiveness of education during pregnancy for preventing toxoplasmosis is hindered by methodological problems in the studies, resulting in weaknesses in the evidence [8]. A recent systematic review revealed that current data do not demonstrate the effectiveness of primary prevention measures for congenital toxoplasmosis in reducing the incidence of the disease [9]. Although there were clinical trials with randomization of the intervention and control groups, the conclusions are limited due to loss to follow-up and the outcome measures utilized [9]. The highest-quality study on education strategies in France did not find significant changes in risk behaviors despite providing detailed and continuous information [9]. The Cochrane systematic review group on primary prevention of maternal toxoplasmosis suggested that, despite the high prevalence of the disease in countries like those in South America, it may be more practical to assess changes in behavior rather than detecting a difference in the incidence of congenital toxoplasmosis that needs to include more than 12,000 mothers and 6000 in each arm [8]. Studies aimed at detecting changes in behavior are essential to identify sociodemographic and serological variables among women in each region and to elucidate patterns, risk factors, knowledge gaps, and public health practices in the community. Knowledge, attitudes, and practice surveys (KAP) are valuable strategies for comprehensively assessing the community's interests, knowledge, sentiments, and behaviors in relation to a specific topic. Previous research on the efficacy of pregnancy education in altering behaviors to prevent gestational toxoplasmosis has overlooked the initial seronegative cohort. The aim of the present study, therefore, was to investigate whether education can modify the risk behaviors associated with toxoplasmosis acquisition during pregnancy in the city of Armenia (Quindío, Colombia), a location with a high incidence of congenital toxoplasmosis [5]. The educational approach was grounded in the risk factors identified in a prior study 19 years ago in the same location [10].

Materials and methods

Design and setting of the study

This cross-sectional study was executed between September 2021 and March 2022 among pregnant women who were enrolled in both private and public prenatal care programs in the urban area of Armenia, which is situated in the central Andes Mountain range of Colombia. The city has a population of approximately 297,655 people, according to the most recent 2018 census projections [11]. In Armenia, there were 5048 births in 2021, and the birth rate was 9.8 per 1000 inhabitants, which is one of the lowest rates in Colombia. The national mean birth rate in 2021 was 12.4 per 1000 inhabitants [11]. The study collected data on maternal age, educational level, and socioeconomic strata, which were determined by the SISBEN level and origin (Colombian or migrant from a foreign country). SISBEN is a socioeconomic index that is used to establish socioeconomic level in Colombia [12]. The index ranges from SISBEN 0, which corresponds to the lowest level of resources or income and need fulfillment, to SISBEN 6, which corresponds to the highest level of resources or income and need fulfillment. Additionally, the study collected data on the types of health assurance regimes, including

subsidized or affiliated health insurance coverage for low-income individuals, and the contributory regime for individuals with higher incomes [12].

Description of the prenatal program for toxoplasmosis where the study was developed

The city of Armenia was the pioneer in Colombia with a formal public regional policy for gestational toxoplasmosis, as evidenced by Resolution No. 336 of 1986, and it was also the first to evaluate the implementation of Colombian evidence-based clinical guidelines through monthly screening for seronegative women [13]. The study population was selected in two different primary health centers in Armenia, where the program of monthly follow-up for seronegative mothers is carried out, as previously described [14]: "CAB del Sur," which covered mothers from the subsidized regime, and "Happy Maternity," a private maternity that served people from the contributive regime. All pregnant women who attended prenatal control during a six-month period, from September 27, 2021, to March 9, 2022, in these two prenatal care centers were invited to participate. The public system covers 30 % of the city's population [15]. The inclusion criteria were pregnant women who agreed to participate voluntarily and received prenatal care in the participating institutions in the city of Armenia, Quindío. Pregnant minors who agreed to participate voluntarily were included if they had the authorization of their legal guardian and both, the pregnant minor and legal guardian, respectively, completed and signed the informed consent.

Knowledge, attitude, and practice (KAP) questionnaire

A comprehensive data collection form ([Supplementary Material](#)) was utilized to examine demographic, clinical, and serological data with respect to anti-*Toxoplasma* antibodies in relation to the KAP survey of gestational and congenital toxoplasmosis. The survey comprised questionnaires in the Spanish language, which featured multiple-choice questions and Likert scale items ranging from 1 to 5, with responses varying from total disagreement/never (1) to full agreement/always. This questionnaire had been previously validated in a similar study of the general population of the same city [16]. The questionnaires were completed by health personnel, including nurses or medical students, at the first prenatal control consultation in person at the health care center and after delivery via phone calls. Participation in the KAP survey was voluntary.

Education about toxoplasmosis and its prevention

The cohort was educated on the ocular and other chronic manifestations of *T. gondii* gestational infection and how to prevent it by healthcare personnel, including nurses or medical students, in short educational sessions lasting 10 min. They were provided with a folder containing additional educational images and materials about toxoplasmosis to bring to all prenatal visits. The recommendations were based on previous studies of risk factors in the region [10]. We recorded the serological and prenatal follow-up of seronegative mothers after the implementation of the survey until delivery and invited seronegative women who initially responded to the pre-educational KAP survey to participate in a post-educational KAP survey. We compared the pre- and post-KAP survey responses to determine changes in the answers and calculated the percentage of mothers who showed changes in their responses.

Serological follow-up

The female participants were subjected to serological tests to verify the existence or absence of anti-*Toxoplasma gondii* IgG/IgM antibodies in accordance with the Colombian guidelines for

preventing congenital toxoplasmosis [13]. In each clinic, reference test results were obtained using automated chemiluminescence assays, the efficiency of which was reported previously [17]. The outcomes of the serological follow-up were extracted from the clinical records of the mothers at the two study centers.

Data analysis

A distinctive identifier was allocated to each participant in order to safeguard their anonymity. The gathered information was documented in Microsoft Excel 2021. The examination of the data was executed with the aid of STATA 18 (StataCorp, College Station, USA), SPSS 25 (IBM Chicago, USA), and Epiinfo 7.2.5 (CDC Atlanta, USA). The measures of central tendency were utilized to characterize the variables. Odds ratios (OR) and their 95% confidence intervals (CI95%) were calculated. Chi-square tests were applied to evaluate the connections between the qualitative variables, while the normalcy of the numerical variables was established. Kruskal-Wallis tests were carried out for non-parametric samples, and ANOVA was employed for parametric data. The McNemar test was conducted to analyze the changes in the knowledge components of the KAP assessment, while the Wilcoxon signed-rank test was used to determine the changes in the attitudes and practices component of the KAP assessment. The statistical significance of the results was determined at $p < 0.05$.

Bioethical aspects

Education had not previously been evaluated within a monthly program in a South American setting, which is a geographical region with high exposure of the human population to this parasite. This lack of evaluation presents an opportunity to identify important factors that could improve compliance. The educational material was developed by professionals and experienced researchers, and it was adapted to the local population's language. Participation in the study was voluntary, and the anonymity of the participants was protected. All participants signed an Informed Consent form, and the study and consent forms were approved by the Institutional Review Board of the Faculty of Health Sciences at the Universidad del Quindío (Act number 8, June 18, 2021).

Results

Between September 27, 2021, and March 9, 2022, a total of 273 initial surveys were administered to pregnant women in prenatal care centers, regardless of seroprevalence. These women attended prenatal checks through public and private healthcare networks in Armenia. The median age of the participants was 24 years, with a standard deviation of 6.2 years, and the median gestational age at the time of the survey was 25 weeks, with a standard deviation of 8 weeks. On average, pregnant women attended 4.2 prenatal checks, and most participants (96.7%) resided in urban areas, with 83% belonging to socioeconomic strata 1 and 2, the lowest-income population segments eligible for economic subsidies for health care benefits. The average years of education completed were 10.6 years, with a standard deviation of 2 years. Seven percent of the participants lacked "Entidad Promotora de Salud" (EPS) services (affiliated regime), indicating that no health coverage was provided based on the national General Social Security System because of their irregular residency status in Colombia. The detailed sociodemographic findings of the overall study population are presented in Table 1 of the Supplementary Material. Fig. 1 shows the flowchart of participation in each step for the evaluation of educational changes in the present Knowledge, Attitudes, and Practices (KAP) survey.

Among the 273 women who responded to the pre-KAP survey, approximately 61.9% reported prior awareness of aspects of the

Table 1

Knowledge in pregnant women in Armenia city (Colombia) attending prenatal care program between September 2021- March 2022, in relation to toxoplasmosis (N = 273).

KNOWLEDGE (correct answer in bold):		
	n	%
K1. Who among the following is most affected by gestational toxoplasmosis and can suffer serious consequences		
A. Baby	169	61.90%
B. Pregnant mother	28	10.26%
C. Elderly	3	1.10%
D. Adolescents	0	0%
E. Don't know/ No response	73	26.74%
K2. Which of the following do you consider to be symptoms of toxoplasmosis during pregnancy:		
A. Alterations in the eyes	11	4.03%
B. Fever, fatigue, node apparitions	41	15.02%
C. Diarrhea, vomit, headaches	21	7.69%
D. Vaginal bleeding	11	4.03%
E. Don't know/ No response	189	69.23%
K3. In which of the following ways is toxoplasmosis transmitted:		
A. Mosquito bite	6	2.20%
B. Drinking raw water, eating half-cooked meat	141	51.65%
C. Plagues like rats and cockroaches	14	5.13%
D. Having sexual relations without condom	14	5.13%
E. Don't know/ No response	98	35.9%

disease, with medical personnel serving as their primary source of information (72.5%), followed by relatives (12.2%). About the patients' knowledge of gestational toxoplasmosis, the average score recorded was 1.2 ± 0.9 correct answers out of 3 multiple-choice questions. The results are presented in Table 1. Most women (70.92%) demonstrated positive attitudes about the importance of toxoplasmosis and indicated their willingness to undergo prenatal examinations and check-ups throughout pregnancy. However, the least receptive attitude was observed towards receiving further information about the disease and making lifestyle changes to prevent infection, as indicated in Table 2. When it came to disease prevention practices, there was a significant discrepancy in the proper washing of vegetables, with 73% of participants reporting that they did not wash their vegetables in boiled water. This was followed by inefficient frozen meat preparation (18%) and non-consumption of bottled and/or boiled water (15%). A notable association was observed between participants' average scores on the knowledge component and their years of education (1.4 vs. 0.8; $p < 0.0001$), where individuals with 11 or more years of education displayed higher knowledge competency. Women at or beyond 20 weeks of gestation and those who attended five or more prenatal check-ups demonstrated increased awareness regarding methods of infection transmission ($p=0.04$ and $p=0.01$, respectively). Moreover, a significant association was observed between attending ≥ 5 prenatal check-ups, prior knowledge of the disease, and consuming boiled or bottled water ($p=0.013$, $p=0.032$, and $p=0.031$, respectively). Women who planned their pregnancies were observed to engage in more frequent handwashing practices throughout their pregnancy ($p=0.015$). Prenatal care attendance and the utilization of these health services were more prevalent among women receiving EPS healthcare services than among migrant women ($p < 0.0001$).

Among the 273 pregnant women, 250 underwent serological analysis for anti-*T. gondii* antibodies. This accounted for 23 out of 273 women (8%) who missed the serological examinations. Out of the 250 participants, 107 (42.8%) tested positive for IgG *T. gondii* antibodies. Women with higher educational levels had a lower frequency of IgG antibody positivity ($p=0.009$). Pregnant women of national origin exhibited a higher frequency of anti-*T. gondii* antibodies than those of foreign origin, all of whom were from Venezuela (46.2% vs. 12.5%, $p=0.003$). The presence of cats in the home was not associated with positivity for anti-*T. gondii* antibodies,

Flow chart of pregnant women participation at each one of steps for knowledge, attitudes and practices (KAP) survey and effect of education in Redsalud (Armenia, Colombia) September 2021–March 2022

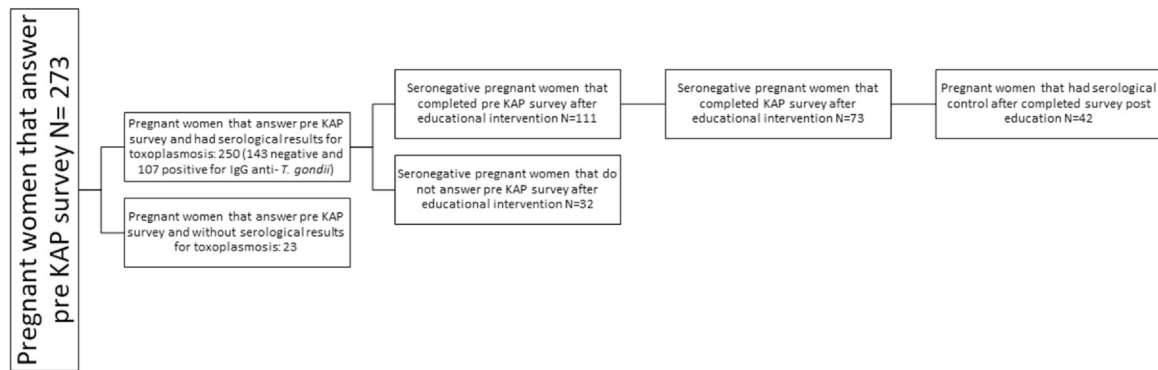


Fig. 1. Flow chart of pregnant women participation at each one of steps for knowledge, attitudes and practices (KAP) survey and effect of education in Redsalud (Armenia, Colombia) September 2021–March 2022: Numbers indicates how many from the initial 273 pregnant women participated at each step of the study: seronegative that completed pre KAP survey, seronegative that completed post KAP survey and seronegative who completed serological follow up.

as seropositivity occurred in 32/80 (40%) of women with cats at home and 75/170 (44%) in women without cats (OR: 0.8 CI95%: 0.4–1.4; $p = 0.31$). Table 4 displays the factors and responses in the pre-KAP survey associated with a lower prevalence of *T. gondii* infections. A response to the P4 question of whether one "freeze[s] meat for at least two days before consumption" was significantly associated with a higher prevalence of toxoplasmosis: 72/144 (50%) vs. 34/102 (32.6%); OR: 2 CI95%: 1.2–3.4; $p = 0.009$ (four mothers did not answer this question). Other responses to the questions were not related to higher or lower prevalence.

In the group of 111 women who fell into the seronegative category and completed pre-educational knowledge, attitudes, and practices (KAP) assessments, a substantial majority, or 95.5%, were residents of urban areas. The median duration for these seronegative women to be free of antibodies against *T. gondii* was 24 weeks, with the range of pregnancy weeks spanning from 4 to 36 weeks. Among the 80 pregnant women who reported having cats at home, 11 of them owned cats less than six months old. Notably, more than 88% of the seronegative participants belonged to the three lowest socioeconomic strata, but they all had access to modern sanitary facilities and the Internet, with a median of 11 years of schooling completed.

The responses to the post-educational KAP survey of 73 out of the 111 seronegative women who initially participated in the pre-educational KAP survey have been detailed in Supplementary Material Tables 2, 3, and 4. Among these women, 18 answered the survey before giving birth (between weeks 23 to 39) and 55 after giving birth (14 by cesarean section and 41 after natural delivery). The median time between the two surveys was 14 weeks (with a range of 3 to 32 weeks).

The educational intervention led to a positive change in all components of the knowledge section of the KAP evaluation for the seronegative cohort. The knowledge section covered the modes of transmission of the parasite, the symptoms of gestational toxoplasmosis, and the risks associated with the infection for the woman and the fetus. The components assessing the consequences of *T. gondii* infection and transmission modes showed the highest improvements after the intervention (Table 5). The assessment of symptoms during pregnancy also demonstrated a significant increase in the correct answers (OR: 5 CI95%: 1.414 – 26.945; $p = 0.0075$).

The attitude components evaluated in the KAP assessment revealed substantial improvement in engagement with personal

behavioral changes to prevent gestational toxoplasmosis. However, some of the assessed components displayed high positive agreement prior to the intervention and did not show significant improvement after the educational intervention.

The findings pertaining to preventive practices revealed that the least adhered to practices prior to intervention were related to drinking bottled/boiled water (P1), adhering to washing vegetables with boiled water (P3), and washing hands before eating and after handling cat feces (P5). However, following educational discussions, there was a significant improvement in adherence to these practices. Specifically, P1 demonstrated a notable 28.77% increase in agreement with the statement, while P3 and P5 showed improvements of 23.29% and 19.18%, respectively ($p < 0.0001$, $p < 0.0001$, $p = 0.0010$).

We investigated the adherence of seronegative women to prenatal checkups and the outcomes of anti-*T. gondii* IgG/IgM serologic tests taken during each visit. For the 42 participants (37% of the sample) who completed the post-education Knowledge, Attitudes, and Practices (KAP) survey, we had access to the follow-up data. Among these mothers, 31 (73.8%) underwent at least three tests, with a range of one to nine tests, and a median follow-up time of four months per person. None of the 42 mothers demonstrated seroconversion. Previous reports [5] from the same prenatal care center documented five cases of seroconversion among 774 seronegative women, indicating a risk of 1.6 seroconversions per month per 1000 seronegative women. Consequently, the low number of women who were followed (42 mothers for four months) limited our statistical power to determine if the educational intervention had an impact on the seroconversion rate.

Discussion

The present investigation constitutes the most substantial cohort of pregnant women in South America who test negative for toxoplasmosis and have undergone a comprehensive assessment of their knowledge, attitudes, and practices regarding toxoplasmosis, as well as measurements of anti-*T. gondii* antibodies. This region has a high incidence of human exposure to this parasitic disease. Most studies that use the Knowledge, Attitudes, and Practices (KAP) method typically involve conducting surveys but do not assess the presence of antibodies or evaluate the effectiveness of education [18–20]. One study conducted in Londrina, Paraná, Brazil, found that 45% of 15 pregnant women who were interviewed had received educational information on preventive measures against

Table 2
Attitudes in pregnant women in Armenia city (Colombia) attending prenatal care program between September 2021– March 2022, in relation to toxoplasmosis (N = 272, one questionnaire without answer).

	Strongly Agree (5 points)		Agree (4 points)		Neither agree nor Disagree (3 points)		Disagree (2 points)		Strongly Disagree (1 point)	
	n	%	n	%	n	%	n	%	n	%
A1. Do you consider toxoplasmosis during pregnancy dangerous to both you and your baby?	240	88.2	31	11.4	0	0	0	0	1	0.37
A2. Would you be willing to take medication to treat gestational toxoplasmosis if diagnosed?	252	92.6	18	6.6	1	0.37	1	0.37	0	0
A3. Would you be willing to change your habits to prevent toxoplasmosis?	237	87.1	35	12.8	0	0	0	0	0	0
A4. Would you be willing to undergo a monthly blood test for disease diagnosis?	250	91.9	18	6.6	0	0	1	0.37	3	1.1
A5. Would you be willing to attend education talks or receive additional information about toxoplasmosis?	191	70.2	64	23.5	1	0.37	8	2.94	8	2.94

toxoplasmosis [20]. In contrast, our study revealed that 61.9% of the participants had some prior knowledge of the disease. In a separate study involving 239 pregnant women in Imperatriz, Maranhão, Brazil, 41.8% of the participants had completed their secondary education [21], while in our population, the proportion was higher at 69.8%. The level of knowledge about the disease among Colombian women increased with the number of years of education, which is consistent with the results reported by other researchers in different geographic locations. These disparities highlight the necessity of analyzing KAP studies within the unique context in which they were conducted. It is crucial to consider the manner in which questions are posed, as this may lead to discrepancies in responses among individuals. As a result, questionnaires assessing knowledge, attitudes, and practices should be validated locally [22]. Cultural and social factors can influence the knowledge, attitudes, and practices related to toxoplasmosis among diverse populations, necessitating the development of culturally sensitive educational strategies [9]. In light of these considerations, KAP studies on toxoplasmosis should incorporate the assessment of infection rates, by measuring specific antibodies, and the implementation of locally validated and evaluated educational strategies that can impact behavior change. These indicators can serve as useful measures for developing effective strategies aimed at reducing infection rates within a particular population.

In the present study, the results of pre KAP survey that included comparison between seropositive and seronegative for toxoplasmosis mothers, to know the sources of infection (water, meat and cat contact) was significantly related with lower prevalence confirming to be main goals for primary prevention. Earlier research in the city showed that water contamination is a significant cause of infection, accounting for 50% of cases in the local population [10]. Additional studies have also highlighted the role of water pollution in increasing the risk of infection during pregnancy. In 108 pregnant women of Ciénaga, Magdalena, Colombia, 29% of participants reported consuming water from rivers or streams [23]. In contrast, within our study population, 45.7% of participants always consumed boiled water or bottled water, while 15.7% never did. The figures presented are significant since water sources not only act as a conduit for the transmission of *T. gondii* infection, but also serve as a means for the spread of other opportunistic infections that can have a profound impact on normal pregnancy and maternal-fetal health. Present work uncovered significant conclusions about the crucial function of healthcare personnel in instructing expectant mothers.

The current study aimed to develop educational materials that would be both appealing and engaging for individuals from diverse socioeconomic backgrounds. Our findings revealed that women displayed and recognized significant differences in their behaviors. However, an important exception to this trend was the assessment of clinic attendance and adherence to monthly testing. Although the participants indicated that they valued attending monthly visits to their doctors, where testing could have occurred, the objective measurement of their attendance did not support this perception. This observation contrasts with previous studies, which have not yet addressed this issue [24]. This study constitutes a substantial departure from previous research, introducing a novel paradigm for education on prenatal care. It emphasizes the importance of collaborating with pregnant women in large-scale screening programs to ensure they understand the necessity of regular visits to healthcare providers or laboratories for optimal care. To the best of our knowledge, this approach has not been documented in any other local, national, or international studies, and its implementation can be invaluable in the development of screening programs in any country. This research also highlights the critical role of educational materials and their effective delivery, as well as how these resources can be leveraged to improve the health outcomes of infants and the well-being of families. In a smaller-scale study conducted in Chicago,

Table 3

Prevention practices in pregnant women in Armenia city (Colombia) attending prenatal care program between September 2021- March 2022, in relation to toxoplasmosis (N = 273).

	Always		Almost Always		Sometimes		Almost Never		Never	
	n	%	n	%	n	%	n	%	n	%
P1. You drink boiled water or bottled water.	125	45.7	41	15	50	18.3	14	5.1	43	15.7
P2. You cook meat completely until it entirely changes color.	263	96.3	8	2.9	2	0.7	0	0	0	0
P3. You wash your vegetables with boiled water.	62	22.7	14	5.13	17	6.23	8	2.9	172	63
P4. You freeze your meat for at least two days before consumption.	156	57.5	20	7.3	39	14.3	6	2.2	50	18.4
P5. You wash your hands with soap and water before eating and after handling cat feces.	171	62.6	48	17.5	39	14.2	5	1.8	10	3.6
P6. You attend routine prenatal testing.	258	94.5	11	4	3	1.1	0	0	1	0.37
P7. You complete routine prenatal examinations.	255	93.4	12	4.4	3	1.1	1	0.37	2	0.73

19 mothers achieved 100% compliance with monthly screening at regular visits [7]. Identifying the factors that led to this high level of compliance in Chicago and among the most compliant Colombian participants in the present study may help enhance the effectiveness of screening programs. Additionally, the benefits that accrue from regular prenatal care, such as improved patient outcomes, can be extended to other areas by understanding who attends monthly prenatal care and why, as well as how this can be improved.

Attendance at prenatal check-ups has emerged as an essential factor influencing knowledge about toxoplasmosis. The relationship between attending these check-ups and greater knowledge competency was statistically significant and related to increases in fetal developmental stage. Consequently, there are concerns regarding prenatal care disparities between pregnant Colombian nationals and migrants, as migrants face limited access to care and follow-up serological tests. This disparity perpetuates a women's health gap between population-guaranteed insurance through citizenship and/or resident status, and those in irregular situations who cannot easily access health services. In measurements of adherence, we hope to establish a prenatal screening program with high demonstrated compliance, as opposed to proxy reflections of high self-reported survey results.

In our cohort, we confirmed a high prevalence of anti-*Toxoplasma* IgG antibodies in the Colombian population (42.8%), consistent with the results of previous studies [4]. There is a significant contrast for the Venezuelan migrant population, where collective population immunity is low, which give more risk for young mothers. We observed that higher levels of education, increased attendance at prenatal check-ups, and utilization of multiple prenatal serological tests were associated with increased knowledge and adherence to preventive practices against gestational toxoplasmosis from the KAP assessment. We noted low compliance with prenatal check-ups through serologic testing of patient records, despite higher adherence in the self-reported assessment. The low number of serological follow-ups (42 of 111 mothers, 37%) was unexpected given that we previously reported the importance of adhering to national guidelines for the prevention of congenital toxoplasmosis [5]. By evaluating 1809 expected RedSalud mothers in 2018, we found that all mothers had at least one serological analysis with a median of four serological tests per mother (range: 1 to 13 tests per mother),

and 74% of subjects had more than three serological tests [5]. Further improvements are necessary in certain areas, particularly during prenatal checkup testing for gestational toxoplasmosis. It is imperative to draft and execute educational strategies targeting the less-educated Colombian population and migrants with low pre-infection immunity. In our earlier studies, we demonstrated that educational materials readily increased knowledge in Colombia, Panama, and the United States [24]. This capacity to learn from educational materials extends from high school, university, and medical students to physicians and pregnant women of varying backgrounds [24]. The present findings confirm the importance of education for preventing maternal toxoplasmosis.

The key finding of this study was that providing a brief educational session along with a hygiene brochure during prenatal care, which was accompanied by a carpet printed with hygienic measures, led to substantial improvements in knowledge and behavior regarding the risk factors for toxoplasmosis. Attitudes were more difficult to be changed after education, such as the importance of follow up and the importance of educational talks, indicating the necessity to explore new educational or non-educational strategies to improve primary prevention. As the number of serological follow-ups increases, the likelihood of prevention increases. To establish control programs for toxoplasmosis during pregnancy, it is necessary to know how the population responds to monthly serological follow-up of seronegative mothers. This information will enable the managers of control programs to determine the appropriate number of tests to be carried out and establish a baseline for setting improvement goals in serological follow-ups.

A limitation of our study was the 8% loss of serology in women who answered the KAP and the low number of participants in the serological follow-up, which reduced the statistical power to detect changes in the seroconversion rates after education. Improving the effectiveness of maternal care program teams through enhanced follow-up of mothers can result in greater adherence to the program guidelines. Our findings have important implications for public health. First, it is necessary to increase awareness about the sources of infection, especially in populations of mothers with fewer years of studies; second, it is necessary to emphasize adequate compliance with the monthly prenatal control during pregnancy; and third,

Table 4

Significant factors related to lower prevalence of toxoplasmosis when the factor is present (exposed) compared when risk factor is absent (non-exposed) in pre-KAP survey in pregnant women in Armenia city (Colombia) attending prenatal care program between September 2021- March 2022 (N = 250).

Risk factor or correct response in pre KAP survey	Anti- <i>T. gondii</i> IgG positive results in exposed vs. non-exposed n/ N (%)	OR	CI 95%	p value*
More than 11 years of studies**	63/169 (37.8%) vs. 44/80 (55%)	0.4	0.2–0.8	0.0094
To listen about toxoplasmosis before pregnancy	58/157 (36.9%) vs. 49/93 (45.7%)	0.5	0.3–0.8	0.017
To have access to internet service	69/197 (35%) vs. 38/53 (71.7%)	0.21	0.1–0.4	0.000002
To be contributive (non-subsidized) for the health system	5/23 (21.7%) vs. 102/227 (44.9%)	0.34	0.1–0.9	0.044
Correct response K3 (to know ways of transmission for toxoplasmosis)	50/136 (36.7%) vs. 57/114 (50%)	0.58	0.3–0.9	0.04

* Two-tailed statistically significant Fisher exact test (p < 0.050) ** One mother without data of number of years of education

Table 5

Knowledge changes regarding gestational toxoplasmosis before and after educational intervention in seronegative women that completed post KAP survey (n = 73).

Knowledge	Number of mothers responding with correct answer	% improvement in correct answer	p-value
K1. Who among the following is most affected by gestational toxoplasmosis and can suffer serious consequences: Baby (infant)	70	32.8%	< 0.0001
K2. Which of the following do you consider to be symptoms of toxoplasmosis during pregnancy: Fever, fatigue, lymph node enlargement	21	28.7%	0.0075
K3. In which of the following ways is toxoplasmosis transmitted: Due to consuming raw water and undercooked meat	71	76.71%	< 0.0001

education on preventive measures can have a significant potential impact on reducing the exposure to risk behavior.

Ethical Considerations

This research was presented to the Committee on Research Bioethics at the University of Quindío and supervised by Dr. Diana Marcela Curtidor. This study was approved on June 22, 2021. Prior to participation in the study, each patient provided informed consent through written documentation (**Annex 2**).

Contribution of authors

- Jorge Enrique Gómez Marín: Conception of the idea, development of protocols, revision, writing, discussion and approval of the final manuscript.
- Daniel Celis Giraldo: development of protocols, collection of information, analysis, and interpretation of data, writing, and discussion of the manuscript.
- Sara Sofía Cordero López: development of protocols, collection of information, writing, and discussion of the manuscript.
- Stefany Velasco Velásquez: development of protocols, collection of information, analysis and interpretation of data, writing, and discussion of the manuscript.
- Morgan Ramirez: collection of information, analysis and interpretation of data, writing and discussion of the manuscript
- Rima McLeod: Conception of design with the idea to test compliance with visits, interpretation of data, writing and discussion of the manuscript

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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.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.jiph.2024.102516](https://doi.org/10.1016/j.jiph.2024.102516).

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