

Impact of the toxoplasmosis intervention program “Toxomemo, aprendemos jugando” in elementary schools teachers from Misiones province, Argentina

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Received: December 2nd, 2025.

Approved: February 7th, 2026.

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Oftalmol Clin Exp (ISSNe 1851-2658)

2026; 19(1): e32-e42.

DOI: <https://doi.org/10.70313/2718.7446.v19.n1.476>

Funding

The ongoing Toxomemo intervention program is supported by private donations made by Fundación Bronislada Kruchowski de Szychowski.

Acknowledgements

The authors express their gratitude to the past and present authorities of the Ministry of Education and the Council of Education of Misiones Province, as well as the Universidad Católica de las Misiones, for their institutional support. We would also like to thank past and present authorities of the Bronislada Kruchowski de Szychowski Foundation for their financial assistance.

Abstract

Purpose: The "Toxomemo, we learn by playing" intervention program was designed to promote toxoplasmosis prevention through an educational process that includes teacher training and game-based learning. This study aimed to assess the program's effectiveness in improving teachers' understanding of preventive behaviors.

Methods: The two-phase intervention began with a teacher training session led by a multidisciplinary team. In the second phase, teachers supervised students in playing the Toxomemo card game, reinforcing key preventive behaviors. Teachers' knowledge was assessed through pre- and post-intervention surveys.

Results: One hundred twenty-seven teachers received the post-intervention survey by email, and 65 responded. Remarkable improvements were observed in recognizing the need to avoid smoked raw pork sausage (29.23% to 83.08%; $p = 0.00000$) and the importance of toxoplasmosis serology testing during pregnancy (49.23% to 83.08%; $p = 0.00000$).

Conclusion: The Toxomemo program enhanced teachers' knowledge of *T. gondii* infection prevention. Future research should aim to improve survey response rates and assess the long-term impact of this intervention on teachers' behaviors and student awareness.

Keywords: toxoplasmosis prevention, health education, teacher training, public health intervention, game-based learning, ocular toxoplasmosis.

Impacto del programa de intervención contra la toxoplasmosis "Toxomemo, aprendemos jugando" en maestros de escuelas primarias de la provincia de Misiones, Argentina

Resumen

Objetivo: El programa de intervención "Toxomemo, aprendemos jugando" fue diseñado con el propósito de capacitar a maestros y enseñar a los alumnos (a través del uso de un juego) las medidas de prevención de la toxoplasmosis. Este trabajo tiene por objetivo analizar el impacto de tal programa en los maestros de escuelas primarias de la provincia de Misiones.

Materiales y métodos: El programa de intervención consta de dos fases: comienza con la capacitación de los maestros por un equipo interdisciplinario. En la segunda fase, los maestros supervisan a los alumnos que usan el juego de cartas Toxomemo en las aulas, reforzando las medidas de prevención. Para evaluar el grado de conocimiento de las medidas de prevención sobre la toxoplasmosis los maestros contestaron un cuestionario pre y post-intervención. Aquellos maestros que recibieron el cuestionario luego de la intervención lo completaron a los 19 meses después de una capacitación.

Resultados: Ciento veintisiete maestros recibieron el cuestionario postintervención. Sesenta y cinco lo respondieron. Cuando se compararon los resultados pre y pos intervención mejorías extraordinarias se observaron en el reconocimiento de las medidas de prevención: evitar el consumo de embutido casero de cerdo ahumado (29,23% a 83,08%; $p = 0,00000$) y la importancia de realizarse análisis serológicos toxoplásmicos durante el embarazo (49,23% a 83,08%; $p = 0,00000$).

Conclusión: El programa de intervención "Toxomemo, aprendemos jugando" aumentó el conocimiento de los maestros en las medidas de prevención de la infección por el parásito *T. gondii*. Investigaciones futuras tendrán por objetivo mejorar el porcentaje de las respuestas y analizar el impacto a largo plazo de esta intervención en el comportamiento preventivo de los maestros y en los alumnos.

Palabras clave: toxoplasmosis, prevención, educación en salud, intervención, aprendizaje basado en juego, toxoplasmosis ocular.

Impacto do programa de intervenção contra a toxoplasmose "Toxo Memo, aprendemos brincando" em professores do ensino fundamental na província de Misiones, Argentina

Resumo

Objetivo: O programa de intervenção "Toxomemo, aprendemos brincando" foi desenvolvido para capacitar professores e ensinar alunos (por meio de um jogo) sobre medidas de prevenção da toxoplasmose. Este estudo visa analisar o impacto des-

se programa em professores do ensino fundamental da província de Misiones.

Materiais e métodos: O programa de intervenção consiste em duas fases: a primeira consiste na formação dos professores por uma equipe interdisciplinar. Na segunda fase, os professores supervisionam os alunos utilizando o jogo de cartas Toxomemo em sala de aula, reforçando as medidas preventivas. Para avaliar o nível de conhecimento sobre as medidas de prevenção da toxoplasmose, os professores responderam a um questionário antes e depois da intervenção. Os professores que receberam o questionário imediatamente após a intervenção responderam novamente 19 meses depois, após uma sessão de formação.

Resultados: Cento e vinte e sete professores receberam o questionário pós-intervenção. Sessenta e cinco responderam. Ao comparar os resultados pré e pós-intervenção, observaram-se melhorias extraordinárias no reconhecimento de medidas preventivas: evitar o consumo de linguiça defumada caseira (de 29,23% para 83,08%; $p = 0,00000$) e a importância de realizar testes sorológicos para toxoplasmose durante a gravidez (de 49,23% para 83,08%; $p = 0,00000$).

Conclusão: O programa de intervenção “Toxomemo, aprendemos brincando” aumentou o conhecimento dos professores sobre medidas preventivas contra a infecção por *T. gondii*. Pesquisas futuras buscarão melhorar a taxa de resposta e analisar o impacto a longo prazo dessa intervenção no comportamento preventivo entre professores e alunos.

Palavras-chave: toxoplasmose, prevenção, educação em saúde, intervenção, aprendizagem baseada em jogos, toxoplasmose ocular.

Introduction

Toxoplasmosis is a zoonotic disease caused by infection with the *Toxoplasma gondii* parasite. While most infected individuals remain asymptomatic, the infection can lead to severe consequences for immunocompromised individuals and developing fetuses¹. Congenital toxoplasmosis (CT) may cause serious neurological damage in newborns. Immunocompromised individuals are at risk of life-threatening diseases. Severe

complications, even, have also been reported in young immunocompetent individuals, such as military recruits, who developed sepsis after infection with virulent *T. gondii* strains prevalent in South American rainforests².

Ocular toxoplasmosis (OT) is a very frequent clinical manifestation of toxoplasmosis in patients from Misiones province, northeastern Argentina and also from the neighboring Brazilian states of Rio Grande do Sul and Santa Catarina³⁻⁴. Several factors contribute to the high prevalence of OT in this region, including the genetic diversity of the parasite⁵⁻⁶, host genetic polymorphisms⁷⁻⁸, and environmental factors such as prolonged rainfall periods^{4,9}.

The primary mode of human *T. gondii* infection is ingestion of the parasite¹⁰. Contaminated water is a well-documented source of infection, with outbreaks reported in countries like Brazil and Canada¹¹⁻¹². In Misiones, 80% of OT patients living in rural areas rely on water from springs or shallow wells¹³. The consumption of raw or undercooked meat, particularly pork, is another risk factor for toxoplasmosis infection. Recently a tissue cyst-based quantitative risk assessment model to estimate the probability of human infection with *T. gondii* from consuming pork, based on pig seroprevalence, was described in Denmark. The probabilities of human infection per tissue portion consumed were estimated at 7.3×10^{-4} ⁽¹⁴⁾. In Misiones province, smoked sausage production made with raw pork meat, was introduced by European immigrants at the beginning of the XX century. While 65.6% of OT patients reported consuming smoked pork sausages, 94% of them denied consuming undercooked meat. This discrepancy suggests that undercooked pork sausages may be a significant yet unrecognized source of infection by the population (smoked raw pork meat sausage paradox)¹³. Indeed, analyses of pork sausages from neighboring Brazilian states have revealed high *T. gondii* contamination rates, confirmed by parasite DNA detection, and bioassays¹⁵⁻¹⁶.

Vertical transmission is another route of infection. While specific data on congenital toxoplasmosis in Misiones province is limited, approximately 14.8% of OT patients were recorded as been

infected congenitally¹⁷. Solid organ transplantation remains a rare transmission mode in the region.

There is no official published data on toxoplasmosis human seroprevalence in Misiones province, despite the mandatory order to report it during pregnancy. Serological studies performed in the neighboring Brazilian state of Rio Grande do Sul, suggest that most individuals in the region acquire the infection during or after puberty³. Quantitative analysis of general knowledge about toxoplasmosis among pregnant women is poor, with 66% of Brazilian women and 72% of women worldwide lacking sufficient understanding¹⁸. Research on the recognition of preventive behaviors of *T. gondii* infection among 363 pregnant women in Misiones province, demonstrated that only 24.5% of them, knew their serologic status against *T. gondii* before pregnancy and 58.4% did not know the need to repeat the serologic analysis during the pregnancy period, in case it resulted negative¹⁹.

To address these knowledge gaps, in 2019 we initiated an educational intervention program named "Toxomemo, aprendemos jugando" [*Toxomemo, we learn by playing*] targeting elementary school teachers and their students in Misiones province. This study aims to evaluate the impact of the "Toxomemo, aprendemos jugando" intervention program on *T. gondii* knowledge of prevention behaviors in elementary school teachers.

Material and methods

"Toxomemo, aprendemos jugando" is an ongoing intervention program designed to educate both elementary school teachers and students (grades 4th-6th) in public schools of Misiones province, Argentina. Developed by the Ophthalmology Department of Universidad Católica de las Misiones (Argentina) and approved by the Ministry of Education and the Education Council of Misiones province, the program focuses on preventing *T. gondii* infection.

Educational intervention program

The intervention program "Toxomemo, aprendemos jugando" comprises two-phases:

Phase 1: Teachers training

A 3-hour teacher training session conducted by a multidisciplinary team of experts covered the biology, epidemiology, and public health impact of *T. gondii*. At the end of the session, each school received a Toxomemo card game. This consists of 9 pairs of cards with figures and legends designed to promote the prevention of toxoplasmosis and other infectious diseases (Fig. 1). One pair of cards explains the objective of the game. Two pairs of cards are dedicated to hand and nail hygiene, one pair explains safe water consumption, one pair focuses on well-cooked meat consumption (including the need for cooking pork meat found in smoked sausages), one pair highlights washing vegetables, one pair covers *T. gondii* serology testing (before and throughout pregnancy), one pair explains cross-contamination in cooking utensils, and finally, one pair focuses on good pet care.

Phase 2: Game base learning

Trained teachers introduced Toxomemo in their classrooms, where students played the memory-based card game. Teachers supervised game-play and facilitated discussions on toxoplasmosis prevention.

Participants

Between October 2019 and November 2024, a total of 586 teachers participated in the teachers training. Two teachers from grades 4-6 in government elementary schools across six departments in Misiones province were trained (Fig. 2).

Study design

This study utilizes a pre-test/post-test design to evaluate the impact of an educational intervention on a cohort of primary school teachers in Misiones province, Argentina. The intervention consisted of a professional training session paired with the implementation of the Toxomemo game-board, an educational tool distributed to all public elementary schools within the participating provincial departments. Given that the intervention was administered to the entire study pop-



Figure 1. Components of the Toxomemo educational game kit: nine pairs of illustrated cards with accompanying text designed to promote the prevention of toxoplasmosis and other infectious diseases through a memory game format. One brochure detailing the rules for the memory game, and other one explains preventive measures against toxoplasmosis infection.

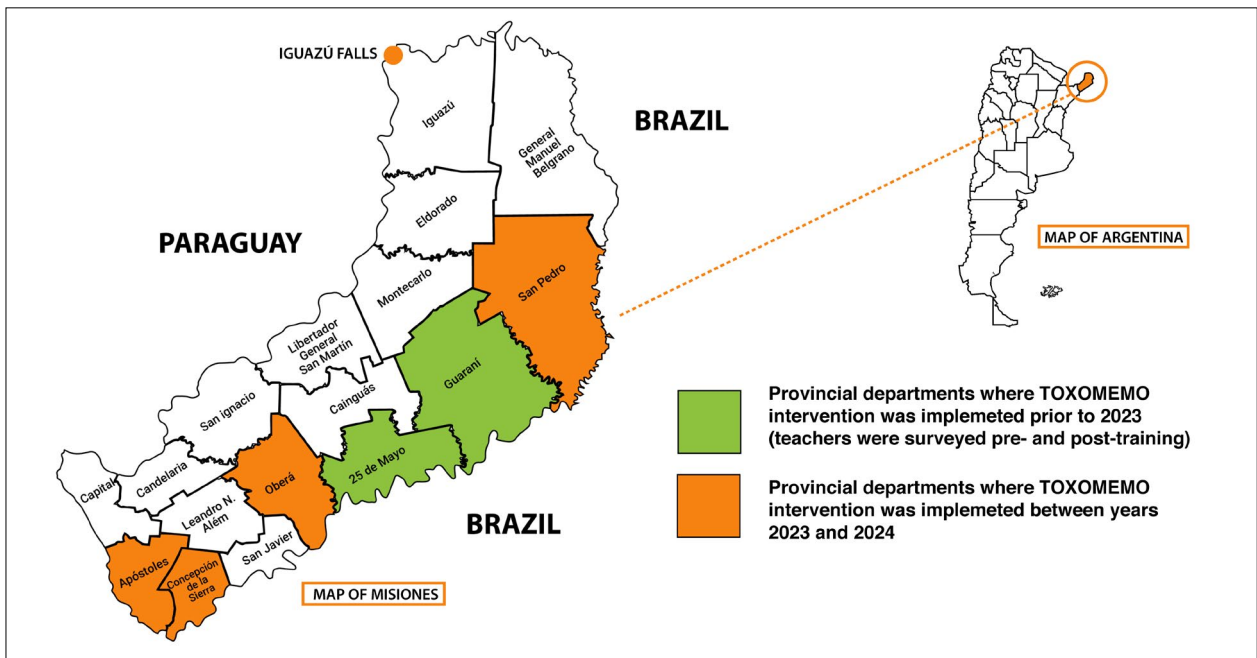


Figure 2. The map of Misiones --in the extreme Northeast of Argentina -- illustrates the provincial departments reached by the “Toxomemo, aprendemos jugando” educational intervention. Areas shaded in green represent departments reached prior to 2023, while those in orange indicate interventions conducted between 2023 and 2024.

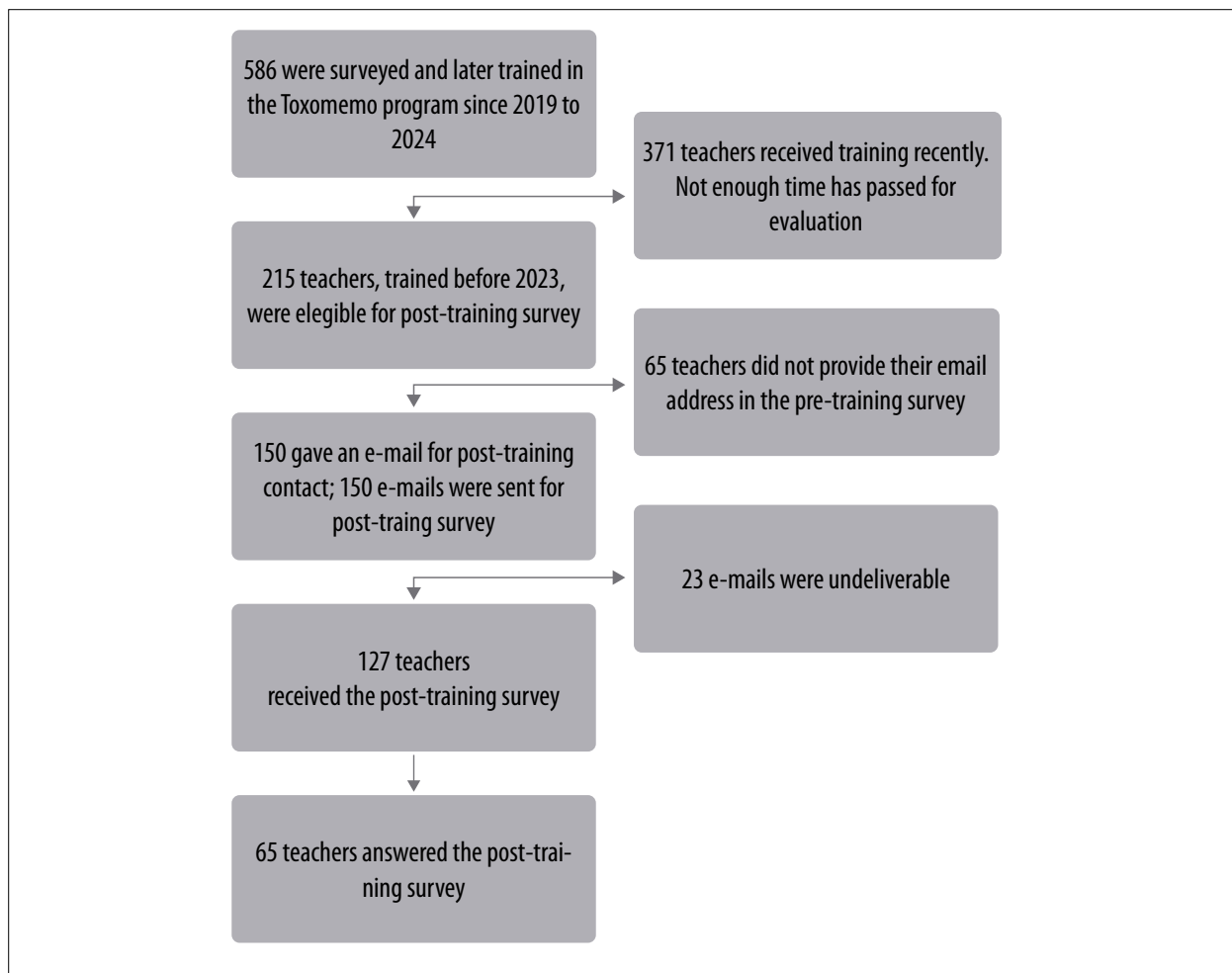


Figure 3. Flow diagram of teacher participation in the “Toxomemo, aprendemos jugando” program training and post-training survey. The diagram illustrates the progression of teachers through the program: initial number included and trained, number subsequently eligible for the post-training survey (n=215), number who received the survey (n=127), and the final number who completed the survey (n=65).

ulation, non-random purposive sampling was employed. This report compares participants’ knowledge of toxoplasmosis prevention, as measured by a standardized questionnaire administered immediately prior to the training (pre-test) and 19 months after the training (post-test) of the “Toxomemo, aprendemos jugando” program.

Inclusion criteria

All teachers that answered the pre-training and post-training questionnaire were included in the analysis. To evaluate the impact of the interven-

tion program on teachers, a post-training survey was sent to 215 of them who had completed the training before December 2022. They were able to use the Toxomemo board game for an average of 19 months before receiving the post-training survey. Of the 215 teachers who completed training before December 2022, 150 provided an email contact for follow-up. Post-training surveys were emailed to these teachers, using the same questionnaire as the pre-intervention survey. Twenty-three emails were undeliverable, leaving 127 recipients. Sixty-five of them answered the post-training survey (Fig. 3).

Instrument

The questionnaire collected personal information (name, age, email) and included a checklist of 11 prevention behaviors against *T. gondii* infection. Participants identified appropriate preventive behaviors, which included: washing hands before eating, tap water consumption, boiled water consumption, avoiding smoked sausages consumption, eating well-cooked meat, brushing nails after soil contact, using gloves when in contact with soil, using separate kitchen utensils for raw and cooked food, washing vegetables before eating, undergoing *T. gondii* serology tests before and during pregnancy, and limiting contact with cats throughout pregnancy.

Statistical analysis

To analyze the statistical significance between recognition results, pre- and post- intervention—of each preventive behavior—the McNemar's chi2 test was used. The analysis was performed using the STATA 16.1 software (StataCorp, Texas, USA). A P value of less than 0.05 was considered significant.

Results

A total of 65 pre- and post-intervention questionnaire data were analyzed. The 83% of teachers (n=54) were female. The mean age (mean + SD; median) was 41.64 ± 8.9; 45 years. Only 3 teachers (4.62%) correctly identified all 11 preventive behaviors in the pre-intervention survey, as compared with 31 (47.69%) who did so in the post-intervention survey (McNemar's chi2 test, $P < 0.0001$) (Table 1). The number of recognized preventive behaviors by the highest proportion of teachers (24.62%) was 7 before intervention. This number increased to 11 by 47.69% of the teachers, post-intervention.

Table 2 summarizes the pre- and post-intervention recognition of individual preventive behaviors. Remarkable improvements in the recognition of preventive behaviors were observed in: avoiding smoked pork sausage consumption (from 29.23% to 83.08%, $P=0.00000$) and per-

forming toxoplasmosis serology tests before and after pregnancy in young women (from 49.23% to 83.08%, $p=0.00000$). No differences were observed for washing hands (96.92% to 100%, $P=0.5000$) and washing vegetables before eating (90.77% to 96.92%, $p=0.2891$).

Discussion

Educational interventions have been recognized as effective strategies for preventing and reducing the prevalence of infectious diseases. Global campaigns have significantly reduced HIV transmission²⁰⁻²¹. Initiatives to prevent congenital toxoplasmosis targeting pregnant women, medical students, and healthcare professionals have been launched in Colombia, the USA, and Panama through educational programs²². The “Toxomemo, aprendemos jugando” program focuses on elementary school students attending 4-6th grade, before they reach the age of seroconversion in our region, estimated at 13 years old. By engaging students through gamification and teacher-led instruction, the program promotes a deeper understanding of *T. gondii* transmission and prevention at an epidemiologically significant earlier age.

The implementation of “Toxomemo, aprendemos jugando” resulted in the improvement in teachers' knowledge of toxoplasmosis prevention. Prior to the intervention, 78% of teachers recognized 5 to 9 preventive behaviors, while post-intervention, 77% of them identified 9 to 11 preventive behaviors.

Pre-intervention data revealed that certain preventive practices, such as handwashing and vegetable washing, were already incorporated into daily routines. These findings are particularly relevant given the epidemiological risk associated with fresh produce consumption. A recent Bayesian QRA model estimated that infections from fresh produce are up to four times more likely than those from meat consumption in neighboring South Brazilian states²³. However, regional variations in parasite contamination levels are influenced by water quality and agricultural practices²⁴, underscoring the need for context-specific interventions.

Table 1. Absolute numbers and percentages of teachers recognizing cumulative preventive behaviors for *Toxoplasma gondii* infection, pre- and post-intervention with the "Toxomemo, aprendemos jugando" program.

Number of preventive behaviors identified	Pre-intervention (frequency, %)	Post-intervention (frequency, %)
0	2 (3.08)	0 (0)
1	0 (0)	0 (0)
2	0 (0)	0 (0)
3	0 (0)	0 (0)
4	4 (6.15)	0 (0)
5	7 (10.77)	0 (0)
6	9 (13.85)	2 (3.08)
7	16 (24.62)	5 (7.69)
8	9 (13.85)	8 (12.31)
9	10 (15.38)	7 (10.77)
10	5 (7.69)	12 (18.46)
11	3 (4.62)	31 (47.69)

As anticipated, the 'smoked pork sausage paradox' was also evident in this study population. While 70.77% of teachers recognized that eating well-done (cooked) meat prevents *T. gondii* infection, only 29.23% initially identified avoiding smoked pork sausages (containing raw pork) as a preventive measure. This discrepancy reflects a widespread lack of awareness about the raw meat content in smoked pork sausages and the associated *T. gondii* transmission route. Following the intervention, 83.08% of teachers correctly identified this preventive behavior, representing a 2.83-fold increase in its recognition from pre-intervention levels. This represents the most significant change in knowledge gained from the intervention. Recent studies have confirmed the high risk of *T. gondii* contamination in pork sausages and processed pork products, with DNA detection rates reaching 94.4% in samples from infected pigs²⁵. These findings highlight the importance of improving public awareness regarding foodborne transmission routes of *T. gondii*.

Globally, 38% of pregnant women associate toxoplasmosis with cats¹⁸. Before the intervention, 38.46% of teachers recognized the importance of limiting cat contact throughout pregnancy before the intervention, a figure comparable to the 46% observed in Brazilian pregnant women. Post-intervention, 66.15% of teachers recognized this preventive measure. Additionally, fewer than half of the teachers initially identified serological testing before and throughout pregnancy as an important preventive behavior, indicating a gap in knowledge regarding the role of early diagnosis in congenital toxoplasmosis prevention. Following the intervention, 83.08% recognized this preventive behavior.

In Misiones province, adolescent pregnancy is a public health concern²⁶⁻²⁷. If we assume a high transmission of knowledge from teachers to their female students—and future mothers-to-be—the impact of the *Toxomemo* intervention may well extend beyond its original objective. By raising awareness of toxoplasmosis prevention

Table 2. Recognition results of preventive behaviors for *T. gondii* infection, pre- and post-intervention with the “Toxomemo, aprendemos jugando” program, including case-control difference, 95% confidence intervals, and exact McNemar’s significance probability (p-value).

Preventive behavior	Recognition pre-intervention [frequency, %]	Recognition post-intervention (frequency, %)	Case- control difference (%)	95% conf. interval	Exact McNemar’s significance probability (p value)
Washing hands before eating	63, (96.92)	65, (100)	3.08	2.65 to 8.81	0.5
Tap water consumption	42, (64.62)	56, (86.15)	21.53	7.57 to 35.50	0.0026
Boiled water consumption	46, (70.77)	58, (89.23)	18.46	3.5 to 33.41	0.016
Avoiding smoked pork sausage consumption	19, (29.23)	54, (83.08)	53.84	40.18 to 67.50	0.0000
Eating well done meat	46, (70.77)	63, (96.92)	26.15	13.93 to 38.37	0.0000
Washing of vegetables prior to eating	59, (90.77)	63, (96.92)	6.15	3.78 to 16.08	0.2891
Avoiding the use of the same kitchen utensils with raw and cooked meat or food	44, (67.69)	59, (90.77)	23.07	10.44 to 35.71	0.0003
Using gloves when in contact with soil	40, (61.54)	59, (90.77)	29.23	15.84 to 42.61	0.0000
Nail brushing after contact with soil	46, (70.77)	61, (93.85)	23.07	10.44 to 35.71	0.0003
Performing toxoplasmosis serology tests before and during pregnancy	32, (49.23)	54, (83.08)	33.84	18.63 to 49.05	0.0000
Limiting contact of pregnant women with cats	25, (38.46)	43, (66.15)	27.69	12.33 to 43.05	0.0005

strategies, the “Toxomemo, aprendemos jugando” program may contribute to improved maternal and child health outcomes in the region.

Conclusion

The “Toxomemo, aprendemos jugando” program improved teachers’ knowledge of *T. gondii* prevention behaviors, demonstrating the poten-

tial of educational interventions to enhance awareness of toxoplasmosis transmission. The program effectively addressed key knowledge gaps, particularly concerning foodborne risks and the importance of serological testing throughout pregnancy. Given the role of educators in shaping students’ knowledge and behaviors, this intervention may have a long-lasting impact on public health beyond the classroom. Future efforts should focus on both scaling up the program

and assessing its direct effects on student learning to maximize its long-term benefits.

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