Prevalence of Porcine Cysticercosis in India: A Meta-Analysis

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Research Article

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Abstract

Porcine cysticercosis (PCC) caused due to *Taenia solium* a tapeworm; is one of the important neglected tropical diseases with a significant zoonotic importance. In view of the underdeveloped swine husbandry practices coupled with negligence of people towards hygienic food habits, a comprehensive estimate on the presence of porcine cysticercosis in India will be helpful for planning control measure. We performed a systematic literature review regarding data about PCC epidemiology in India and meta-analyses for its prevalence in different zones of country and the methods employed for detection and based on this discussed possible control strategies. A total 27 studies spanned over period from 2000 to 2019 from different parts of India were included for meta-analysis which were obtained through a systematic search from online free databases. The overall prevalence using random effects model was found 5.21% with substantial heterogeneity ($I2 = 96.52$, $p = 0.0001$). However subgroup analysis revealed higher prevalence due to smaller sample size and also method of detection has also significant effect on the pooled data. Considering the zoonotic significance as well as economic losses to pork industry, control strategies need to be devised with regards to health monitoring, improvements in ante-mortem diagnostics, hygienic meat practices coupled with education to both the producers and consumers about this important disease through one health approach.

1. Introduction

Zoonotic tapeworm *Taenia solium* which causes taeniasis in human and porcine cysticercosis (PCC) in pigs is a food-borne cestode; albeit its public health importance and global trade implications, remain neglected. The disease is manifested in different ways according to its location in the body of the host. When present in striated muscles of host, it remains without any clinical disease. But when vital organs particularly brain and eyes are involved, clinically it results in epileptic seizures and even death in pigs as well as humans (Wardrop et al. 2015). In human, involvement of brain and eye leads to severe complications under the disease entity ‘neurocysticercosis’ which is endemic to tropical countries (Rajshekhar 2016) and contributed as a major etiology for 30% of total epilepsy cases in those areas (García et al. 2003). Primarily the disease is prevalent in pigs reared under extensive management without proper sanitation and hygienic and scavenging pigs in close proximity with human settlements. It is even considered as a perfect zoonosis or euzoonosis where human acts both as a definitive and an intermediate host for the tapeworm *Taenia solium*. It has been proved that the infected host with *Taenia solium* tapeworm does not necessarily harbour a single worm, contrast to its name (Jeri et al. 2004). However, *T. solium* is unable to mature to adult stages in pigs to complete its reproductive cycle. Pigs acquire *T. solium* from ingesting Taenia eggs present in the human feces, whereas humans acquire the infection directly from eating viable cysticerci present in uncooked pork or through ingestion of contaminated food or water containing eggs or proglottids of *T. soilum*. Hence consumption of undercooked measly pork is the major route of human infection (Adesokan and Adeoye 2019).

In humans, the diagnosis of cysticercosis depends primarily on the detection of cysticerci by computed tomography (CT) and radiography of nervous system and on the finding of antibodies to cysticerci in the

cerebrospinal fluid (Dixon et al. 2019). On the other hand, detection of *Taenia solium* cysts in the pork at the stage of slaughter itself is the effective method to limit the infection in human (Lightowlers and Donadeu 2017). Several earlier studies proved that pork consumption is one of the main cause of acquired epilepsy in human in endemic low income countries which was also supported by certain systematic reviews from across globe (Quet et al. 2010; Debacq et al. 2017). In addition pre-slaughter examination of pork carcasses for detection of infections of zoonotic importance are also mandatory under food safety laws in most of the countries including India. few studies from India indicated human cysticercosis scenario and its association with swine rearing practices (Pathak and Chhabra 2012). The condemnation of pork infected with *Taenia* cysts on the other hand imparts economic losses to meat industry (Vaidya et al. 2014). Yet their studies were limited to certain geographical locations such as states and regions, the present study highlights on meta-analysis of pig cysticercosis on national scale.

2. Materials And Methods

2.1 Search strategy

The online free databases were searched for the primary studies which reported prevalence of cysticercosis in pigs during 2000 to 2019. The databases searched were GoogleScholar, PubMed, J-GatePlus by using keywords *viz*. *Taenia solium*, Pig, Human, Cysticercosis, *Cysticercus tenuicolis*, Pork tapeworm, India singly or different combinations with Booleans AND / IN / OR *etc*. The titles, abstracts and full length papers were read thoroughly and their suitability was assessed. Primary research articles containing the data on the number of animals/carcasses screened, number of animals/ carcasses found positive for cysticercus cysts and limited to Indian cities/ towns were included in this study. Studies with data of prevalence work carried out from 2000 to 2019 were only included in this meta-analysis.

2.2 Data extraction

Studies / papers obtained through systematic search as per PRISMA guidelines (Moher et al. 2009) were then read thoroughly and requisite data was extracted and entered in MS-Excel sheet. Data from individual study necessarily included study details *viz* name of authors and year of publication, year of abattoir survey / sampling, place of work, method of detection, organs detected, number of carcasses/ animals detected and number of carcasses / samples found positive for harbouring *Taenia solium* cysts. Data were arranged systematically in excel sheet for further statistical analyses.

2.3 Study quality and characteristics

Following the predefined inclusion and exclusion criteria, study reports were assessed for suitability. The selected study must have provided the data pertaining to year of study, number of carcasses/ samples tested and positives reported, area of study and method employed. As regards method of detection slaughter house survey / necropsy studies, serological tests and molecular methods employed were taken into account. Studies without these parameters were not included in final analysis. Initial screening

of studies for compliance with the objective and relevance was done and this was followed by thorough reading of reports for extraction of requisite data.

2.4 Meta-analysis

Owing to significant heterogeneity between studies, a random-effects model was adopted for this meta-analysis. The prevalence data on total sample size and number of positives was analyzed to obtain the effect size and standard error of the effect size. The estimates were then pooled with a 95% confidence interval. Cochran's Q and Higgin's I^2 statistics were used for measuring the between-study variance. The I^2 values of 25%, 50%, and 75% were considered low, moderate and high heterogeneity, respectively (Higgins and Thompson 2002). In addition, publication bias was assessed using funnel plot visualization and LFK Index respectively (Kanamori et al. 2018). To appraise the sources of heterogeneity subgroup meta-analysis was conducted by grouping variables according to regions of studies, methods of detection of cysts and sample size in the included studies. All the analyses were done with the help of MetaXL add-in (EpiGear International Pty Ltd, Queensland, Australia).

3. Results

3.1 Studies' profile with methods used, locations and apparent prevalence obtained

Altogether 27 studies were selected for this meta-analysis, the geographical setup of which were spread across the country (Fig. 1). Locational distribution of studies revealed that most of the studies were from Northern Region (08 Nos.) followed by Western Region (07), East / NorthEastern and Southern (06 each). Enrolled studies showed that multiple methods were employed in same study for detection of cysts. Amongst them most used method for the detection of cysticercus cysts was post mortem inspection. Amongst the sites for detection of cysts shoulder muscle, thigh muscle, masseter muscle, neck, diaphragm and heart were most preferred ones while tongue, greater omentum, mesentery, other visceral organs including liver were also included for searching of cysts in some studies. Serological detection was also found on rising trend of utility and varied serological tests *viz.* ELISA, IFAT, CIEP, Western Blot were mostly followed methods. Single study reported adoption of molecular diagnostic method *i.e* PCR for pre slaughter detection. While a single study reported detection of cysticercus cysts in 3% swine brains (n = 200) subjected for histo-pathological examination (Prakash et al. 2007). The apparent prevalence in the range of 0.3–59% was noted by these studies.

3.2 Prevalence Meta-analysis results

The pooled estimate of porcine cysticercosis prevalence using random effect model from 2000 to 2019 was found 5.21% with 95% CI as 4.04–6.52% and prediction interval (95% PI) as 0.016 to 0.154. Proportion forest plot of pooled prevalence was depicted in Fig. 2. A wide variation in the prevalence estimates among studies under this analysis was observed which is confirmed through Q statistics = 1322.38 with DF = 29 and P = 0.000. Substantial heterogeneity was observed between studies which is

significant (I2 = 96.52. p = < 0.0001 and Tau squared value = 0.0341) considering the diversity of populations reported in recruited studies.

3.3 Subgroup analysis results

The sub-group analysis of the prevalence of cysticercosis among pig in India has shown that more prevalence was noted in South (9.09% CI – 6.08–12.40%, PI – 2.6–26.8%; p = 0) region followed by North (4.88% 95%CI = 2.34–7.85%; PI – 1.1–18.9%; p = 0), East / North-east (3.67%, CI = 1.54–6.22%; PI – 0.6–18%; p = 0) and West (2.46% CI = 1.55–3.53%, PI – 0.6–8%; p = 0) which was significant (Table 2). As regards the methods employed for detection of cysticerci from pigs, it was found that serological method had shown precision in detecting the cysts in porcine hosts. Overall prevalence of 10.66% (95% CI = 5.63–15.95%; PI – 3.31–31.2%; p = 0) is reported from those studies which used serological methods whereas carcass examination which most followed method detected only 3.71% prevalence (95% CI = 2.77–4.78%; PI – 1.1–11.7%; p = 0) and other methods such as molecular and histo-pathological studies for prevalence detected cysticercosis in 4.19% (95% CI = 2.61–5.99%; PI – 0 to 90%, p = 0.49) carcasses over the study period under this meta-analysis. Studies with sample size than 200 have revealed higher pooled prevalence than both the other subgroups and the overall pooled estimate.

3.4 Publication bias

For publication bias assessment, the funnel plot was used and it showed presence of bias to the right side which could be attributed to more studies with relatively higher prevalence estimates. This was also supported by the Doi plot and LFK index (4.63) showing major asymmetry and thereby a substantial publication bias.

4. Discussion

Taenia solium infection is considered endemic for tropical and sub-tropical countries from Asia, Africa, South and Central America regions (Coral-Almeida et al. 2015; Dixon et al. 2020). The disease is unique in itself where taeniasis is manifested as an intestinal disease and is caused by accidental ingestion of viable *T. solium* cysticercus. On the other hand, human cysticercosis is caused due to ingestion of *T. solium* eggs. In India the exact epidemiology of adult tapeworms in human is documented through several studies yet the focus was primarily on addressing neurocysticercosis (Rajshekhar 2016; Sankhyan et al. 2015)

Current review revealed pooled prevalence of cysticercus cysts to the tune of 5.21% in pork samples/ pig carcasses. These results corroborates with (Atawalna and Mensah 2015) from Ghana where they reported % prevalence of PCC in sows. Also, Adesokan and Adeoye (2019) reported 4.4% prevalence of PCC from Nigeria. Similarly, Rajshekhar (2004) in a review reported its prevalence in the range of 7–26% from India and 14–32% from Nepal. Mwabonimana et al. (2020) found porcine cysticercosis detected visually in 3.7% carcasses while that with serological methods they detected in 5.3% carcasses. None of the studies under meta-analysis reported organ wise prevalence. Yet it is established that lingual palpation is the best suited method for accurate diagnosis of cysticercosis in pig carcasses (Shonyela et

al. 2018). As far as diagnostic approach with serological or molecular methods are concerned, it is not widely adopted evidenced by the reports under this meta-analysis. The sub group analysis according to detection methods suggests that due to higher prevalence values in seroprevalence studies, overall pooled prevalence is higher which would not be actual prevalence as detected by direct detection of cysts through carcass examination or histopathological investigation. Yet their utility in ante-mortem screening followed by treatment must be encouraged for assuring the food safety standards. Even Goussanou et al. (2014) have recommended for need of development of newer diagnostic approaches synergistically with immunological and molecular tools, as they found unsatisfactory reports on the part of specificity and sensitivity issues of existing methods. Sub-group analysis according to the sample size of studies shows no major deviation in heterogeneity and indicates that as the sample increases prevalence rates decreases.

Most of the studies in this meta-analysis cover the urban or city areas where slaughtering is practiced under the aegis of regulations of municipal corporations. Yet the data on swine diseases including PCC from pigs slaughtered in rural settings has not been recorded or documented. This might reveal presence of the disease at relatively greater extent (Jayashi et al. 2012). Geographically uneven distribution of PCC may be attributed to the social and culinary preferences of various regions for swine husbandry in general and pork as a food in particular as compared to other regions of the country (Sithole et al. 2020).

In India, pigs' husbandry in urban areas is mostly under scavenging system of rearing. Usually pigs are marked for identification and let free for roaming in town and city areas in open public places and sewage streams or tanks. Roaming of pigs around and proximity of slaughter facility to localities contribute significantly in risks of NCC in human. Although no correlation reported between consumption of meat type and occurrence of NCC in human (Girotra et al. 2014). The usual practice of pig rearing as free range or semi-intensive system relying primarily on scavenging in garbage dumps or open sewers provides easy access to human feces contaminated with eggs of the parasite actually increases the risk of zoonotic taeniasis in the population surrounding them (Rout and Saikumar 2012). Therefore control efforts should be focused from these initial stages in value chain.

As per standards set by food regulatory authorities in the country as well as abroad, it is mandatory to discard the PCC infected pork meat considering it unsuitable for human consumption. This usually incur significant cost to producers in terms of edible pork and/or offal being discarded which otherwise would have earned a monetary return. However very few studies have dealt with economic costs of parasitic diseases including cysticercosis in livestock most of which were done far before (Pathak and Gaur 1989; D'Souza and Hafeez 1998). Recently Vaidya et al. (2014) from western states and Barua et al. (2019b) from Northeast Indian states estimated economic costs to pork industry associated with PCC and suggested detailed works on this aspect. Although the economic losses due to PCC reported from earlier studies may appear apprehensively lower as compared to the economic scale of the country to justify the steps to be taken for its control; its public health importance need significant attention undeniably.

On account of the large degree of heterogeneity among studies the current study has some limitations. Therefore while concluding results of this analysis, critical interpretation of the risks and biases should be considered. Firstly, the heterogeneity in the data among studies remained even after sub-group analysis due to which the outcomes of study may not necessarily reflect the real situation of PCC in entire country. Another limitation would be about the probability of inaccurate and incomplete data provided from the primary reports cannot be ruled out. Thirdly since the studies obtained through comprehensive search of only online free databases were included in present analysis, the other primary studies which are not available online mode may have skipped from inclusion in this met-analysis which might have impacted the effect size obtained.

5. Conclusion

It is herewith concluded that porcine cysticercosis being of prime zoonotic importance has shown pooled prevalence of 5.21% in India. Therefore, it needs special attention in terms of planned epidemiological studies with widening the scope of animals to be screened by seroprevalence. Measures to limit the contact between pigs and human needs be strengthened through education on hygienic food and culinary habits. Also diagnostic methods shall be developed with enhanced specificity and sensitivity.

Declarations

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Conflicts of interest/Competing interests (include appropriate disclosures)

None.

Availability of data and material

All data generated during the study are presented in this article itself.

Code availability

Not applicable

Ethics approval

Since no harm was given to animals under study and sample collection, there are no ethical issues.

Consent to participate

Not applicable

Consent for publication

Not applicable

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Tables

Table 1. Characteristics of the studies included in meta-analysis

Study details	State	No of carcass examined	No of carcass with PCC	Prevalence (%)	Method of detection
Sarma et al. 2000	Assam	279	5	1.79	Visual
Prasad et al. 2002	Uttar Pradesh	50	13	26.00	Visual
Hafeez et al. 2004	Andhra Pradesh	935	33	3.52	Visual
	Tamilnadu	345	19	5.50	Visual
	Karnataka	366	21	5.73	Visual
	Kerala	167	9	5.38	Visual
	Andhra Pradesh	584	36	6.16	CIEP
	Tamilnadu	257	15	5.83	CIEP
	Karnataka	281	17	6.05	CIEP
	Kerala	123	7	5.69	CIEP
	Andhra Pradesh	584	38	6.50	ELISA
	Tamilnadu	257	16	6.22	ELISA
	Karnataka	281	18	6.40	ELISA
	Kerala	123	8	6.50	ELISA
Selvam et al. 2004	Karnataka	507	21	4.14	Visual
Sharma et al. 2005	Punjab	236	15	6.35	Visual
Sharma et al. 2005	Punjab	236	34	14.40	CIEP
Prakash et al. 2007	Uttar Pradesh	200	6	3.00	Histopathology of brain
Borkataki et al. 2012	Assam	978	93	9.50	Visual
Sreedevi et al. 2012	Andhra Pradesh	225	25	11.11	Visual
Rout and Saikumar 2012	Uttar Pradesh	119	4	3.36	Visual
Kalai et al. 2012	Maharashtra	114	5	4.38	Visual

Mohan et al. 2013	Tamilnadu	112	67	59.82	ELISA
Bhadrige et al. 2014	Maharashtra	4042	23	0.56	Visual
Koushik and Islam 2014	Assam	316	4	1.26	Visual
Saravanan et al. 2014	Uttar Pradesh	175	9	5.14	Visual
Vaidya et al. 2014	Maharashtra	1820	18	0.98	Visual
Chawhan et al. 2015	Punjab	519	22	4.23	Visual
Sahoo et al. 2016	Uttar Pradesh	185	14	7.56	Visual
Sreedevi et al. 2016	Andhra Pradesh	345	41	11.88	Visual
Sharma et al. 2017	J&K	600	7	1.16	Visual
Shende et al. 2016	Maharashtra	1735	6	0.34	Visual
Abirami et al. 2018	Tamilnadu	175	46	26.28	ELISA
Satyaprakash et al. 2018	Maharashtra	1000	3	0.30	Visual
Singh et al. 2018	Punjab	1092	24	2.19	Visual
Vaidya et al. 2018	Maharashtra	13596	120	0.88	Visual
Barua et al. 2019a	Nagaland	360	6	1.66	Visual
Barua et al. 2019a	Nagaland	300	9	3.00	ELISA
Barua et al. 2019b	Assam, Meghalaya, Arunachal Pradesh, Mizoram and Tripura	4856	47	0.96	Visual
Wavhal et al. 2019	Maharashtra	815	4	0.49	Visual
		2228	20	0.89	PCR
		524	34	6.48	ELISA

	226	12	5.31	FTA
	226	12	5.31	Western Blot
	172	14	8.14	ELISA
	172	13	7.55	FTA
	172	12	6.97	Western Blot

Table No 2: Subgroup analysis of studies on porcine cysticercosis in India

	No of reports	Prevalence (%)	95% C.I.	Q Statistics	Heterogeneity I^2 (%)	p value	95% P.I.
Sub-Group: Method of detection							
Carcass examination	26	3.7106	2.77 - 4.78	699.75	96.00	0.00	1.1 - 11.7
Serology	18	10.6587	5.93 - 15.95	239.15	95.00	0.00	3.1 - 31.2
Others	3	4.1869	2.61 - 5.99	1.44	0.00	0.49	0 - 90.0
Sub-Group: Region							
East / NorthEast	6	3.6684	1.54 - 6.22	201.39	96.00	0.00	0.6 - 18.0
North	9	4.8831	2.34 - 7.85	72.25	90.00	0.00	1.1 - 18.9
South	17	9.0865	6.08 - 12.40	271.86	94.00	0.00	2.6 - 26.8
West	15	2.4590	1.55 - 3.53	201.34	94.00	0.00	0.6 - 8.0
Sub-Group: Sample size							
Less than 200	13	11.3526	5.58 - 17.90	215.55	94.00	0.00	3.0 - 34.6
200-500	17	5.5693	3.99 - 7.33	102.98	94.00	0.00	1.6 - 17.5
501-1000	10	3.6595	1.66 - 6.03	219.06	96.00	0.00	0.8 - 14.3
More than 1000	7	0.8594	0.65 - 1.17	27.20	78.00	0.00	0.1 - 3.9

C.I. – Confidence Interval P.I. – Prediction Interval

Figures

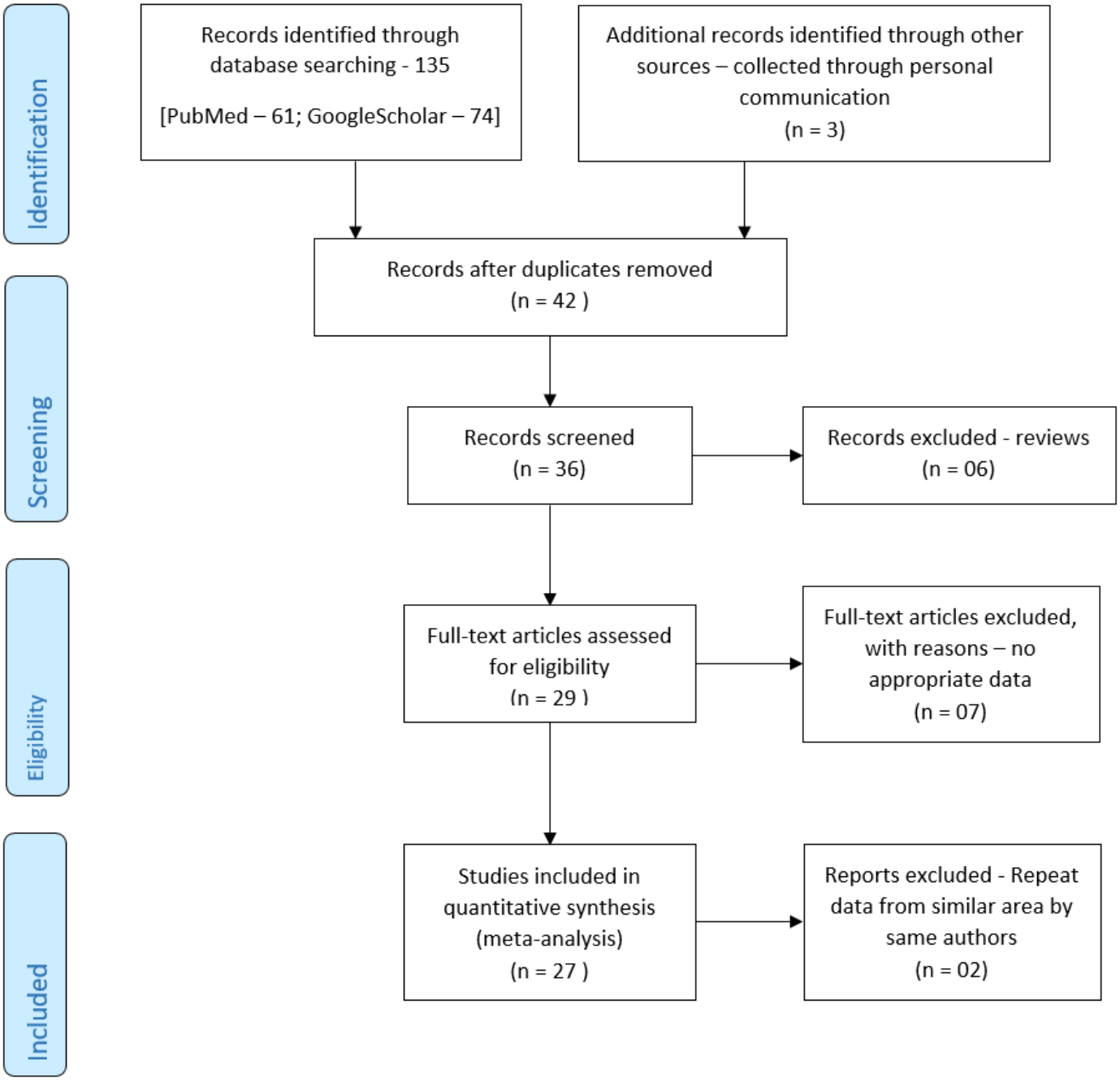

Figure 1

PRISMA 2009 Flow Diagram for Porcine cysticercosis in India Moher et al (2009). www.prisma-statement.org

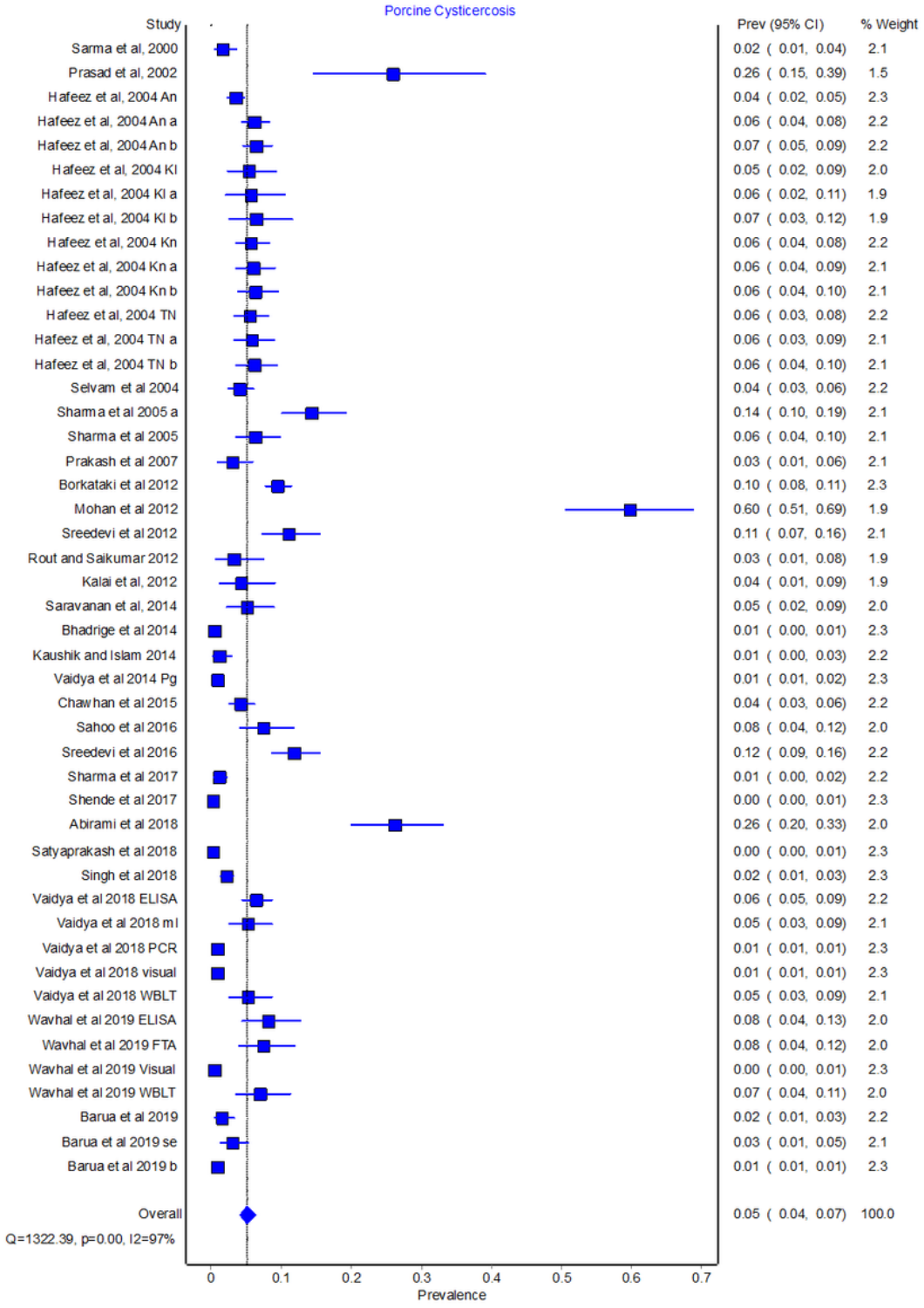

Figure 2

Forest plot of pooled prevalence of Porcine cysticercosis in India

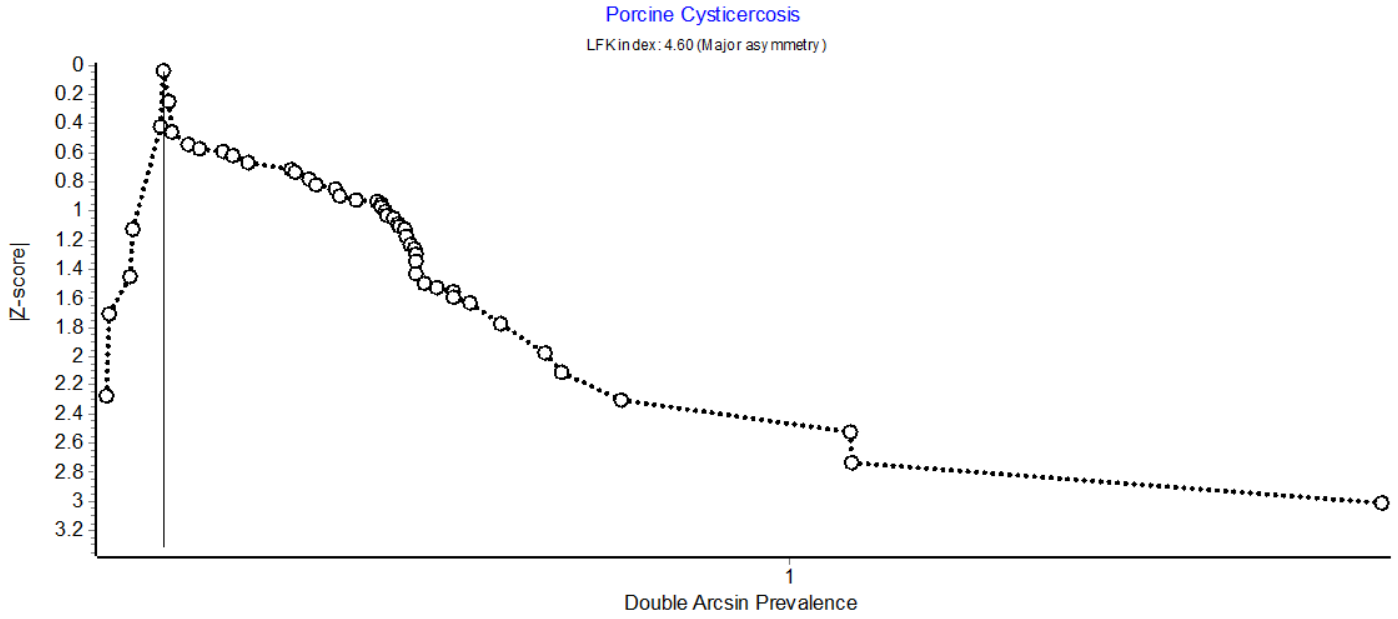

Figure 3

Doi Plot for publication bias in meta-analysis of Porcine cysticercosis in India

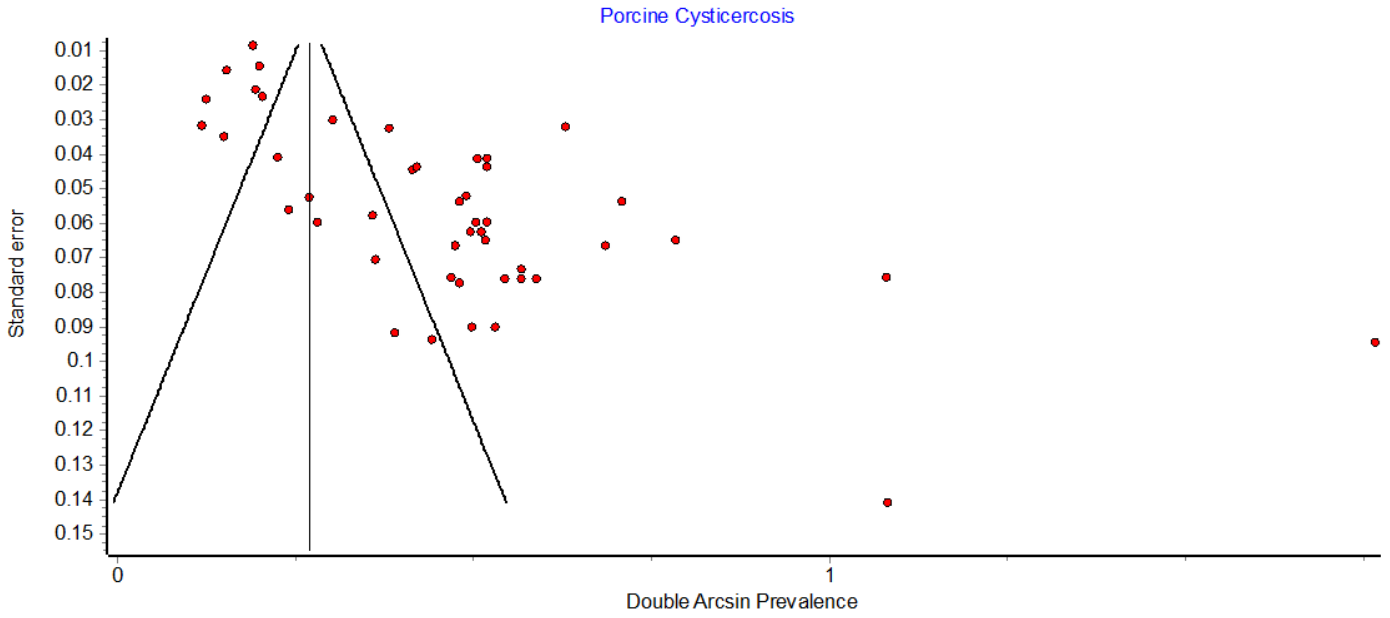

Figure 4

Funnel Plot for publication bias in meta-analysis of Porcine cysticercosis in India

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- PRISMA2009ChecklistPCC.doc