Parasitol Res (2008) 103:67–74
DOI 10.1007/s00436-008-0928-1

ORIGINAL PAPER

Seroprevalence and sources of *Toxoplasma* infection among indigenous and immigrant pregnant women in Taiwan

Ya-Ling Lin · Yen-Shun Liao · Long-Ren Liao · Fei-Na Chen · Hsiu-Maan Kuo · Shiping He

Received: 6 November 2007 / Accepted: 6 February 2008 / Published online: 8 March 2008

Abstract Investigation on seroprevalence and risk factors of *Toxoplasma gondii* infections among indigenous and immigrant pregnant women in Mid-Taiwan showed that anti *Taxoplasma*-specific IgG antibody counts were significantly higher in indigenes (40.6%) than in immigrants (18.2%), with an odds ratio of OR=3.34 (95% CI: 1.93–4.80). The titre of *Taxoplasma*-specific IgG was also significantly higher in indigenes than in immigrants ($P<0.001$). Differences of living styles for *Toxoplasma* infection between the two groups were drinking untreated water (OR=2.34, 95% CI: 1.36–4.02), consumption of raw/undercooked meats (OR=10.11 95% CI: 4.92–20.78), especially raw/undercooked pork ($P=0.000$), or raw/undercooked viscera (OR=9.16, 95% CI: 2.97–27.94), contact with cats (OR=5.69, 95% CI: 2.83–11.47), or soil (OR=2.55 95% CI: 1.72–3.80). Differences of risk factors for *Toxoplasma* infection in terms of positive IgG in the two groups were consumption of raw/undercooked meats ($P=0.005$) especially raw/undercooked pork ($P=0.004$), and contact with cats ($P=0.013$) or soil ($P=0.028$). It is concluded that seroprevalence of *Toxoplasma* infection is higher in indigenous pregnant women and related to their living styles. To prevent congenital toxoplasmosis, health education seems required.

S. He (✉)
Department of Biological Sciences,
National Sun Yat-Sen University,
70 Lien-Hai Road,
804 Kaohsiung, Taiwan, Republic of China
e-mail: shiping@mail.nsysu.edu.tw

Y.-L. Lin · H.-M. Kuo
Department of Parasitology,
China Medical University School of Medicine,
Taichung, Taiwan, Republic of China

Y.-S. Liao
Department of Epidemiology, Kaohsiung Medical University,
Kaohsiung, Taiwan, Republic of China

L.-R. Liao
Health Bureau, Nantou County Government,
Nantou, Taiwan, Republic of China

F.-N. Chen
Department of Social Medicine,
China Medical University School of Medicine,
Taichung, Taiwan, Republic of China

Introduction

Toxoplasmosis is a world-wide endemic disease caused by an obligate intracellular parasite, *Toxoplasma gondii* (*T. gondii*). The presence of immunoglobulins specifically to the parasite in the sampling population estimated that about 20 to 80% of human beings could have been infected. Studies showed that the prevalence of *Toxoplasma* infection in pregnant women was 10% in Britain (Allain et al. 1998) and Norway (Jenum et al. 1998) and 50% in France (Ancelle et al. 1996) and Greece (Decavalas et al. 1990). In addition, women at child-bearing age also showed a high prevalence of 58% in Central European countries, 51–72% in Latin America, 54–77% in West Africa and 4–39% in China (Tenter et al. 2000), whereas a low rate (15%) in the USA (Jones et al. 2001). The infection is acquired by contact with cats, which excrete living oocysts into the environment and cause environmental contamination (Dubey 1996). Thus, the accidental ingestion of oocysts through contact with soil or the cleaning up of cat faeces could be sources of *T. gondii* infection, especially for pregnant women. In addition, consumption of raw meat containing tissue cysts of *T. gondii* is also an important route for the infection. Tissue cysts are mostly found in

pigs, sheep and goats but less often in poultry, horses and cattle (Tenter et al. 2000). Although the overall infection rates have been decreasing over the last decades (Horion et al. 1990; Ades and Blokes 1993; Nokes et al. 1993), environmental characteristics (Jenum et al. 1998) and some particular living styles prevalent in some ethnic groups (Gilbert et al. 1993; Dupouy et al. 1993; Remington et al. 1995) are still the major factors causing toxoplasmosis.

Babies with congenital toxoplasmosis develop intracerebral lesions and chorioretinitis leading to mental retardation and blindness. This is due largely to trans-placental transmission of the parasite during pregnancy. Thus, investigation of the paths of infection with *T. gondii* and examination of the presence of acute and chronic immune responses to the parasite in pregnant women are critical references for prevention of congenital toxoplasmosis and clinical care.

Infection with *T. gondii* is usually determined by detection of specific immunoglobulins to *Toxoplasma* in patient sera. The presence of IgG is generally regarded as an indication that an infection has occurred (Beaman et al. 1995), but IgM indicates an urgent state or an infection that has occurred within the last year (Liesenfeld et al. 1997; Wilson et al. 1997; Wong and Remington 1994) although IgM remains detectable 12 years after infection in some special cases (Bobic et al. 1991). Because humans are intermediate hosts for *T. gondii*, and the parasite invades patients' muscles and organs, it is convenient to test the presence of specific antibodies directly from blood samples rather than by detecting the parasite. Alternative methods to diagnose recent infections are to measure the level of specific IgM or other specific antigens in patients' blood samples (Li et al. 2000). Different titres of specific immunoglobulins against the parasite may indicate different densities of infections. Relative amounts of antibodies to *T. gondii* in relation to different living styles, however, require special studies with suitable samples.

Indigenous tribes in Taiwan and recent immigrants represent different cultures from the general population of Taiwan, including particular living styles, educational backgrounds and environmental characteristics. Traditionally, indigenous tribes hunt prey and share their captures with their people, and thus consumption of raw meats is a part of their traditional cultures. Immigrants (most are women) have become a special and sizeable population in Taiwan. There is a rapid increase in the number of groups on the island with 1/8 of pupils being born to immigrant women. Seroprevalence of toxoplasmosis is approximately 9% in pregnant women and their babies in Taiwan. However, 93% of the study population is Taiwanese (Hu et al. 2006). No study on the infection of *T. gondii* among indigenes and immigrants has ever been conducted, nor have pregnant women and their newborn babies been investigated. Therefore, this study was aimed to reveal seroprevalence and the risk factors for *Toxoplasma* infection among indigenous and immigrant pregnant women and their babies in relation to different cultures.

Materials and methods

Blood samples were collected from hospitals and clinics in mid-Taiwan, and tested in laboratories. The Institutional Review Board of the China Medical University Hospital approved the ethnic experiment, and all the participating pregnant women signed their written consents before samples were taken. Parents signed written consents for cord blood samples of their babies.

Participants

Indigenous and immigrant pregnant women who were in the first trimester gestation and visited hospitals or clinics for their first antenatal check would be participants for the present study. Blood samples taken for antenatal routine examination and the anti-*Toxoplasma* antibody test were collected at the same time. Because not all women delivered their babies during the investigation period or at participating hospitals, only 160 cord blood samples were collected for the investigation. Indigenous tribes including Atayal, Bunun, Amis, Yami and Palwan were studied, and immigrant women from Vietnam, Indonesia, Laos, Mainland China, Thailand and the Philippines were included in the current study (Table 1).

Samples

Pregnant women (426) and 160 1-day-old newborn babies donated their blood samples. Blood samples were spun at 3,000 rpm for 10 min to remove cells and the sera were shipped to the laboratory in dry ice. All samples were stored at −80°C until use.

IgG and IgM assays

T. gondii IgM μ-capture ELISA (enzyme linked immunosorbent assay) kit and *T. gondii* IgG ELISA kit were purchased from IBL (Immuno-Biological Laboratory, Hamburg, Germany). Assays for specific IgG and IgM of the blood samples were carried out according to the manufacturer's instructions. A series of dilutions were prepared from serum samples and then added to the ELISA plates coated with specific antigens of *T. gondii*. This was followed by a 2-h incubation at room temperature. After blocking, rabbit anti-human Ig conjugated with horse radish peroxidase (HRP) was added and incubation was carried out as described above. After the unbound materials were

Table 1 Information of participants

Tribes	No. of indigenes (%)		Nationalities	No. of immigrants (%)	
Atayal	130	(53.1)	Vietnam	124	(68.5)
Bunun	108	(44.1)	Indonesia	31	(17.1)
Amis	5	(2.0)	Laos	9	(5.0)
Yami	1	(0.4)	Mainland China	6	(3.3)
Palwan	1	(0.4)	Thailand	4	(2.2)
			Philippines	3	(1.7)
			Unknown	4	(2.2)
Age					
15–19	32	(13.1)		5	(2.9)
20–24	113	(46.1)		110	(64.0)
25–29	55	(22.4)		43	(25.0)
30–34	25	(10.2)		11	(6.4)
35–39	15	(6.1)		3	(1.7)
40–44	4	(1.6)		0	(0.0)
45–49	1	(0.4)		0	(0.0)
Education					
Illiteracy	0	(0.0)		3	(2.0)
Primary school	14	(5.9)		37	(25.0)
Junior high school	93	(39.4)		67	(45.3)
Senior high school	116	(49.2)		35	(23.6)
Bachelor	13	(5.5)		5	(3.4)
Master	0	(0.0)		1	(0.7)
Occupation					
Civil service	4	(1.7)		0	(0.0)
Teacher	4	(1.7)		1	(0.6)
House wife	189	(79.1)		154	(92.8)
Farmer	23	(9.6)		6	(3.6)
Service trade	12	(5.0)		2	(1.2)
Others[a]	7	(2.8)		3	(1.8)

[a] Others among the indigenes and immigrants include businessmen (0.8 and 0.6%), labourers (0.8 and 0.6%) and free lance workers (1.2 and 0.6%), respectively.

washed away in PBS, the plate was finally developed with tetramethylbenzidine (TMB) and read in an ELISA reader at 450 nm. The cut-off for IgG was >35 IU/ml and the equivocal threshold was 30–35 IU/ml, whereas the cut-off for IgM was 1.1 U. For instance an IgM measurement between 0.9 and 1.1 U could not be considered positive or negative as an equivocal threshold.

Information collection

Information on sources of the infection and on environmental characteristics was collected by means of a questionnaire given out on the day blood samples were taken. Those who could not read the questionnaire were interviewed instead. Questionnaires were designed to reveal the participant's knowledge of the parasite, the ways of infection and prevention. These were followed by their tribe/nationality, age, educational background, occupation, maternal history, and habits of consumption of such items as unwashed vegetable/fruit, untreated water, raw/undercooked meats or viscera; questionnaires finally asked whether interviewees came in contact with cats, cat faeces or soil, or lived on farms and worked with animals.

Statistical analysis

For data analysis and statistics, the PC-based software SPSS 13.0 was applied. Population constituents, age, education and occupation were analyzed in relative to the presence of specific anti-*Toxoplasma* IgG and IgM. The correlation of antibody titre between mothers and babies was tested by the Spearman test. The titre of antibodies of two groups was expressed as mean±SE. The difference between two groups was tested by Student *t* test. Risk factors responsible for *T. gondii* infection were analyzed using odd ratios, chi-square test and Fisher exact test.

Results

Information on participants

As already stated, a total of 426 pregnant women and 160 newborn babies from mid-Taiwan participated in this study. The 245 indigenous pregnant women were from five different indigenous tribes. The 181 pregnant immigrant women were from Vietnam, Indonesia, Laos, Mainland

China, Thailand and the Philippines (Table 1). The majority of indigenous women were from the Atayal (53.1%) and Bunun (44.1%) tribes and the majority of immigrant women were from Vietnam (68.5%). The distribution of age 20–29 was 68.5% in indigenes and 89% in immigrants. Their highest level of education was mostly high school and the occupation of 79.1% of indigenes and 92.8% of immigrants was given as "house wife."

Seroprevalence of toxoplasmosis

Sera of pregnant women and cord blood samples of newborn babies were obtained and tested for specific antibodies (IgG and IgM) to *Toxoplasma* by ELISA. Initial antibody assays showed that about 40.6% (99 of 244) of indigenous and 18.2% (33 of 188) of immigrant pregnant women developed specific anti-*Toxoplasma* IgG (Table 2). The relative risk (RR) of indigenous to immigrant women was 2.35 and the odds ratio (OR) was 3.34, 95% CI: 1.93–4.8 ($P<0.001$). For IgM assay, 2.9% (7 of 244) indigenous and 2.2% (4 of 181) immigrant women present specific anti-IgM positive. Among the newborn babies, 44.3% (39 of 88) of indigenous and 23.6% (17 of 72) of immigrant babies had specific anti-*Toxoplasma* IgG. No specific IgM for *Toxoplasma* was detected in both groups of babies and the body weight of babies showed no marked different between the two groups. Assays for specific IgG titre showed that indigenous women had an 8.5-fold-higher reading than the immigrant ($P<0.001$) and their babies had 10-fold difference ($P<0.001$; Fig. 1). Cross analysis demonstrated that the IgG titre in both indigenous and immigrant mothers had significant correlation to the IgG titre of their babies ($P<0.001$; Table 3).

Risk factors for toxoplasmosis

To assess the knowledge of *Toxoplasma* and source of infection, the information was collected by questionnaire or interview. Only 4.2% (10 of 236) of indigenous and 1.7% (3 of 177) of immigrant women ever heard about the parasite. Seven indigenous women but none of the immigrant women knew how to avoid *T. gondii* infection.

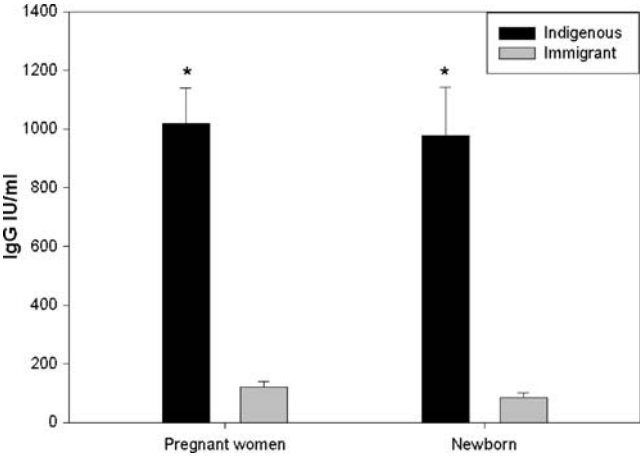

Fig. 1 Positive titre of specific anti-*Toxoplasma* IgG antibody in pregnant women and newborns. Sera from indigenous and immigrant women with 12-week pregnancy and 1-day-old newborn babies were tested for the titre of specific anti-*Toxoplasma* IgG antibody by ELISA. The statistics was indigenes versus immigrants using Student *t* test *$P<0.001$

Information of living styles pertaining to the sources of infection revealed that drinking untreated water (OR=2.34. 95% CI: 1.36–4.02), eating raw or undercooked meats (OR=10.11 95% CI: 4.92–20.78) and viscera (OR=9.16, 95% CI: 2.97–27.94), contact with cats (OR=5.69, 95% CI: 2.83–11.47), contact with soil (OR=2.55 95% CI: 1.72–3.80), working with animals (OR=2.03, 95% CI: 1.04–3.97) and living on a farm (OR=2.95, 95% CI: 1.17–7.39) were significantly different between indigenous and immigrant groups (Table 4). Risk factors of *Toxoplasma* infection in terms of positive IgG between these two groups were also analyzed. The significantly higher percentage of infection in indigenous women compared to immigrant women seems caused mainly by the consumption of raw/undercooked meats (OR=4.47, 95% CI: 1.46–13.74, $P=0.005$), contact with cats ($P=0.013$) and contact with soil (OR=2.56, 95% CI: 1.12–5.85, $P=0.028$; Table 5).

Further analysis of the investigated indigenous women who indicated that they regularly ate raw/undercooked meats (85 of 244) or viscera (33 of 242) showed that they mainly consumed raw/undercooked pork (67.1%) and the

Table 2 Specific anti-*Toxoplasma* IgG and IgM antibodies positive rate in pregnant women and newborn babies

	Indigenes (no. positive/no. total)		Immigrants (no. positive/no. total)	
Antibodies	Mothers	Babies[a]	Mothers	Babies
IgG (+)	40.6% (99/244)*	44.3% (39/88)	18.2% (33/181)	23.6% (17/72)
IgM (+)	2.9% (7/244)	0% (0/88)	2.2% (4/181)	0% (0/72)

*$P<0.001$, indigenous versus immigrant mothers, OR=3.34, 95% CI: 1.93–4.80.
[a] Not every mother delivers her baby during the investigation period.

Table 3 Correlation of specific anti-*Toxoplasma* IgG titre between mothers and their newborn babies

Mum's IgG level	Parameters[a]	Baby's IgG level	
		Indigene	Immigrant
Indigene	*r*	0.616	NA
	P	0.000*	NA
Immigrant	*r*	NA[b]	0.882
	P	NA	0.000**

*$P<0.001$, correlation of specific IgG titre between indigenous mothers and their babies.
**$P<0.001$, correlation of specific IgG titre between immigrant mothers and their babies.
[a] Spearman's rho test.
[b] NA means not applicable.

raw/undercooked viscera of pigs (31.8%), whereas only three immigrant women consumed raw/undercooked meat or viscera and only one of those ate raw/undercooked meat or the viscera from pigs. Investigation also showed that some of the indigenous women also consumed other raw or undercooked meats (19.3%) from seafood, boar or polatouche. Analysis of risk factors in different raw/undercooked meats or viscera (Table 6) showed that indigenes and immigrants had significantly different habits of eating raw/undercooked pork ($P=0.000$). Further study of these categories in women who had specifically positive IgG to *Toxoplasma* also showed that consumption of raw/undercooked pork was significantly different in the cases of indigenes and immigrants ($P=0.004$).

Table 5 Risk factors responsible for *T. gondii* infection among pregnant women compared to immigrant pregnant women, who had specific anti-*Toxoplasma* IgG positive

Exposure to risk factors	Indigene		Immigrant		*P* value
	Yes	No	Yes	No	
Fruits/vegetables with soil	21	76	7	25	1.000
Unwashed fruits/vegetables	17	81	5	28	1.000
Untreated water	24	74	4	28	0.336
Raw/undercooked meats	37	60	3	29	0.005*,[a]
The raw/undercooked viscera	14	84	2	30	0.559
Contact with cat	25	71	1	32	0.013*
Cat at home	12	41	2	8	0.710
Cleaning cat faeces	4	26	0	5	1.000
Cat fed raw meat	2	23	0	6	1.000
Cat that hunts	7	17	0	5	1.000
Cat fed tinned food	3	21	0	5	1.000
Contact with soil	55	43	11	22	0.028*,[b]
Working with animals	12	86	3	29	1.000
Living on farm	5	94	0	32	1.000
Travel outside Taiwan	1	91	4	29	0.034*

*$P<0.05$, indigenes versus immigrants, using Fisher exact test
[a] OR=4.47, 95% CI: 1.46–13.74.
[b] OR=2.56, 95% CI: 1.12–5.85.

Discussion

The investigation of toxoplasmosis in Taiwan is focused on two special groups: indigenes of Taiwan and immigrants from Mainland China or Southeast Asian countries (Table 1; Hu et al. 2006). Specifically positive IgG and IgM standard

Table 4 Risk factors responsible for *T. gondii* infection among indigenous pregnant women compared to immigrant pregnant women

Exposure to risk factors[a]	Indigenes		Immigrants		Odds ratio (95% CI)	
	Yes	No	Yes	No		
Fruits/vegetables with soil	59	181	42	133	1.03	(0.66–1.63)
Unwashed fruits/vegetables	37	206	25	151	1.08	(0.63–1.87)
Untreated water	58	183	21	155	2.34	(1.36–4.02)*
Raw/undercooked meats	85	157	9	168	10.11	(4.92–20.78)**
The raw/undercooked viscera	33	209	3	174	9.16	(2.97–27.94)**
Contact with cat	61	178	10	166	5.69	(2.83–11.47)**
Cat at home	30	106	8	25	0.88	(0.36–2.15)
Cleaning cat faeces	13	58	1	19	–	$P=0.506$[b]
Cat fed raw meat	7	49	2	18	–	$P=1.000$[b]
Cat that hunts	14	38	7	13	0.68	(0.23–2.06)
Cat fed tinned food	13	38	4	16	1.37	(0.40–4.64)
Contact with soil	152	91	70	107	2.55	(1.72–3.80)**
Working with animals	34	210	13	163	2.03	(1.04–3.97)*
Living on farm	23	222	6	171	2.95	(1.17–7.39)*
Travel outside Taiwan	1	243	12	164	–	$P=0.001$[b]

*$P<0.05$, indigenes versus immigrants, using Chi-square test.
**$P<0.001$, indigenes versus immigrants, using Chi-square test.
[a] Exposure to risk factors in the past four months.
[b] Fisher exact test.

Table 6 Detailed categories of raw/undercooked meats or the viscera consumed by indigenous and immigrant pregnant women

Exposure to risk factors	Total women *P* value	IgG positive women *P* value
Raw/undercooked pork	0.000*	0.004**
Raw/undercooked beef	1.000	1.000
Raw/undercooked lamb	0.641	0.442
Raw/undercooked chicken	1.000	1.000
Other raw/undercooked meats[a]	0.111	0.714
The raw/undercooked viscera of pig	0.201	0.450
The raw/undercooked viscera of cow	1.000	1.000
The raw/undercooked viscera of sheep	1.000	0.442
The raw/undercooked viscera of chicken	0.402	1.000
The other raw/undercooked viscera[a]	0.313	1.000

*$P<0.001$, total indigenous pregnant women versus total immigrant pregnant women.
**$P<0.005$, anti-*Toxoplasma* IgG antibody positive indigenous pregnant women versus anti-*Toxoplasma* IgG antibody positive immigrant pregnant women.
[a] Others mean meats or the viscera were from seafood, boar or polatouche.

titre were used to predict the prevalence of *T. gondii* infection (Jenum et al. 1998; Decavalas et al. 1990; Paul et al. 2001; Montoya et al. 2001), and these are still the best way to predict possible congenital toxoplasmosis from the sera of pregnant women.

The presence of immunoglobulins G and M specifically against *T. gondii* suggests chronic or recent infection in mothers and congenital infection in babies. IgG present in pregnancy and cord blood samples indicates maternal exposure to toxoplasmosis during her lifetime, whereas IgM in the pregnancy samples reflects recent infection in the woman. Moreover the presence of IgM in cord blood reflects congenital toxoplasmosis. Our present study shows that seroprevalence of specific IgM for toxoplasmosis does not differ much in indigenous and immigrant groups. However, for specific IgG study, we found that specific IgG for *Toxoplasma* was higher in indigenes (40.6%) and immigrants (18.2%) as compared with 9.1% in Taiwanese (Hu et al. 2006). Especially in indigenous tribes, *T. gondii* infection is closely related to traditional cultures. The majority of indigenous women investigated in the current study live in mountainous areas of Taiwan and some of them eat raw prey. Immigrants, however, do not generally do so and thus a 2.2-fold-higher (in percentage) infection was found in the indigenous group as compared to the immigrant group (Table 2). Moreover, their specific IgG titre was 8.5-fold higher than the immigrants, suggesting high-density infection (or repeated infections) could have occurred (Fig. 1). Immigrant women counted for 16.8% in all the married couples of Taiwan and 11.6% of babies were born to immigrant mothers in 2006 (Bulletin of Department of Statistics 2007). As the positive rate of specific IgG for *Toxoplasma* indicates, childhood infection and the positive rate in immigrants is still higher than in Taiwanese, implying that the living style in their mother countries may differ from that in Taiwan. In analyses of relative amounts of specific antibodies of mothers pertaining to their babies, the total amount of antibodies is an important indicator especially for high-density and repeated infection. The IgG titre found in newborn babies are significantly related to their mothers' infection in both indigenous and immigrant ($P<0.001$) groups (Table 3), indicating that the IgG was probably transmitted from mother to baby via the placenta. We did not find specific IgM positive for *Toxoplasma* in the babies, however, seroprevalence of IgG for toxoplasmosis in mothers, especially in indigenous mothers, presents a high positive rate and it reflects the possibility that congenital infection could have occurred.

Risk factors for *Toxoplasma* infection were analyzed from living styles and listed in Table 4, showing that living styles in indigenous women including drinking untreated water, consumption of raw/undercooked meats (especially raw/undercooked pork), or viscera, contact with cats or soil, working with animals or living on a farm are the most likely ways to the infection. Risk factors for positively specific IgG to *Toxoplasma* were further analyzed (Table 5), showing that consumption of raw/undercooked meats, especially raw/undercooked pork (Table 6), contact with cats and contact with soil are the most important risk factors for *Toxoplasma* infection in indigenous women. Similar results regarding the risk factors for *Toxoplasma* infection had been reported elsewhere (Cook et al. 2000). Pork was shown to be a major infection source from food (Dubey 1994), thus we also paid much attention to the raw or undercooked meats in our investigation of risk factor for *T. gondii* infection. Some edible meats from commercial products in the UK were also found to contain virulent *T. gondii* (Aspinall et al. 2002). Although only 2.8% immigrant women consumed raw/undercooked meats, a common feature between indigenous and immigrant groups is that the majority of them are housewives (Table 1), and thus, most of them typically come in contact with raw meats in kitchens. Therefore, processing or tasting meats during meal preparations could be another risk source of infection. Some reports have ruled out contact with cats as a risk factor (Cook et al. 2000), and others suggested that there was no close correlation between cat owners and the *T. gondii* infection (Dubey 1995). Examination for the presence of oocyst indicated that, though no oocyst on cat fur was found, the oocyst was found in faeces buried in soil (Dubey 2000). Our results showed, however, that contact with cats is also an important risk factor for pregnant women and this is closely related to another risk factor, contact with soil, in the present study.

Indigenous people living in the mountainous areas of mid-Taiwan are more likely than the general population to drink untreated water (especially untreated spring water), work with animals and live on farms. Although these factors were related to *Toxoplasma* infection in overall analysis (Table 4), they were not significantly related to the infection if only positively specific IgG samples were analyzed (Table 5). The safety of drinking untreated water is largely related to the hygiene conditions of the investigated region, and investigation has disclosed that some outbreaks associated with toxoplasmosis are closely related to contaminated water (Benenson et al. 1982; Bowie and King 1997; Bahia-Oliveira et al. 2003); thus, drinking untreated water should be avoided during pregnancy.

In conclusion, our study revealed seroprevalence of toxoplasmosis in indigenous and immigrant pregnant women in Taiwan. We also identified some risk factors for the infection. High seroprevalence of toxoplasmosis in the mother implies a possibility of congenital toxoplasmosis in the baby. This investigation also revealed that educational backgrounds were not significantly related to *Toxoplasma* infection, however, knowledge of the parasite and prevention as a part of special antenatal health education seems required in both groups of women.

Acknowledgment This project was supported by a grant from Centre for Disease Control, Taiwan, ROC (DOH92-DC-1054).

References

Ades AE, Blokes DJ (1993) Modeling age- and time-specific incidence from seroprevalence: toxoplasmosis. Am J Epidemiol 137:1022–1034

Allain JP, Palmer CR, Pearson G (1998) Epidemiological study of latent and recent infection of *Toxoplasma gondii* in pregnant women from a regional population in the CK. J Infect 36:189–196

Ancelle T, Goulet V, Tirard-Fleury V, Baril L, du Mazaubrun C, Thulliez P (1996) La *Toxoplasma* chez la femme emceinte en France en 1995. Resultats dune enquete nationale perinatale. Bulltin Epidemiologique Hebdomadaire 51:227–229

Aspinall TV, Marlee D, Hyde JE, Sims PF (2002) Prevalence of *Toxoplasma gondii* in commercial meat products as monitored by polymerase chain reaction-food for thought? Int J Parasitol 32:1193–1199

Bahia-Oliveira LMG, Jones JL, Azevedo-Silva J, Alves CCF, Orefice F, Addiss DG (2003) Highly endemic, waterborne toxoplasmosis in north Rio de Janeiro state, Brazil. Emerg Infect Dis 9:55–62

Beaman MH, McCabe RE, Wong SY, Remington JS (1995) *Toxoplasma gondii*. In: Mandel GL, Bennett JE, Dolin R (eds) Principles and practices of infectious diseases, 4th edn. Churchill Livingstone, Inc., New York, NY, pp 2455–2475

Benenson MW, Takafuji ET, Lemon SM, Greenup RL, Sulzer AJ (1982) Oocyst-transmitted toxoplasmosis associated with ingestion of contaminated water. N Eng J Med 307:666–669

Bobic B, Sibalic D, Djurkovic-Djakovic O (1991) High titre of IgM antibodies specific for *Toxoplasma gondii* in pregnancy 12 years after primary *Toxoplasma* infection. Case report. Gynecol Obstet Invest 31:182–184

Bowie WR, King AS (1997) Outbreak of toxoplasmosis associated with municipal drinking water. The BC Toxoplasma Investigation Team. Lancet 350:173–177

Bulletin of Department of Statistics (2007) Ministry of Interior, Taiwan

Cook AJ, Gilbert RE, Buffolano W (2000) Sources of *Toxoplasma* infection in pregnant women: European multicentre case-control study. European Research Network on Congenital Toxoplasmosis. BMJ 321:142–147

Decavalas G, Papapetropoulou M, Giannoulaki E, Tzigounis V, Kondakis XG (1990) Prevalence of *Toxoplasma gondii* antibodies in gravidas and recent aborted women and study of risk factor. Eur J Epidemiol 6:223–226

Dubey JP (1994) Toxoplasmosis. J Am Vet Med Assoc 205:1593–1598

Dubey JP (1995) Duration of immunity to shedding of *Toxoplasma gondii* oocysts by cats. J Parasitol 81:410–415

Dubey JP (1996) Infectivity and pathogenicity of *Toxoplasma gondii* oocysts for cats. J Parasitol 82:957–961

Dubey JP (2000) Sources of *Toxoplasma gondii* infection in pregnancy. Until rates of congenital toxoplasmosis fall, control measures are essential. BMJ 321:127–128

Dupouy Camet J, Gavinet BIF, Paugm A, Tourte Schaeffer C (1993) Transmission, incidence and prevalence of toxoplasmosis. Med Mal Infect 23:139–147

Gilbert RE, Tooleu YA, Cubitt WD, Ades AE, Masters J, Peckham CS (1993) Prevalence of *Toxoplasma* IgG among pregnant women in west London according to country of birth and ethnic group. BMJ 306:185

Horion M, Thoumsin H, Senterre F, Lambotte R (1990) 20 years of screening for toxoplasmosis in pregnant women. The Liege experience in 20,000 pregnancies. Rev Med Liege 45:492–497

Hu I-J, Chen P-C, Su F-C, Hsieh C-J, Jeng S-F, Liao H-F, Su Y-N, Lin S-J, Hsieh W-S (2006) Perinatal toxoplasmosis, Northern Taiwan. Emerg Infect Dis 12:1460

Jenum PA, Kapperud G, Stray Pedersen B, Melby KK, Eskild A, Eng J (1998) Prevalence of *Toxoplasma gondii* specific immunoglobulin G antibodies among pregnant women in Norway. Epidemiol Infect 120:87–92

Jones JL, Kruszon-Moran D, Wilson M, Mc Quillan G, Navin T, McAuley JB (2001) *Toxoplasma gondii* infection in the United States: seroprevalence and risk factors. Am J Epidemiol 154:357–365

Li SL, Maine G, Suzuki Y, Araujo FG, Van GG, Remington JS, Parmley S (2000) Serodiagnosis of recently acquired *Toxoplasma gondii* infection with a recombinant antigen. J Clin Microbiol 38:179–184

Liesenfeld O, Press C, Montoya JG, Gill R, Isaac-Renton JL, Hedman K, Remington JS (1997) False-positive results of immunoglobulin M (IgM) toxoplasma antibody tests and importance of confirmatory testing: the Platelia Toxo IgM Test. J Clin Microbiol 35:174–178

Montoya G, Kinney S, Press C, Remington JS (2001) Effect of testing for IgG avidity in the diagnosis of *Toxoplasma gondii* infection in pregnant women: experience in a US reference laboratory. J Infect Dis 183:1248–1253

Nokes DJ, Forsgren M, Gille E, Ljungstrom IL (1993) Modelling *Toxoplasma* incidence from longitudinal seroprevalence in Stockholm, Sweden. Parasitology 107:33–40

Paul M, Petersen E, Szczapa J (2001) Prevalence of congenital *Toxoplasma gondii* infection among new-borns from the Poznan region of Poland: validation of a new combined enzyme immunoassay for *Toxoplasma gondii*-specific immunoglobulin A and immunoglobulin M antibodies. J Clin Microbiol 39:1912–1916

Remington JS, Mcleod R, Desmonts G (1995) Toxoplasmosis. In: Remington JS, Klein JO (eds) Infectious diseases of the fetus and newborn infant. 4th edn. WB Saunders, Pennsylvania, pp 140–267

Tenter AM, Heckeroth AR, Weiss LM (2000) *Toxoplasma gondii*: from animals to humans. Int J Parasitol 30:1217–1258

Wilson M, Remington JS, The FDA Toxoplasmosis Ad Hoc Working Group (1997) Evaluation of six commercial kits for the detection of human immunoglobulin antibodies to *Toxoplasma gondii*. J Clin Microbiol 35:3112–3115

Wong SY, Remington JS (1994) Toxoplasmosis in pregnancy. Clin Infect Dis 18:853–862