J Vet Sci. 2022 Jan;23(1):e13
https://doi.org/10.4142/jvs.21209
pISSN 1229-845X·eISSN 1976-555X

Journal of Veterinary Science

Original Article
Parasitology

Check for updates

Seroprevalence of *Toxoplasma gondii* in cats in mainland China 2016–2020: a meta-analysis

Siyu Zhou [1,2], **Ziyin Sang** [1,2], **Lijun Wang** [1,2], **Tangjie Zhang** [1,2,*]

[1]Institute of Comparative Medicine, College of Veterinary Medicine, Yangzhou University, Yangzhou, Jiangsu 225009, China
[2]Jiangsu Co-innovation Center for Prevention and Control of Important Animal Infectious Diseases and Zoonoses, Yangzhou, Jiangsu 225009, China

OPEN ACCESS

Received: Jul 28, 2021
Accepted: Sep 14, 2021
Published online: Sep 26, 2021

***Corresponding author:**
Tangjie Zhang
Institute of Comparative Medicine, College of Veterinary Medicine, Yangzhou University, Yangzhou, Jiangsu 225009, China.
Email: slx@yzu.edu.cn

ORCID iDs
Siyu Zhou
https://orcid.org/0000-0001-7459-9982
Ziyin Sang
https://orcid.org/0000-0003-3036-4123
Lijun Wang
https://orcid.org/0000-0002-4231-6551
Tangjie Zhang
https://orcid.org/0000-0001-5170-6298

Funding
This research was supported by the Priority Academic Program Development of Jiangsu Higher Education Institutions and Jiangsu Co-innovation Center for Prevention and Control of Important Animal Infectious Diseases and Zoonoses, Yangzhou, 225009.

Conflict of Interest
The authors declare no conflicts of interest.

ABSTRACT

Background: *Toxoplasma gondii* can infect humans and most animals and has a very high infection rate worldwide, including in China. The number of people infected with *T. gondii* in China increases with the number of cats.
Objectives: We investigated the seropositive rate of *T. gondii* in cats over the last five years and analyzed the risk factors via meta-analysis.
Methods: We retrieved 20 studies, with a total of 5,158 cats, published between 2016 and 2020, used the DerSimonian-Laird model and calculated seroprevalence estimates with the variance stabilizing double arcsine transformation.
Results: The overall seroprevalence rate after sinusoidal conversion was 19.9% (95% confidence interval [CI], 15.9–23.9; 966/5,158), lower than the domestic report from 1995 to 2015 (24.5%, 95% CI, 20.1–29.0). There was substantial heterogeneity among studies (χ^2 = 262.32; $p < 0.001$; I^2 = 64.6%). Regression analysis of possible heterogeneous causes and subgroup analysis showed that age and whether cats were stray or not have a significant effect on the seropositive rate.
Conclusions: Articles published in recent five years suggest that the seroprevalence estimates of *Toxoplasma gondii* in cats has decreased. Cats, as the final host of *T. gondii*, are an important cause of the spread of the parasite, and this is an important concern for public health.

Keywords: *Toxoplasma gondii*; cats; mainland China; seroprevalence; meta-analysis

INTRODUCTION

Toxoplasma gondii is an obligate intracellular protozoan parasite that causes toxoplasmosis. The parasite is globally distributed and can infect a wide range of warm-blooded animals. As the final host of *T. gondii*, cats are very important in the life cycle. After being infected, they excrete oocysts in their feces which can subsequently infect all non-feline warmblood animals (including humans) as intermediate hosts [1]. People living in high-density cat population cities are likely to be at risk of infection.

Normally, people infected with *T. gondii* do not have obvious symptoms, and in some patients with immune diseases such as AIDS it can have severe consequences [2]. Primary *T. gondii*

Author Contributions

Conceptualization: Zhou S; Data curation: Zhou S, Sang Z; Formal analysis: Wang L; Funding acquisition: Zhang T; Investigation: Zhou S; Methodology: Zhou S; Project administration: Zhang T; Writing - original draft: Zhou S; Writing - review & editing: Zhou S.

infection in pregnant women may result in abortion, stillbirth, or lifelong disabilities of the unborn child [3]. Risk factors for *T. gondii* infection in humans include eating raw meat, drinking unpasteurized goat milk and having three or more cats [4]. although in pregnant women the rate is < 5% [5]. Approximately 0.3% of pregnant women were diagnosed with an acute infection of *T. gondii* between 1990 and 2010 [6]. Pregnant people raising cat at home is associated with a significantly higher seroprevalence of *T. gondii* than having no cat at home [7].

Most animals can be infected with *T. gondii,* so food-borne infection and pet is the main route of transmission. Raw or undercooked meat consumption is significantly associated with human *T. gondii* infection [8]. The *T. gondii* average seroprevalence in mainland China of food-borne infection is 12%–53%, among them the chicken rate is 7.7%–31% and in small ruminants it is 6.5%–18% [5]; The average seropositive rate of *T. gondii* in pet dogs in mainland China is 11.1% [9].

A survey of seroprevalence rate in cats in China found that this value was 24.5% before 2016 [10]. With the recent development of the economy and urbanization, more people choose to keep pets. Many stray cats become pets in the family, which greatly increases the frequency of contact between people and cats. Increasing epidemiological data provide more detailed information on the seropositive rate of *T. gondii* in cats, allowing an evidence-based method to prevent and control this infectious disease.

MATERIALS AND METHODS

The study was conducted according to the PRISMA guideline (Preferred Reporting Items for Systematic Reviews and Meta-Analyses. The PRISMA checklist was used to ensure inclusion of all relevant information in the analysis (see **Supplementary Data 1**).

Search strategy

We searched five bibliographic databases, of which 2 were in English and 3 were in Chinese. The English PubMed search used ("Toxoplasma" [All Fields]) OR "Toxoplasma gondii" [All Fields]) AND (cat [All Fields] OR "pet" [Supplementary Concept]) AND (China) AND ("2016/01/1"[PDAT]: "2020/12/31"[PDAT]). The Science Direct search used the MeSH terms "Toxoplasma/ Toxoplasma gondii" and "China" and "cat/pet", published date limited 2016/01/01 to 2020/12/31. The Chinese Biomedical Literature Database (CBM), China National Knowledge Infrastructure (CNKI) and WanFang database were searched using the terms "Toxoplasma gondii" and "cat/pet" in Chinese ("gongxingchong/gongxingti", and "mao/chongwu", respectively). The search time limit publication date was from January 2016 to December 2020. We manually searched the reference list in each paper for further articles, but did not contact the authors of the original study for more information. All articles are obtained through library resources.

Inclusion and exclusion criteria

Full texts were obtained and read to see if they met the following conditions: (i) targeted objectives included cats; (ii) locations within mainland China; (iii) cross-sectional study; (iv) clear serological research methods; (v) exact total and positive numbers were provided; and (vi) sample size between 25 and 3,000. Studies were excluded if they did not fulfil all of these criteria. The selection and identification of the literature were carried out independently by 2 reviewers. If the results were inconsistent, they were resolved by a third party or through discussion and negotiation.

Literature data extraction

The data extracted included (i) study characteristics: the first author and year of publication; (ii) study methodology: sampling location, time and method and the serological test used; (iii) characteristics of cats: pet or stray, sex, age category; (iv)sample size, the number of positives and/or *T. gondii* seroprevalence.

Literature quality assessment

Since animal cross-sectional studies differ from randomized clinical trials, methods for their systematic evaluation are not yet mature. Therefore, based on the Cochrane quality assessment, we adjusted the systematic review method of the animal cross-sectional study clinical trials and assessed the risk of bias in the included studies. RevMan 5.3 was used for quality assessment in terms of selection bias, performance bias, detection bias and report bias. The following seven items were examined and given a score based on a simple scale: 2 for "yes", 1 for "unsure" or 0 for "no". ① Was the research question/objective clearly described and stated? ② Was animal characteristics clarified? ③ Was the sampling method clearly stated? ④ Was the serological test method clearly pointed out? ⑤ Were the subjects categorized into different subgroups? ⑥ Did they use blind method when measuring? ⑦ Was there selective result bias?

Pooling and heterogeneity analyses

Stata 15.0 software was used for statistical analysis. First, I^2 and Q tests were used to evaluate whether the effect size of each study was heterogeneous [11], and then the effect model was selected. $p \geq 0.10$ and $I^2 < 50\%$ indicate that there is low or no statistical heterogeneity between the effect sizes of each study, and therefore the inverse variance model should be used for analysis. $p < 0.10$ and $I^2 \geq 50\%$ indicate a large statistical heterogeneity between the effects of each study and that the DerSimonian-Laird model should be used. Meta-regression is used for different subgroups to calculate odds ratios to determine whether it is a possible source of heterogeneity, and to perform subgroup analysis on the possible causes of heterogeneity.

Although the inverse variance method is widely used and is suitable for prevalence rates around 0.5, when it is too small or large (0%–30%, 70%–100%), the research will get more weight and other issues, extreme values affect the final result and need to be adjusted to achieve a normal distribution as much as possible. Therefore, we calculated seroprevalence estimates with the variance stabilizing double arcsine transformation by the following formula:

$$t = \arcsin\left[\sqrt{\{r/(n+1)\}}\right] + \arcsin\left[\sqrt{\{(r+1)/(n+1)\}}\right],$$

where t = transformed seroprevalence, r = positive numbers and n = sample size; se(t) = sqrt {1/(n + 0.5)}, where se = standard error and the back transformation to a proportion is done using: $p = (\sin(t/2))^2$. The seroprevalence and its 95% confidence interval (CI) for each study were calculated, and then point estimates and their 95% CIs of pooled seroprevalence of all included studies were analyzed.

Potential sources of heterogeneity were investigated further by arranging groups of studies according to potentially relevant characteristics. In this study, subgroup analysis was stratified by type of cat (stray or pet), sex (male or female), age (≤ 1 year, > 1 year ≤ 3 years, or > 3 years), geographical region (Eastern region including: Beijing, Tianjin, Hebei Province, Liaoning Province, Shanghai, Jiangsu Province, Zhejiang Province, Fujian Province, Shandong Province, Guangdong Province and Hainan Province; Central region including:

Shanxi Province, Jilin Province, Heilongjiang Province, Anhui Province, Jiangxi Province, Henan Province, Hubei Province and Hunan Province; or Western region including: Sichuan Province, Chongqing, Guizhou Province, Yunnan Province, Tibet Autonomous Region, Shanxi Province, Gansu Province, Qinghai Province, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous region, Guangxi Zhuang Autonomous Region and Inner Mongolia Autonomous Region), and main serological test. Meta-regression was used to investigate any significant difference between/among subgroups and the value of each odds ratio was calculated, if the sources of heterogeneity meta-regression result $p < 0.05$, we will caculate the subgroup odds ratio (OR).

Bias and sensitivity tests

The across-study (publication) bias was examined by funnel plots. In addition, statistical significance was assessed by the Egger's regression asymmetry test [12]. $p \geq 0.05$ indicates that the risk of publication bias is small and $p < 0.05$ indicates a possible publication bias. Sensitivity analyses were conducted by the systematic exclusion of one study at a time and recalculating the pooled seropositive rate. A study was deemed to have no influence if the pooled estimate without it was within the 95% CI of the overall seroprevalence. Extracted data were entered into Microsoft Office Excel 2019 and Adobe Illustrator was used to polish the figure.

Changes in the seroprevalence of cat *T. gondii* in different regions of mainland China over time

We researched the studies published between 1995 and 2020 used the previous search strategy and analyzed them to calculate trends in seroprevalence in four regions: Yangtze River Delta: Shanghai, Jiangsu, Zhejiang, Shandong; Pearl River Delta: Fujian, Guangdong, Hainan; Beijing and surroundings: Beijing and Hebei; North West: Xinjiang, Gansu, Inner Mongolia.

RESULTS

Literature search results

According to the search strategy, the above 5 databases and publications were searched to obtain 816 related documents (**Fig. 1**). After four screenings, 20 papers were included for meta-analysis [13-32]. The cumulative sample size was 5,158 cats.

Baseline data of the included literature and quality assessment

The final 20 studies eligible for inclusion covered 14 provinces and municipalities. The studies were performed between 2008 and 2019; and published from 2016 to 2020. The total number of cats was 5,158, with a range of 28–1,141. Serological assays were enzyme-linked immunosorbent assay (ELISA, n = 14), indirect hemagglutination assay (IHA, n = 1), modified agglutination test (MAT, n = 3) and gold-immunochromatography assay (GICA, n = 2).

According to the seven quality assessment items, the total possible score was 14 points. The scores of the included studies ranged from 9 to 13, indicating that the studies were of high quality (**Table 1** and **Fig. 2**).

Pooling and heterogeneity analyses

The seroprevalence estimates of *T. gondii* in cats in mainland China from 2008 to 2019 (published from 2016–2020) are shown in a forest plot (**Fig. 3**). Seroprevalence varied from 2.7% to 47.5% with substantial heterogeneity among studies ($\chi^2 = 262.32$; $p < 0.001$;

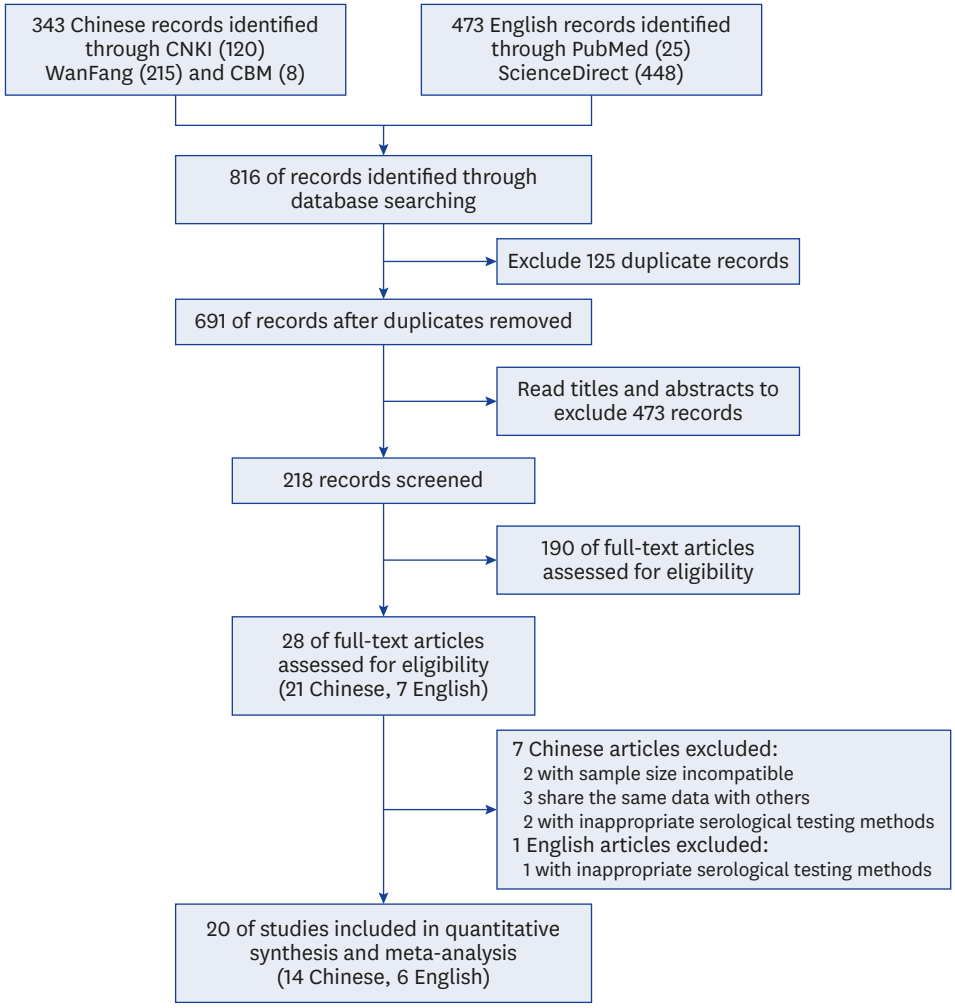

Fig. 1. Flow diagram of the selection of eligible studies.

I^2 = 64.6%). The pooled overall seroprevalence was 19.9% (95% CI, 15.9%–23.9%) when calculated using the DerSimonian-Laird model.

The pooled estimates by potential risk factors are presented in **Table 2**. Since there was a significantly high level of heterogeneity among the studies within most subgroups, all estimates of pooled seroprevalence for each subgroup were calculated using the DerSimonian-Laird model. Meta-regression demonstrate living condition, sex and age $p < 0.01$, may be the heterogeneity of cats *T. gondii* seroprevalence therefore calculate the OR, region $p = 0.593$ and serological test $p = 0.179$. All 20 studies provided information on the groups of cats investigated (17 about stray cats and 14 about pet cats), and the pooled seroprevalence was significantly higher in stray cats (26.8%) than in pet cats (12.8%; OR, 2.26; 95% CI, 1.66–3.08; $p < 0.01$; **Table 2** and **Fig. 4**). Seroprevalence varied significantly from 10.0% to 24.1% among the 3 age groups (≤ 1 year, > 1 year ≤ 3 years, or > 3 years) ($p < 0.01$; **Table 2** and **Fig. 4**). A total of six studies provided estimates about sex, but no significant difference was observed between male and female cats (OR, 1.03; 95% CI, 0.87–1.24; $p = 0.71$; **Fig. 4**). On the basis of geographical regions, the lowest pooled estimates seroprevalence (15.9%) was in Central China and the highest (21.0%) was in Eastern China,

Table 1. Characteristics of the eligible studies

Author	Year	Region	Period of study	Serological method	Positivity	Detailed information on cats	Total No. of cats	No. of positive cats (%)
Cong et al. [13]	2016	Lanzhou, Gansu	2014–2015	MAT	≥ 1:25	Age, sex, stray or pet	362	70 (19.34)
Cong et al. [14]	2018	Shandong	2016–2017	MAT	≥ 1:64	Stray	180	39 (21.67)
Han [15]	2019	Fuzhou, Fujian	2018–2019	ELISA[a]		Age	221	6 (2.71)
Hou et al. [16]	2018	Jiangsu	2013–2015	ELISA[b]		Stray	64	16 (25)
Huang et al. [17]	2017	Fujian	UN	ELISA[c]		Stray	40	19 (47.5)
Kang et al. [18]	2016	Northeastern	2012–2015	IHA[d]	≥ 1:64	Age, sex	1,141	176 (15.3)
Li and Jia [19]	2017	Jiangsu	2017	IHA	≥ 1:64	Stray or pet	53	19 (35.85)
Qin and Zhuge [20]	2018	Guilin, Guangxi	2015–2016	ELISA[e]		Stray or pet	111	5 (4.5)
Tian [21]	2020	Beijing	2018	ELISA[f]		Age, sex, stray or pet	130	27 (20.77)
Wang et al. [22]	2019	Beijing	2018–2019	ELISA[e]		Stray or pet	265	53 (20)
Wang et al. [23]	2017	Henan	2015–2016	ELISA[c]	≥ 1:100	Age, sex	843	178 (21.16)
Wen et al. [24]	2018	Dandong, Liaoning	2015–2017	ELISA[e]		Age, sex, stray or pet	856	199 (23.25)
Wu and Zhao [25]	2018	Zunyi, Guizhou	2017–2018	GICA[g]		Stray or pet	103	29 (28.16)
Xia et al. [26]	2018	Yining, Xinjiang	2016	ELISA[e]		Stray or pet	40	10 (25)
Xu et al. [27]	2018	Guiyang, Guizhou	2018	ELISA[e]		Stray or pet	32	7 (21.88)
Yang et al. [28]	2017	Henan	2015–2016	MAT	≥ 1:25	Pet	28	2 (7.14)
Ying et al. [29]	2018	Hangzhou, Zhejiang	2016–2017	ELISA[a]		Stray	34	7 (20.59)
Yu et al. [30]	2016	Beijing	2008–2011	ELISA[h]		Stray or pet	323	58 (18)
Yu et al. [31]	2018	Jia xing, Zhejiang	UN	ELISA[e]		Age, sex, stray or pet	256	29 (11.3)
Zhuo et al. [32]	2019	Taizhou, Jiangsu	2016–2017	ELISA[e] & GICA		Age, stray or pet	212	41 (19.34)

MAT, modified agglutination test; ELISA, enzyme-linked immunosorbent assay; IHA, indirect hemagglutination assay; GICA, gold-immunochromatography assay.
[a]The test kits were produced by By French ID-VET company (IgG positive); [b]By Shanghai Ding Biological Technology Co., Ltd. Shanghai, China (Cut-off titer 1:5); [c]By Shenzhen Combined Biotech Co., Ltd. (IgG positive); [d]By Lanzhou Veterinary Research Institute, Chinese Academy of Agricultural Science (Cut-off titer 1:64); [e]By Zhuhai S.E.Z Haitai Biological Pharmaceuticals Co., Ltd. (IgG positive); [f]By GuangZhou Jianlun biology Technology Co.,Ltd. (IgG positive); [g]By Quicking Biotech Co., Ltd. (antigen positive); [h]By Animal Medicine College, China Agricultural University (IgG positive).

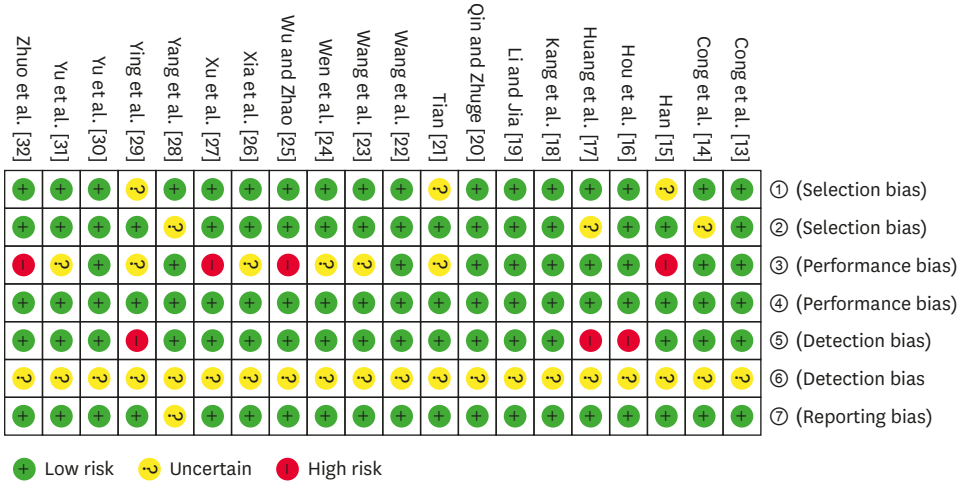

Fig. 2. Quality evaluation of eligible studies

pooled estimates Western seroprevalence was 19.4% (**Table 2** and **Fig. 5**). When stratified according to the main serological test used, no significant difference was found among the five methods (**Table 2** and **Fig. 5**).

In **Figs. 4** and **5** forest plot of the total and subgroup seroprevalence was constructed to express the results of each study and the heterogeneity among studies. The national cat *T. gondii* seropositive rate published from 2016 to 2020 is shown in **Fig. 6**.

https://doi.org/10.4142/jvs.21209

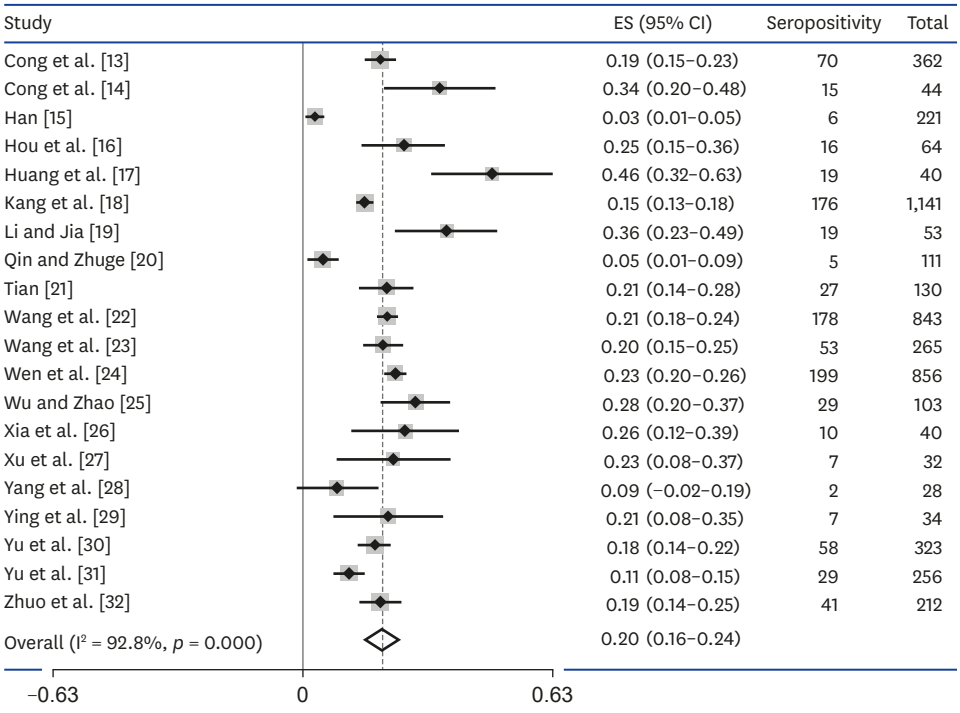

Fig. 3. Forest plot of the seroprevalence estimates of *T. gondii* in cats with random-effects analyses.
ES, effect size; CI, confidence interval.

Sensitivity analysis and publication bias analysis

The Sensitivity analysis results show that the point effect values of all indicators fall within the 95% CI of the final effect value of overall seroprevalence. The pooled seroprevalence was

Table 2. Pooled estimates of *T. gondii* in cats by potential risk factors with meta-analysis

Factors related to *T. gondii* seroprevalence in cats	No. of studies included	No. of positive cats	Total No. of cats	Pooled seroprevalence (95% CI)	Heterogeneity			Meta-regression	OR	
					Q (x^2)	*PQ*	I^2 (%)	*p* value	OR (95%CI)	*p* value
Overall	20	966	5,158	0.199 (0.159–0.239)	262.32	< 0.001	64.6			
Group								0.001		
Stray	17	454	1,795	0.268 (0.229–0.306)	45.16	< 0.001	67.6		2.26 (1.66–3.08)	0.001
Pet	14	352	2,435	0.128 (0.115–0.141)	63.48	< 0.001	79.5		Reference	
Sex								0.001		
Male	6	317	1,724	0.180 (0.162–0.198)	13.85	0.017	63.9		1.03 (0.87–1.24)	0.71
Female	6	286	1,590	0.176 (0.157–0.195)	12.16	0.033	58.9		Reference	
Age								0.001		
Y ≤ 1	6	126	1,096	0.100 (0.058–0.143)	28.63	< 0.001	82.5		2.79 (1.66–4.71)	0.001
1 < Y ≤ 3	6	209	1,447	0.143 (0.124–0.162)	5.16	0.397	3		2.44 (1.81–3.29)	0.0436
Y > 3	8	290	1,115	0.241 (0.127–0.354)	177.89	< 0.001	96.1		Reference	
Region								0.593		
Eastern	13	665	3,639	0.210 (0.158–0.262)	199.96	< 0.001	94		n	
Central	2	180	871	0.159 (0.037–0.281)	5.32	0.021	81.2		n	
Western	5	121	648	0.194 (0.095–0.293)	41.10	< 0.001	90.3		n	
Serological test								0.179		
ELISA	14	655	3,427	0.191 (0.138–0.244)	228.79	< 0.001	94.3		n	
IHA	1	19	53	0.361 (0.232–0.490)	0	n	n		n	
MAT	3	113	598	0.161 (0.102–0.221)	8.41	0.038	64.3		n	
GICA	2	68	315	0.228 (0.133–0.324)	3.59	0.058	72.7		n	

CI, confidence interval; OR, odds ratio; ELISA, enzyme-linked immunosorbent assay; IHA, indirect hemagglutination assay; MAT, modified agglutination test; GICA, gold-immunochromatography assay; n, no data.

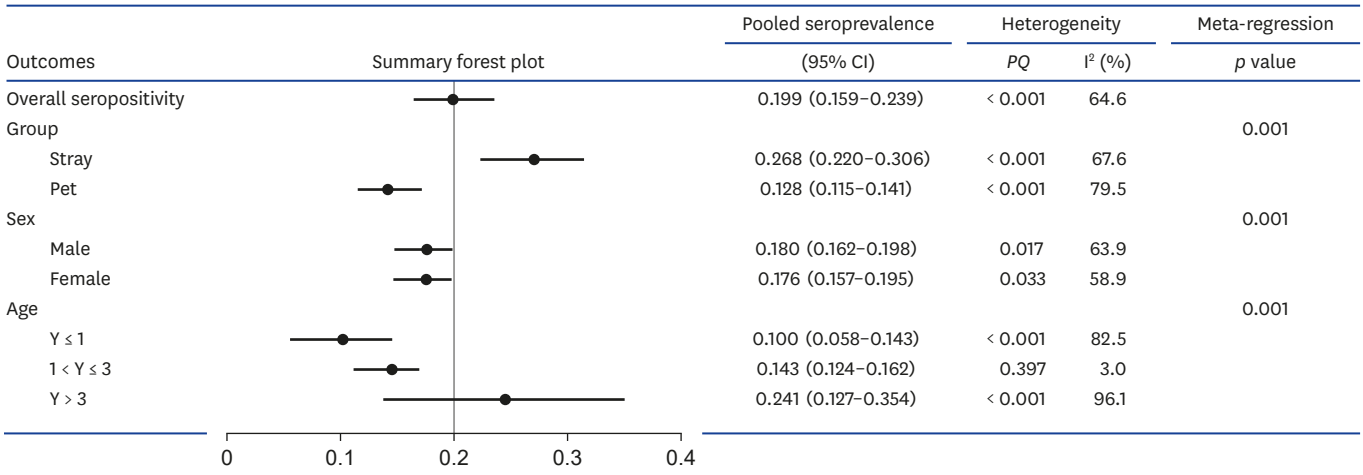

Fig. 4. Forest plot of the seroprevalence estimates of *T. gondii* in cats by living condition sex age subgroup cats.
CI, confidence interval.

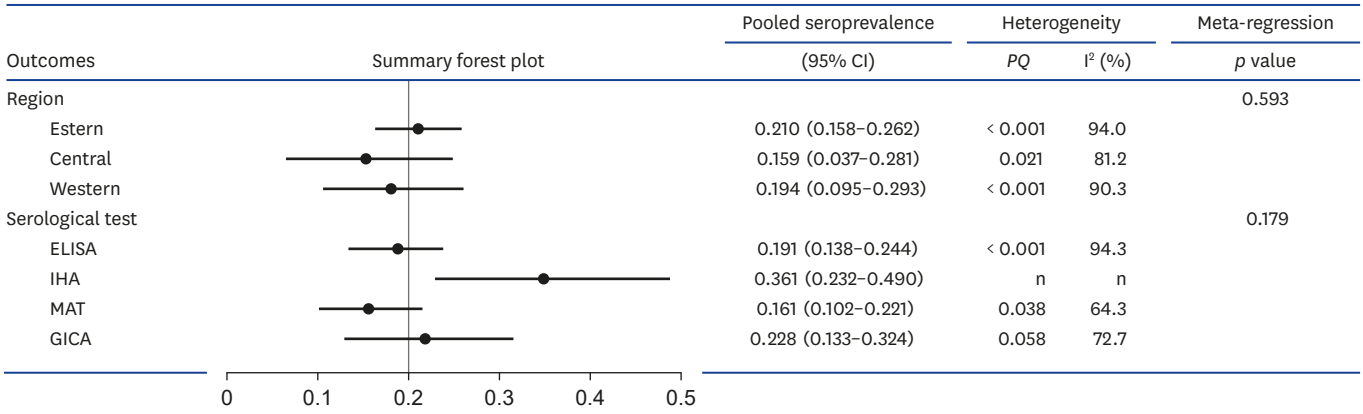

Fig. 5. Forest plot of the seroprevalence estimates of *T. gondii* in cats by region serological test subgroup cats.
CI, confidence interval.

not substantially influenced by any single study. The funnel plots showed no publication bias, which was also confirmed by Egger's test (the bias coefficients β = 2.88; 95% CI, −0.052–5.816; t = 2.06; $p = 0.054$) (**Supplementary Fig. 1**).

Changes in the seroprevalence of cat *T. gondii* in different regions of mainland China with time

The data sources include 46 articles published 1995–2020. Of these, 6 articles were published 1995-2004, 11 articles from 2005–2010, 15 articles from 2011–2015 and 20 from 2016–2020. The seropositive rate in the Yangtze River Delta showed a downward trend, from 45% in 1995–2005 to about 20% in 2020. The rate in Beijing and nearby areas has fell to 20% after 2006. The rates in the Pearl River Delta and the Northwest were unstable (**Fig. 7**).

DISCUSSION

The overall seroprevalence rate after sinusoidal conversion was 19.9% (95% CI, 15.9–23.9; 966/5,158), which is lower than the 1995–2015 domestic report of 24.5% (95% CI, 20.1–29.0)

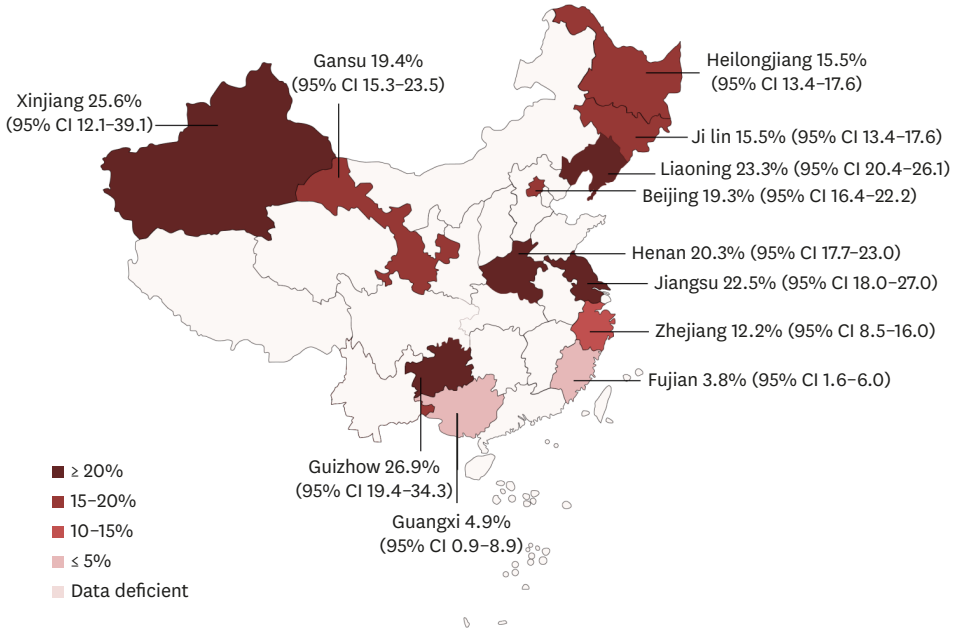

Fig. 6. Mainland China cat *T. gondii* seropositive rate published from 2016–2020.

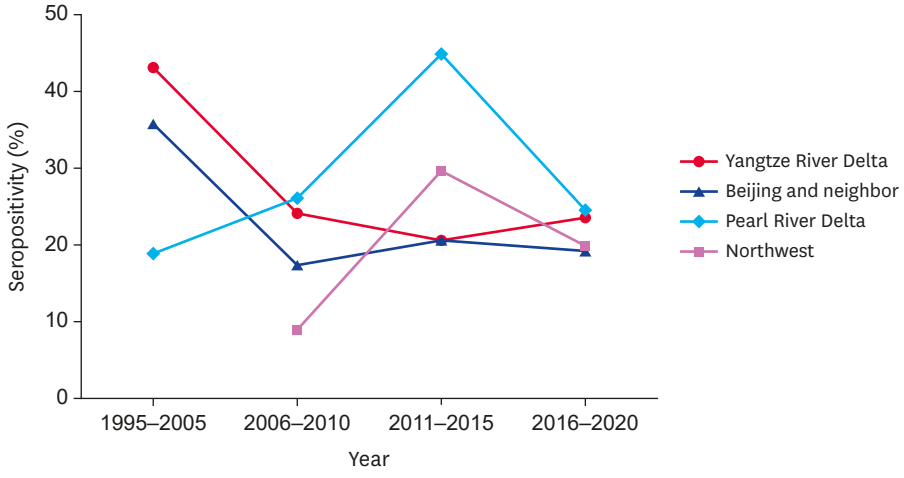

Fig. 7. Changes in the seroprevalence of cat *T. gondii* in different regions of mainland China with time.

[10]. It is also much lower than other countries, such as Ethiopia (87.72%; 95% CI, 78.63–93.28) [33];Qatar (82%; 95% CI, 76.11–86.79) and Russia (39.9%) [34,35]. However, it is higher than in Japanese stray cats (9%) [36].

The I^2 value shows a high degree of heterogeneity among the 20 studies. However, Egger's test and funnel plot found no publication bias, so the heterogeneity may be due to the characteristics of the sample, such as sex, age, geographic area or season of investigation, or the diagnostic methods used. Regression analysis into the possible causes of heterogeneity showed that the seropositive rate of *T. gondii* in stray cats was significantly higher than in domestic cats. In the age subgroup, the seropositive rate in cats over 3 years old was significantly higher than in those under 3 years old. A possible reason is that stray cats have a wide range of activities and are not restricted by people. Eating wild animals and unclean food and living wild long-term can increase the chance of contact with *T. gondii*. The seroprevalence rate of people who feed

cats that have outdoor activities is twice as high than in people who only contact indoor cats ($p = 0.027$) [37]. There is no significant difference in seroprevalence rate between sexes; nor between the eastern, central and western regions. Detection methods used are mainly ELISA and MAT, all the four detections method used is specific and reliable [38]. The seropositive rate was not significantly different between methods.

The investigation of seroprevalence rates in the four regions, over time, showed that rates in Beijing and surrounding areas and the Yangtze River Delta decreased from nearly 40% 25 years ago to about 20% now. Rates in the Pearl River Delta region and the Northwest region have a large gap in different periods, possibly due to fewer relevant reports, and thus do not reflect the true local seroprevalence rate. With the increase of published literature, the gap in the seroprevalence rate of the four regions between 2016 and 2020 gradually decreased. In a report on seroprevalence of *T. gondii* in cattle [39], the rate was highest in southwestern China (21.6%) and lowest in northern China (4.5%). This suggests that the temperature of different latitudes may influence seroprevalence: in warm, moist and low altitude regions and at temperate to tropical temperatures oocysts remain infectious for up to 1.5 years. However, an influence of latitude on the seropositive rate was not found in this literature.

Due to the small sample size and the lack of more detailed grouping of some data in the literature, we only selected five potential causes of heterogeneity for regression analysis and subgroup analysis. The next step could be to investigate cats' living habits and environment, including an analysis of indoor, free-range and rural free-range breeding, eating raw bones and meat and eating commercial cat food. Among the many *Toxoplasma* spp. strains found in China, 142 viable *T. gondii* isolates were found in animals and humans, and most of these (85 strains, 69.7%) were derived from cats [40]. Moreover, because of the close relationship between animals and humans, *T. gondii* can be transmitted to humans. Future research will focus more on the connection between residents and cats, such as whether the seropositive rate of *T. gondii* in local people is related to the rate in cats, and whether the population living in high-density population of wildcat cities is more likely to be at risk of infection.

More relevant reports will allow us to classify the data in greater detail and provide a more accurate grasp of the true seropositive rate of *T. gondii* in cats. Cats, as the final host of *T. gondii*, are instrumental in the spread of the parasite, and this is of great importance in public health. This study collected the latest cat parasite infection rates and analyzed risk factors, providing basic information for prevention and control, which is of great significance for preventing human zoonotic parasite infections.

SUPPLEMENTARY MATERIALS

Supplementary Data 1

PRISMA 2009 checklist.

Click here to view

Supplementary Fig. 1

Egger's test.

Click here to view

REFERENCES

1. Dubey JP. History of the discovery of the life cycle of *Toxoplasma gondii*. Int J Parasitol. 2009;39(8):877-882.
PUBMED | CROSSREF
2. Moro JC, Moreira NM. Clinico-epidemiological and sociodemographic profile of HIV/AIDS patients who are co-infected with *Toxoplasma gondii* in the border region of Brazil. An Acad Bras Cienc. 2020;92(4):e20200293.
PUBMED | CROSSREF
3. Robinson E, de Valk H, Villena I, Le Strat Y, Tourdjman M. National perinatal survey demonstrates a decreasing seroprevalence of *Toxoplasma gondii* infection among pregnant women in France, 1995 to 2016: impact for screening policy. Euro Surveill. 2021;26(5):1900710.
PUBMED | CROSSREF
4. Jones JL, Dargelas V, Roberts J, Press C, Remington JS, Montoya JG. Risk factors for *Toxoplasma gondii* infection in the United States. Clin Infect Dis. 2009;49(6):878-884.
PUBMED | CROSSREF
5. Deng H, Devleesschauwer B, Liu M, Li J, Wu Y, van der Giessen JW, et al. Seroprevalence of *Toxoplasma gondii* in pregnant women and livestock in the mainland of China: a systematic review and hierarchical meta-analysis. Sci Rep. 2018;8(1):6218.
PUBMED | CROSSREF
6. Gao XJ, Zhao ZJ, He ZH, Wang T, Yang TB, Chen XG, et al. *Toxoplasma gondii* infection in pregnant women in China. Parasitology. 2012;139(2):139-147.
PUBMED | CROSSREF
7. Jiang RL, Ma LH, Ma ZR, Hou G, Zhao Q, Wu X. Seroprevalence and associated risk factors of *Toxoplasma gondii* among Manchu pregnant women in northeastern China. Microb Pathog. 2018;123:398-401.
PUBMED | CROSSREF
8. Belluco S, Simonato G, Mancin M, Pietrobelli M, Ricci A. *Toxoplasma gondii* infection and food consumption: a systematic review and meta-analysis of case-controlled studies. Crit Rev Food Sci Nutr. 2018;58(18):3085-3096.
PUBMED | CROSSREF
9. Gao YM, Ding H, Lamberton PH, Lu DB. Prevalence of *Toxoplasma gondii* in pet dogs in mainland China: a meta-analysis. Vet Parasitol. 2016;229:126-130.
PUBMED | CROSSREF
10. Ding H, Gao YM, Deng Y, Lamberton PH, Lu DB. A systematic review and meta-analysis of the seroprevalence of *Toxoplasma gondii* in cats in mainland China. Parasit Vectors. 2017;10(1):27.
PUBMED | CROSSREF
11. Huedo-Medina TB, Sánchez-Meca J, Marín-Martínez F, Botella J. Assessing heterogeneity in meta-analysis: Q statistic or I^2 index? Psychol Methods. 2006;11(2):193-206.
PUBMED | CROSSREF
12. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315(7109):629-634.
PUBMED | CROSSREF
13. Cong W, Meng QF, Blaga R, Villena I, Zhu XQ, Qian AD. *Toxoplasma gondii*, *Dirofilaria immitis*, feline immunodeficiency virus (FIV), and feline leukemia virus (FeLV) infections in stray and pet cats (*Felis catus*) in northwest China: co-infections and risk factors. Parasitol Res. 2016;115(1):217-223.
PUBMED | CROSSREF
14. Cong W, Elsheikha HM, Zhou N, Peng P, Qin SY, Meng QF, et al. Prevalence of antibodies against *Toxoplasma gondii* in pets and their owners in Shandong province, Eastern China. BMC Infect Dis. 2018;18(1):430.
PUBMED | CROSSREF
15. Han Y. Investigation on the prevalence of toxoplasmosis in dogs and cats in urban area of Fuzhou. Fujian J Anim Husban Vet Med. 2019;41(6):12-13.
16. Hou ZF, Su SJ, Liu DD, Wang LL, Jia CL, Zhao ZX, et al. Prevalence, risk factors and genetic characterization of *Toxoplasma gondii* in sick pigs and stray cats in Jiangsu Province, eastern China. Infect Genet Evol. 2018;60:17-25.
PUBMED | CROSSREF
17. Huang C, Chen R, Wang K, Wen F, Zheng X, Wang S. Detection of antibody IgG, PCR-RFLP genotyping and sequence variation analysis of *Toxoplasma gondii* from cat in Fujian. Chin Vet Sci. 2017;47(12):1562-1569.
18. Kang YH, Cong W, Qin SY, Shan XF, Gao YH, Wang CF, et al. First report of *Toxoplasma gondii*, *Dirofilaria immitis*, and *Chlamydia felis* infection in stray and companion cats in northeastern and eastern China. Vector Borne Zoonotic Dis. 2016;16(10):654-658.
PUBMED | CROSSREF

19. Li QC, Jia CL. Epidemiological investigation and analysis of *Toxoplasma gondii* in cats in Suqian, Jiangsu Province. Graziery Vet Sci. 2017;(10):9-10.
20. Qin ZF, Zhuge Z. Investigation on *Toxoplasma gondii* infection in dogs and cats in Guilin City. Guangxi J Anim Husband Vet Med. 2018;34(2):106-107.
21. Tian Y. Epidemiological survey of toxoplasmosis in pet dogs and cats in Fangshan District, Beijing. J Beijing Vocat Coll Agric. 2020;34(3):39-43.
22. Wang S, Zhou Y, Niu J, Xie Q, Xiao T, Chen Y, et al. Seroprevalence of *Toxoplasma gondii* infection in domestic cats in central China. Parasite. 2017;24:10.
PUBMED | CROSSREF
23. Wang X, Zheng X, Gong H, Liu S, Wang Y. Epidemiological risk analysis of *Toxoplasma gondii* infection in cats in Beijing. Chin J Vet Med. 2019;55(9):71-74.
24. Wen X, Luo Y, Ma H, Ning M, Liu Y, Yu X, et al. Serological survey of *Toxoplasma gondii* in dogs and cats in Dandong area. Chin J Vet Med. 2018;54(12):50-52.
25. Wu BT, Zhao HT. Investigation on *Toxoplasma gondii* infection in pet cats and dogs in Zunyi City. Guizhou J Anim Husband Vet Med. 2018;42(4):45-47.
26. Xia CF, Gao L, Wei B, Tian T. Epidemiological investigation of toxoplasmosis of dogs and cats in Yining City. Anhui Acad Agric Sci. 2018;46(3):71-73.
27. Xu L, Yuan J, Wen G, Luo B, Xie X, He T, et al. Investigation and study on *Toxoplasma gondii* infection in dogs, cats and pigs in Guiyang City in 2017. Guizhou J Anim Husband Vet Med. 2018;42(5):17-20.
28. Yang YR, Feng YJ, Lu YY, Dong H, Li TY, Jiang YB, et al. Antibody detection, isolation, genotyping, and virulence of *Toxoplasma gondii* in captive felids from China. Front Microbiol. 2017;8:1414.
PUBMED | CROSSREF
29. Ying Z, Huang S, Chen D, Wang C, Gong L, Hu X, et al. Epidemiological investigation on toxoplasmosis of stray cats in West Lake scenic area. Zhejiang J Anim Sci Vet Med. 2018;43(4):19-21.
30. Yu HJ, Jia Y, Zhu TL, Pan CM, Shen CC. Seroepidemiological survey of toxoplasmosis in dogs and cats in Jiaxing City. Today Anim Husban Vet Med. 2018;34(11):8-9.
31. Yu SS, Qian WF, Xu JH, Liu Q. Detection and analysis of *Toxoplasma* and *Neospora* infection in dogs and cats in Beijing area. Chin J Vet Med. 2016;52(9):31-34.
32. Zhuo G, Zhou H, Lu W, Wei N, Liu J, Gao X. Investigation and prevention of Toxoplasma gondii infection in pets in Taizhou area. Jiangsu Agricu Sci. 2019;47(28):191-194.
33. Gebremedhin EZ, Tadesse G. A meta-analysis of the prevalence of *Toxoplasma gondii* in animals and humans in Ethiopia. Parasit Vectors. 2015;8(1):291.
PUBMED | CROSSREF
34. Boughattas S, Behnke J, Sharma A, Abu-Madi M. Seroprevalence of *Toxoplasma gondii* infection in feral cats in Qatar. BMC Vet Res. 2017;13(1):26.
PUBMED | CROSSREF
35. Shuralev EA, Shamaev ND, Mukminov MN, Nagamune K, Taniguchi Y, Saito T, et al. *Toxoplasma gondii* seroprevalence in goats, cats and humans in Russia. Parasitol Int. 2018;67(2):112-114.
PUBMED | CROSSREF
36. Matsuu A, Yokota SI, Ito K, Masatani T. Seroprevalence of *Toxoplasma gondii* in free-ranging and feral cats on Amami Oshima Island, Japan. J Vet Med Sci. 2017;79(11):1853-1856.
PUBMED | CROSSREF
37. Jung BK, Song H, Lee SE, Kim MJ, Cho J, Shin EH, et al. Seroprevalence and risk factors of *Toxoplasma gondii* infection among cat sitters in Korea. Korean J Parasitol. 2017;55(2):203-206.
PUBMED | CROSSREF
38. Gu Y, Wang Z, Cai Y, Li X, Wei F, Shang L, et al. A comparative study of *Toxoplasma gondii* seroprevalence in mink using a modified agglutination test, a Western blot, and enzyme-linked immunosorbent assays. J Vet Diagn Invest. 2015;27(5):616-620.
PUBMED | CROSSREF
39. Gong QL, Li J, Li D, Tian T, Leng X, Li JM, et al. Seroprevalence of *Toxoplasma gondii* in cattle in China from 2010 to 2019: a systematic review and meta-analysis. Acta Trop. 2020;211:105439.
PUBMED | CROSSREF
40. Fu X, Feng Y, Liang H, Yang Y. Genotypes and pathogenesis of *Toxoplasma gondii* isolates in China. Chin J Zoonoses. 2015;31(7):669-673.
CROSSREF