Current global status, subtype distribution and zoonotic significance of *Blastocystis* in dogs and cats: a systematic review and meta-analysis

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**Abstract**

**Background:** *Blastocystis* is a common intestinal protozoa found in animal and human fecal samples, with over 1 billion individuals infected worldwide. Since domestication, dogs and cats have had a close bond with humans. However, their close proximity poses a potential health risk since they may harbor several zoonotic agents. A global estimate of *Blastocystis* infection and subtype (ST) distribution in dogs and cats would therefore be of great health importance to humans.

**Methods:** We performed a comprehensive systematic search of four English-language databases (PubMed, Scopus, Google Scholar, Web of Science) for relevant articles up to 8 November 2021. The random-effects model was used to make pooled estimates with confidence intervals (CIs).

**Results:** In total, we identified 49 publications that met our inclusion criteria and subsequently analyzed the 65 datasets in these articles, of which 23 and 42 datasets were on cats and dogs, respectively. Among the 2934 cats included in the 23 datasets, which involved 16 countries, the prevalence rate of *Blastocystis* infection was 9.3% (95% CI 5.3–15.9%). The prevalence of *Blastocystis* infection was slightly lower (7%, 95% CI 4.7–10.4%) among the 7946 dogs included in the 42 datasets, involving 23 countries. The sensitivity analysis showed that no remarkable variation in the estimates upon the stepwise removal of each dataset. Higher ST diversity was found among the examined dogs (ST1-8, ST10, ST23, ST24) than among cats (ST1-4, ST10, ST14). Among dogs, ST3 was the most frequent ST (41.3%), followed by ST2 (39.3%), ST1 (30.9%), ST4 (13.4%), ST8 (12.7%), ST10 (11%) and ST5 (8.1%). Also among dogs, each of ST6, ST7, ST23 and ST24 was observed in only one study. Of the ST found in the cats examined, ST4 (29.5%), followed by ST10 (22.5%), ST1 (19.8%) and ST3 (17.6%) were the most common. A single study also reported the presence of both ST2 and ST14 in cats. With respect to zoonotic *Blastocystis* STs (ST1–ST9 and ST12), eight were reported from dogs (ST1–ST8) and four were isolated from cats (ST1–ST4), showing the implication of dog and cats in zoonotic transmission.

**Conclusions:** Taken together, our results show that elucidation of the true epidemiology and ST distribution of *Blastocystis* in dogs and cats demands more comprehensive studies, particularly in the neglected regions of the world.

**Keywords:** *Blastocystis*, Prevalence, Subtypes, Distribution, Dogs, Cats, Systematic review, Meta-analysis

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**Background**

*Blastocystis* is a common enteric protozoa found in fecal samples of humans and animals. Over 1 billion people are infected globally [1, 2]. Four major life stages have
been described in this polymorphic parasite, comprising vacuolar, granular, amoeboid and cyst stages; among these, the vacuolar and multimaculovacular forms are less common during encystation or excytation [3, 4]. General consensus on the transmission of Blastocystis and that infection occurs through the fecal–oral route with the ingestion of cyst-contaminated water or food [5]. Zoonotic transmission may also be possible through close animal-human contact, but the extent and frequency of such events remain largely unknown, requiring more in-depth investigation [6, 7]. Symptomatic human infections may manifest as diarrhea, abdominal pain, flatulence, inflammatory bowel disease, irritable bowel syndrome (IBS) and cutaneous lesions (urticaria) [8, 9]. Nevertheless, it is not fully known whether Blastocystis possesses pathogenic potential since carriage state is highly frequent [10].

Microscopy, culturing and molecular assays are the primarily methods used to detect Blastocystis infection in hosts. However, the discrimination of subtypes (STs) is only possible using DNA-based methods and sequence analysis of the small subunit ribosomal RNA (SSU rRNA) gene [2, 11]. A total of 32 phylogenetically distinct Blastocystis subtypes have been proposed based on SSU rRNA analysis, including zoonotic STs (ST1–9, ST12) and STs isolated only from animals (ST10, ST11, ST13–17, ST21, ST23–32). Some experts have noted that ST18-20 and ST22 are invalid due to ambiguities in the 5′ and 3′ ends of the SSU rRNA sequences. Nevertheless, according to the criteria currently in place to qualify as a unique subtype, a total of 28 subtypes (ST1–17, ST21 and ST23–32) are generally widely recognized as being valid subtypes [12–14].

The One-Health concept is an integrated approach to human healthcare that considers human health to be closely connected to animal health and the environment, proposing that each constituent (e.g. animals) may play a principal role in transmission dynamics of Blastocystis [15]. Dogs and cats, as important pet animals, may harbor zoonotic agents and be considered potential reservoirs for Blastocystis. Hence, detection of Blastocystis infection in these animals is important for improving human health levels. We performed the present systematic review and meta-analysis to clarify the global epidemiology, subtype distribution and zoonotic importance of this parasitic protozoan in dogs and cats.

**Methods**

**Study design and reporting protocol**

A systematic review and meta-analysis of the worldwide epidemiology, subtype distribution and zoonotic importance of Blastocystis was designed and implemented in 2021, with dogs and cats as the target population. The reporting protocol was designed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline [16].

**Databases and search strategies**

A comprehensive search of four electronic databases (PubMed, Scopus, Google Scholar, and Web of Science) was conducted by two of the authors (AA and MSH) for relevant articles published up to 8 November 2021, using the keywords: “Blastocystis,” “Blastocystis sp,” “Subtypes,” “Prevalence,” “Epidemiology,” “Frequency,” “Occurrence,” “Dog,” “Cat,” “Canine” and “Feline,” with “OR” and/or “AND” operators. To expand the search for relevant publications, additional keywords were also used and the reference lists of identified papers were explored. The titles and abstracts of the identified publications were reviewed, duplicated papers were removed and the full-text of each article identified as being relevant was obtained. The eligibility of the papers was evaluated independently by six of the authors (GH, BM, LSH, AY, AS, SSH); any disagreement was resolved through consultation with the leading reviewer (AA).

**Eligibility criteria**

Observational cross-sectional studies reporting the prevalence and/or subtypes of Blastocystis in dogs and cats utilizing microscopy of stool samples and/or molecular techniques up to 8 November 2021 were included in present systematic review. Excluded from this systematic review and meta-analysis were case reports, reviews, letters, studies on humans or other animals, studies involving experimentally infected animals, studies without Blastocystis prevalence rates and studies containing unclear/confusing information.

**Quality assessment and data extraction**

The Joanna Briggs Institute (JBI) critical appraisal checklist for studies reporting prevalence data was used for qualitative evaluation of the articles [17]. Articles were included in this systematic review and meta-analysis if they were assessed to have checklist scores of 4–6 points (moderate quality) or 7–9 points (high quality); papers with a checklist score of ≤ 3 points were excluded. The following items were extracted using a pre-piloted checklist for each study: the first author’s last name, quality assessment score, publication year; implementation year, country, continents, WHO regions, related STs, total sample size and infected sample size. In the current review, information regarding WHO regions was obtained from the relevant WHO URL (https://www.who.int/standards/classifications).
Data analysis

The extracted data were exported to the Comprehensive Meta-Analysis (CMA) version 3 software for meta-analysis, with $P<0.05$ considered to be a statistically significant value [18]. A Forest plot diagram was designed using a random-effects model to represent the weighted frequencies with 95% confidence intervals (CIs). The $I^2$ index was used to assess heterogeneity between included studies, ranging from <25% (low variation) and 25–50% (moderate variation), to >50% (high variation) [19]. The subgroup analysis of the pooled prevalence of the parasitic infection among dogs and cats was performed based on publication year, WHO region, country, continent and sample size. Additionally, variations in the final weighted prevalence of Blastocystis infection upon stepwise removal individual studies were assessed by sensitivity analysis. Meta-regression was performed to evaluate the likely association between some variables (publication year and sample size) and Blastocystis frequency among examined animals. The funnel plot was used to check the probability of publication bias during the analysis.

Results

Description of the systematic search and article selection

The strategy for the systematic search and study selection is shown in Fig. 1. In brief, 12,321 articles were identified during the primary systematic search; of these 4,300 were duplicate papers and discarded, leaving 8,021 articles for review of the title and abstract. Of these 8,021 articles, 63 met the inclusion criteria and were fully reviewed. Qualitative evaluation using the JBI checklist resulted in the exclusion of an additional 14 articles. Ultimately, 49

![Flowchart of the included eligible studies in the present study](image)
studies (65 datasets) [13, 20–67] were assessed as eligible to be included in the meta-analysis (Table 1). Reasons for removing studies from the meta-analysis included animals other than dogs and cats (4 papers), intestinal parasites other than Blastocystis (7 articles), repetitive results (1 study) and ambiguous findings (2 papers).

The quality assessment output
All of the included studies were critically appraised using the JBI quality assessment checklist adapted for cross-sectional studies. Based on the JBI score, 15 studies were of high quality (≥ 7 points) and the remaining 34 studies were of moderate quality (4–6 points) (Additional file 1: Table S1).

Global epidemiology of Blastocystis infection in dogs
The estimated pooled prevalence of Blastocystis derived from the 42 datasets on 7946 examined dogs was 7% (95% CI 4.7–10.4%) (Fig. 2). A significantly high heterogeneity was also identified among assessed studies (Cochran’s Q = 730.2, I² = 94.4%, P = 0.001). The global prevalence of Blastocystis in dogs by country is shown in Fig. 3.

Worldwide prevalence of Blastocystis infection in cats
The estimated weighted frequency of Blastocystis obtained from the 23 datasets on 2934 examined cats was 9.3% (95% CI 5.3–15.9%) (Fig. 2). A substantially high heterogeneity was reported among the assessed studies (Cochran’s Q = 350.4, I² = 93.7%, P = 0.001). The worldwide frequency of Blastocystis in cats by country is shown in Fig. 4.

Sensitivity analysis
The sensitivity analysis showed that the stepwise removal of individual studies (i.e., each dataset) did not result in any significant variation in the final calculated prevalence (Additional file 2: Figure S1; Additional file 3: Figure S2). However, considering the omission of the studies, the prevalence of Blastocystis infection in dogs and cats was estimated to be between 6.3–7.7% and 8.1–10.7%, respectively.

Overall prevalence of Blastocystis in dogs and cats based on investigated subgroups
The results of the subgroup analyses are shown in Table 2 and Additional files 4, 5, 6, 7, 8, 9, 10, 11, 12, 13: Figures S3, S4, S5, S6, S7, S8, S9, S10, S11, S12.

Prevalence of each Blastocystis subtype in dogs
Among the 11 genetically diverse STs identified in dogs (ST1–8, ST10, ST23, ST24), ST3 (5 datasets; 41.3%, 95% CI 16.2–71.8%) showed the highest frequency, followed by ST2 (4 datasets; 39.3%, 95% CI 24.9–55.9%), ST1 (8 datasets; 30.9%, 95% CI 19.8–44.7%), ST4 (5 datasets; 13.4%, 95% CI 7.8–22.3%), ST8 (2 datasets; 12.7%, 95% CI 4.6–30.7%), ST10 (5 datasets; 11%, 95% CI 3.8–28%) and ST5 (3 datasets; 8.1%, 95% CI 2.6–22.4%) (Fig. 5). Each of ST6, ST7, ST23 and ST24 was observed in only one study (Table 3). Unlike cats, ST5–8, ST23 and ST24 were only reported in dogs.

Prevalence of each Blastocystis subtype in cats
Relative to dogs, fewer genetically diverse STs were identified in the cats (ST1-4, ST10, ST14). The highest prevalence was observed for ST4 (2 datasets; 29.5%, 95% CI 12.5–54.9%), followed by ST10 (2 datasets; 22.5%, 95% CI 9–46.1%), ST1 (3 datasets; 19.8%, 95% CI 9.1–37.8%) and ST3 (3 datasets; 17.6%, 95% CI 5.6–43.6%) (Fig. 6). Only a single study reported ST2 and ST14, as shown in Table 3. Interestingly, ST14 has only been reported in cats, and there were no reports of dogs being infected with this subtype.

Uncharacterized Blastocystis isolates and zoonotic potential of Blastocystis STs in dogs and cats
As shown in Table 3, not all positive samples were characterized in the included studies, possibly leading to underreporting of the true subtype population in both dogs and cats. Of the 10 recognized zoonotic STs of Blastocystis (ST1–9, ST12), eight were reported in dogs (ST1–8) and four were isolated from cats (ST1–4), suggesting the importance of these animals, particularly dogs, in zoonotic transmission of Blastocystis (Table 3).

Meta-regression
No significant association was found between Blastocystis prevalence and sample size in cats (regression coefficient (Reg Coef) = – 0.0033, P = 0.101), and publication year in dogs (Reg Coef = – 0.0315, P = 0.364). A statistically substantial association was reported between the frequency of Blastocystis infection in cats and the year of publication (Reg Coef = – 0.0931, P = 0.028), and the sample size in dogs (Reg Coef = – 0.0017, P = 0.046) (Additional files 14, 15, 16 and 17: Figures. S13, S14, S15 and S16).

Publication bias
There was a significant publication bias in the present systematic review and meta-analysis (Egger’s regression: intercept = – 3.126, 95% lower limit = – 4.412, 95% upper limit = – 1.841, t-value = 4.86, P < 0.001) (Fig. 7).

Discussion
The domestication of dogs and cats may be considered as a double-edged sword for humans; these animals are considered to be part of human families on the one hand,
| First author, year | Study period | Country | Total samples (n) | Infected samples (n) | Prevalence (%) | Diagnostic method | Reference |
|--------------------|--------------|---------|-------------------|---------------------|----------------|--------------------|-----------|
| **Dogs**           |              |         |                   |                     |                |                    |           |
| Abe, 2002          | 1999         | Japan   | 54                | 0                   | 0              | Mic                | [20]      |
| Boutellis, 2021    | 2018         | Algeria | 9                 | 1                   | 11.1           | Mol                | [28]      |
| Roberts, 2013      | UC           | Australia| 56                | 0                   | 0              | Mol                | [59]      |
| Osman, 2015        | 2012–2013    | France  | 116               | 4                   | 3.4            | Mol                | [52]      |
| Duda, 1998a        | UC           | Australia| 72                | 51                  | 70.8           | Mic                | [31]      |
| La Sala, 2015      | 2012–2013    | Argentina| 475               | 14                  | 2.9            | Mic                | [41]      |
| Udonsom, 2018      | UC           | Thailand| 13                | 1                   | 7.7            | Mol                | [64]      |
| Sardarian, 2015    | 2012         | Iran    | 1500              | 1                   | 0.1            | Mic                | [62]      |
| Ramirez, 2014      | UC           | Colombia| 40                | 15                  | 37.5           | Mol                | [58]      |
| Sanchez-Thevenet, 2019 | 2014–2016 | Spain   | 263               | 3                   | 1.1            | Mic                | [61]      |
| Wang, 2013         | 2010–2011    | Australia| 80                | 2                   | 2.5            | Mol                | [66]      |
| Wang, 2013         | 2010–2011    | Cambodia| 80                | 1                   | 1.3            | Mol                | [66]      |
| Wang, 2013         | 2010–2011    | India   | 80                | 19                  | 24             | Mol                | [66]      |
| Puebla, 2015       | UC           | Cuba    | 97                | 2                   | 2.1            | Mic                | [57]      |
| Hurtado, 2019      | UC           | Colombia| 421               | 62                  | 14.7           | Mic                | [37]      |
| Bandaranayaka, 2019| UC           | Sri Lanka| 50                | 2                   | 1              | Mic                | [26]      |
| Spanakos, 2011     | 2008         | Greece  | 72                | 0                   | 0              | Mol                | [63]      |
| Belleza, 2016      | 2011–2012    | Philippines| 145              | 20                  | 13.8           | Mol                | [27]      |
| Li, 2016           | 2013         | China   | 315               | 6                   | 1.9            | Mol                | [43]      |
| Mohaghhegh, 2018   | 2014–2015    | Iran    | 301               | 32                  | 19.6           | Mic                | [47]      |
| Ruaux, 2014        | 2012         | USA     | 103               | 10                  | 9.7            | Mol                | [60]      |
| Higuera, 2021      | UC           | Colombia| 4                 | 2                   | 50             | Mol                | [13]      |
| Gazzonis, 2019     | UC           | Italy   | 99                | 21                  | 21.2           | Mol                | [32]      |
| König, 1997        | UC           | Germany | 20                | 0                   | 0              | Culture and Sero   | [39]      |
| Leelayoova, 2009   | 2006         | Thailand| 189               | 5                   | 2.6            | Mic and Mol        | [42]      |
| Dalimisal, 2001    | UC           | Iran    | 305               | 1                   | 0.3            | Mic                | [30]      |
| López, 2006        | 1996–2003    | Chile   | 972               | 351                 | 36.1           | Mic                | [46]      |
| Onder, 2021        | 2020–2021    | Turkey  | 200               | 0                   | 0              | Mol                | [51]      |
| Parkar, 2007       | UC           | Australia| 20                | 2                   | 10             | Mol                | [54]      |
| Parkar, 2007       | UC           | Thailand| 3                 | 3                   | 100            | Mol                | [54]      |
| Awadallah, 2015    | 2013         | Egypt   | 130               | 4                   | 3.1            | Mic                | [24]      |
| Gonzalez, 2015     | 2011–2012    | Colombia| 175               | 32                  | 18.3           | Mic                | [34]      |
| Gillespie, 2017    | 2014–2015    | Australia| 300              | 10                  | 3              | Mic                | [33]      |
| Hemalatha, 2014    | 2012         | Malaysia| 32                | 0                   | 0              | Mic                | [35]      |
| Noradilah, 2017    | 2014–2015    | Malaysia| 40                | 21                  | 52             | Mol                | [49]      |
| Liao, 2020         | 2018         | China   | 651               | 35                  | 5.4            | Mol                | [45]      |
| Mohammadpour, 2020b| 2016–2018    | Iran    | 154               | 29                  | 18.8           | Mol                | [48]      |
| Paulos, 2018       | 2014         | Spain   | 55                | 0                   | 0              | Mol                | [55]      |
| Perera, 2013       | 2010–2011    | Sri Lanka| 90                | 11                  | 12.2           | Mic                | [56]      |
| Mokhtar, 2018      | 2015–2016    | Egypt   | 21                | 0                   | 0              | Mol                | [22]      |
| Wang, 2018         | 2015–2017    | China   | 136               | 4                   | 2.9            | Mol                | [67]      |
| Villamizar, 2019   | UC           | Colombia| 8                 | 1                   | 12.5           | Mol                | [65]      |
| **Cats**           |              |         |                   |                     |                |                    |           |
| Boutellis, 2021    | 2018         | Algeria | 19                | 12                  | 63.1           | Mol                | [28]      |
| Roberts, 2013      | UC           | Australia| 43                | 0                   | 0              | Mol                | [59]      |
| Duda, 1998         | UC           | Australia| 52                | 35                  | 67.3           | Mic                | [31]      |
| Udonsom, 2018      | UC           | Thailand| 11                | 0                   | 0              | Mol                | [64]      |
| Pagati, 2018       | UC           | Indonesia| 90                | 48                  | 53.3           | Mic                | [33]      |
but they may carry several zoonotic agents, which can threat human health on the other hand [68]. *Blastocystis* is a zoonotic protozoa that infects a broad range of animals as well as humans [69]. Consequently, prediction of the global prevalence and subtype distribution of *Blastocystis* infection in dogs and cats is of great importance for humans. In the present study, we investigated this subject at a global scale.

Information was extracted from a total of 65 datasets (49 papers) on *Blastocystis* spp. infection in dogs and cats, and pooled frequencies of 9.3% (95% CI 5.3–15.9%) and 7% (95% CI 4.7–10.4%) were estimated for the cat and dog populations included in these datasets, respectively. A true comparison of both groups could not be conducted since a much lower number of studies examined *Blastocystis* spp. infection in cats. Individual studies had no substantial impact on the total prevalence of *Blastocystis* infection, as evidenced by the sensitivity analysis results. An obvious gap exists in terms of comprehensive epidemiological studies on *Blastocystis* infection in animal taxa, and only recently have meta-analyses derived from single studies, the highest prevalence was recorded in examined dogs in Chile (36.1%, 95% CI 33.1–39.2%) and India (23.8%, 95% CI 15.7–34.3%), as well as examined cats in Algeria (63.2%, 95% CI 40.3–81.3%). Although derived from single studies, the highest prevalence was recorded in examined dogs in Chile (36.1%, 95% CI 33.1–39.2%) and India (23.8%, 95% CI 15.7–34.3%), as well as examined cats in Algeria (63.2%, 95% CI 40.3–81.3%). These high prevalences emphasize the importance of this parasitic infection in these countries. Nevertheless, the limited geographical areas studied and the lack of a sufficient number of studies in each country make it impossible for us to make an accurate assessment of the epidemiology of this parasitic infection. Inevitably, the

| First author, year | Study period | Country | Total samples (n) | Infected samples (n) | Prevalence (%) | Diagnostic method | Reference |
|--------------------|--------------|---------|------------------|---------------------|----------------|-------------------|-----------|
| Can, 2021          | UC Turkey    | 465     | 17               | 3.6                 | Mol            | [29]             |
| Badparva, 2020     | 2017 Iran    | 120     | 0                | 0                   | Mol            | [25]             |
| Arbabi, 2009       | 2004–2005 Iran | 113  | 19               | 16.8                | Mic            | [23]             |
| Li, 2019           | 2015–2018 China | 346  | 2                | 0.6                 | Mol            | [44]             |
| Ruaux, 2014        | 2012 USA     | 105     | 12               | 11.7                | Mol            | [60]             |
| Khademvatan, 2014  | 2012 Iran    | 140     | 20               | 14.3                | Mic            | [38]             |
| Konig, 1997        | UC Germany   | 13      | 0                | 0                   | Culture and Sero | [39]           |
| Albakri, 2016      | 2014 Iraq    | 50      | 18               | 36                  | Mic            | [21]             |
| López, 2006        | 1996–2003 Chile | 230  | 86               | 37.4                | Mic            | [46]             |
| Okoye, 2014        | 2011–2012 Nigeria | 119  | 2                | 1.7                 | Mic            | [50]             |
| Onder, 2021        | 2020–2021 Turkey | 200  | 0                | 0                   | Mol            | [51]             |
| Parkar, 2007       | UC Australia | 10      | 0                | 0                   | Mol            | [54]             |
| Kwak, 2020         | UC South Korea | 158  | 1                | 0.6                 | Mol            | [40]             |
| Hemalatha, 2014    | 2012 Malaysia | 24   | 0                | 0                   | Mic            | [35]             |
| Mohammadpour, 2020 | 2016–2018 Iran | 119  | 21               | 17.7                | Mol            | [48]             |
| Paulos, 2018       | 2014 Spain   | 34      | 0                | 0                   | Mol            | [55]             |
| Karakavuk, 2021    | 2017 Turkey  | 465     | 49               | 10.5                | Mic            | [37]             |
| Mokhtar, 2018      | 2015–2016 Egypt | 8    | 0                | 0                   | Mol            | [22]             |

Mic: Microscopic detection method, Mol: Molecular detection method, Sero: Serological detection method, UC: Unclear
### Fig. 2

Global prevalence of *Blastocystis* spp. infection in dogs and cats using a random-effects model and 95% confidence intervals.

| Group by Hosts | Study name | Event rate | Lower limit | Upper limit | p-Value |
|----------------|------------|------------|-------------|-------------|---------|
| Cat Bouteille, 2021a | 0.632 | 0.403 | 0.813 | 0.257 | |
| Cat Roberts, 2013a | 0.011 | 0.001 | 0.157 | 0.600 | |
| Cat Dude, 1998b | 0.673 | 0.536 | 0.786 | 0.015 | |
| Cat Udornlong, 2018a | 0.042 | 0.003 | 0.425 | 0.630 | |
| Cat Pagani, 2018 | 0.533 | 0.430 | 0.634 | 0.527 | |
| Cat Can, 2021 | 0.037 | 0.023 | 0.058 | 0.000 | |
| Cat Badaeva, 2020 | 0.004 | 0.000 | 0.063 | 0.000 | |
| Cat Anaya, 2009 | 0.168 | 0.110 | 0.240 | 0.000 | |
| Cat Li, 2019 | 0.006 | 0.001 | 0.022 | 0.000 | |
| Cat Runyan, 2014a | 0.114 | 0.066 | 0.191 | 0.000 | |
| Cat Khademmers, 2014 | 0.143 | 0.094 | 0.211 | 0.000 | |
| Cat Kong, 1997a | 0.036 | 0.002 | 0.384 | 0.622 | |
| Cat Almada, 2016 | 0.360 | 0.240 | 0.503 | 0.051 | |
| Cat López, 2006a | 0.374 | 0.314 | 0.438 | 0.000 | |
| Cat Okuy, 2014 | 0.017 | 0.004 | 0.065 | 0.000 | |
| Cat Onder, 2021a | 0.002 | 0.000 | 0.038 | 0.000 | |
| Cat Karkuth, 2007a | 0.045 | 0.003 | 0.448 | 0.000 | |
| Cat Kwak, 2020 | 0.006 | 0.001 | 0.044 | 0.000 | |
| Cat Hemelhaha, 2014a | 0.020 | 0.001 | 0.251 | 0.006 | |
| Cat Mohimmadpour, 2020a | 0.176 | 0.118 | 0.256 | 0.000 | |
| Cat Pavesio, 2018a | 0.014 | 0.001 | 0.193 | 0.003 | |
| Cat Karakanuck, 2021 | 0.105 | 0.081 | 0.137 | 0.000 | |
| Cat Makhtar, 2018a | 0.056 | 0.003 | 0.505 | 0.052 | |
| Cat Li, 2019 | 0.093 | 0.053 | 0.159 | 0.000 | |
| Dog Abe, 2002 | 0.009 | 0.001 | 0.129 | 0.001 | |
| Dog Bouteille, 2021b | 0.111 | 0.015 | 0.500 | 0.650 | |
| Dog Roberts, 2013b | 0.009 | 0.001 | 0.125 | 0.001 | |
| Dog Vargas, 2015 | 0.034 | 0.013 | 0.088 | 0.000 | |
| Dog Dude, 1998a | 0.708 | 0.594 | 0.801 | 0.001 | |
| Dog La Sala, 2015 | 0.029 | 0.018 | 0.049 | 0.000 | |
| Dog Udornlong, 2018b | 0.077 | 0.011 | 0.391 | 0.017 | |
| Dog Sardarian, 2015 | 0.001 | 0.000 | 0.005 | 0.000 | |
| Dog Ramírez, 2014 | 0.375 | 0.240 | 0.532 | 0.118 | |
| Dog Sanchez-Thevenet, 2019 | 0.011 | 0.004 | 0.035 | 0.000 | |
| Dog Wang, 2013a | 0.025 | 0.006 | 0.094 | 0.000 | |
| Dog Wang, 2013b | 0.013 | 0.002 | 0.083 | 0.000 | |
| Dog Wang, 2013c | 0.238 | 0.157 | 0.343 | 0.000 | |
| Dog Puelles, 2015 | 0.021 | 0.005 | 0.079 | 0.000 | |
| Dog Hurtado, 2019 | 0.147 | 0.117 | 0.184 | 0.000 | |
| Dog Bandaranayake, 2019 | 0.040 | 0.010 | 0.146 | 0.000 | |
| Dog Spanakos, 2011 | 0.007 | 0.000 | 0.100 | 0.000 | |
| Dog Belousova, 2016 | 0.138 | 0.091 | 0.204 | 0.000 | |
| Dog Li, 2016 | 0.019 | 0.009 | 0.042 | 0.000 | |
| Dog Mohagheghi, 2018 | 0.196 | 0.155 | 0.245 | 0.000 | |
| Dog Ruax, 2014b | 0.097 | 0.053 | 0.171 | 0.000 | |
| Dog Higuera, 2021 | 0.500 | 0.253 | 0.877 | 1.000 | |
| Dog Giannoni, 2019a | 0.212 | 0.143 | 0.304 | 0.000 | |
| Dog Kong, 1997b | 0.024 | 0.001 | 0.287 | 0.000 | |
| Dog Leebyovoe, 2009 | 0.026 | 0.011 | 0.062 | 0.000 | |
| Dog Oxlind, 2001 | 0.010 | 0.000 | 0.023 | 0.000 | |
| Dog López, 2006b | 0.361 | 0.315 | 0.392 | 0.000 | |
| Dog Onder, 2021b | 0.002 | 0.000 | 0.038 | 0.000 | |
| Dog Parker, 2007a | 0.100 | 0.025 | 0.324 | 0.003 | |
| Dog Parker, 2007c | 0.875 | 0.266 | 0.993 | 0.198 | |
| Dog Javedallah, 2015 | 0.031 | 0.012 | 0.079 | 0.000 | |
| Dog González, 2015 | 0.183 | 0.132 | 0.247 | 0.000 | |
| Dog Gilisip, 2017 | 0.033 | 0.018 | 0.061 | 0.000 | |
| Dog Hemelhaha, 2014b | 0.015 | 0.001 | 0.201 | 0.003 | |
| Dog Haddad, 2017 | 0.525 | 0.373 | 0.693 | 0.752 | |
| Dog Liso, 2020 | 0.054 | 0.039 | 0.074 | 0.000 | |
| Dog Mohimmadpour, 2020a | 0.188 | 0.134 | 0.258 | 0.000 | |
| Dog Pavesio, 2018b | 0.009 | 0.001 | 0.127 | 0.000 | |
| Dog Pavesio, 2013 | 0.122 | 0.069 | 0.207 | 0.000 | |
| Dog Makhtar, 2018b | 0.023 | 0.001 | 0.277 | 0.000 | |
| Dog Wang, 2018 | 0.029 | 0.011 | 0.076 | 0.000 | |
| Dog Villamizar, 2019 | 0.125 | 0.017 | 0.367 | 0.689 | |
| Dog | 0.070 | 0.047 | 0.104 | 0.000 | |

CI = Confidence interval
Sample size has a large effect on the estimated prevalence of an infection, as reflected in our results: sample sizes of $\leq 50$ and $51$–$100$ animals demonstrated the highest prevalence rates for *Blastocystis* infection, a prevalence of $18.6\%$ (95% CI 8.6–35.8%) in dogs and $67.3\%$ (95% CI 5.3.6–78.6%) in cats. It would appear that the results
### Table 2: Prevalence of Blastocystis sp. in dogs and cats based on examined subgroups

| Subgroup variable | Prevalence, % (95% CI) | Heterogeneity (Cochran’s Q) | df (Cochran’s Q) | I^2 (%) | P-value |
|-------------------|-------------------------|----------------------------|-----------------|---------|---------|
| **Publication year** |                         |                            |                 |         |         |
| Prior to and including 2000 | 23.2 (0.3–96.4) | 26.1 (0.7–94.6) | 10 | 7.5 | 1 | 90 | 86.6 | P = 0.002 | P = 0.006 |
| 2001–2005 | 0.5 (0.1–2.2) | – | 0.3 | – | 1 | – | – | P = 0.555 | – |
| 2006–2010 | 20.1 (3.4–64.6) | 22.3 (9.2–44.8) | 51.2 | 16.8 | 3 | 2 | 94.1 | 88.1 | P < 0.001 | P < 0.001 |
| 2011–2015 | 4.5 (2.3–8.8) | 6.4 (2.7–14.2) | 138.1 | 13.6 | 14 | 4 | 89.8 | 70.6 | P < 0.001 | P = 0.009 |
| 2016–2021 | 8.4 (5.2–13.1) | 7 (2.9–15.8) | 189.3 | 217.1 | 18 | 12 | 90.5 | 94.5 | P < 0.001 | P < 0.001 |
| **Continent** |                         |                            |                 |         |         |
| Africa | 3.7 (1.6–8.4) | 11.4 (0.4–80) | 1.5 | 30.6 | 2 | 2 | – | 93.4 | P = 0.472 | P < 0.001 |
| Asia | 6 (3.3–10.4) | 7.2 (3.5–14.2) | 441.4 | 193.9 | 20 | 12 | 95.4 | 93.8 | P < 0.001 | P < 0.001 |
| Europe | 3.6 (0.8–15.5) | 2.3 (0.3–14.4) | 23.8 | 0.2 | 4 | 1 | 93.2 | 0 | P < 0.001 | P = 0.643 |
| North America | 5.1 (1.1–20.7) | 11.4 (6.6–19.1) | 4.3 | 0 | 1 | 0 | 76.6 | 0 | P = 0.032 | NA |
| Oceania | 7.5 (0.7–48.3) | 11.3 (0.3–82.9) | 1299 | 18.5 | 4 | 2 | 96.9 | 89.2 | P < 0.001 | P < 0.001 |
| South America | 16 (7.7–30.4) | 37.4 (31.4–43.8) | 60.3 | 0 | 5 | 0 | 91.7 | 0 | P < 0.001 | NA |
| **WHO region** |                         |                            |                 |         |         |
| AFR | 11.1 (1.5–50) | 15 (0.2–94.2) | – | 28.9 | 0 | 1 | 0 | 96.5 | NA | P < 0.001 |
| AMR | 14.6 (7.5–26.3) | 22.2 (6.5–56.1) | 196.3 | 20.8 | 8 | 1 | 95.9 | 95.2 | P < 0.001 | P < 0.001 |
| EMR | 3.2 (1–9.3) | 16.8 (10.1–26.6) | 66.7 | 20.2 | 5 | 5 | 92.5 | 75.3 | P < 0.001 | P = 0.001 |
| EUR | 2.1 (0.5–8.8) | 3.8 (1.4–9.9) | 483 | 23.3 | 6 | 4 | 87.5 | 82.8 | P < 0.001 | P < 0.001 |
| SEAR | 11.3 (4.3–26.5) | 23.4 (13.8–76.7) | 31.9 | 5 | 5 | 1 | 84.3 | 80 | P < 0.001 | P = 0.025 |
| WPR | 6.2 (2.2–15.1) | 3.1 (0.2–38.6) | 262.9 | 95.8 | 12 | 5 | 95.4 | 94.8 | P < 0.001 | P < 0.001 |
| **Country** |                         |                            |                 |         |         |
| Algeria | 11.1 (1.5–50) | 63.2 (40.3–81.3) | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA |
| Argentina | 2.9 (1.8–4.9) | – | 0 | – | 0 | – | 0 | – | NA | – |
| Australia | 7.5 (0.7–48.3) | 11.3 (0.3–82.9) | 129.9 | 18.5 | 4 | 2 | 96.9 | 89.2 | P < 0.001 | P < 0.001 |
| Cambodia | 1.3 (0.2–8.3) | – | 0 | – | 0 | – | 0 | – | NA | – |
| Chile | 36.1 (33.1–39.2) | 37.4 (31.4–43.8) | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA |
| China | 3.4 (1.7–6.7) | 0.6 (0.1–2.3) | 6.5 | 0 | 2 | 0 | 69.4 | 0 | P = 0.038 | NA |
| Colombia | 21.8 (13.9–32.6) | – | 14.9 | – | 4 | – | 73.2 | – | P = 0.005 | – |
| Cuba | 2.1 (0.5–7.9) | – | 0 | – | 0 | – | 0 | – | NA | – |
| Egypt | 3 (1.2–7.3) | 5.6 (0.3–50.5) | 0.04 | 0 | 1 | 0 | 0 | 0 | P = 0.838 | NA |
| France | 3.4 (1.3–8.8) | – | 0 | – | 0 | – | 0 | – | NA | – |
| Germany | 2.4 (0.1–28.7) | 3.6 (0.2–38.4) | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA |
| Greece | 0.7 (0–10) | – | 0 | – | 0 | – | 0 | – | NA | – |
| India | 23.8 (15.7–34.3) | – | 0 | – | 0 | – | 0 | – | NA | – |
| Indonesia | – | 53.3 (43.6–63.4) | – | 0 | – | 0 | – | 0 | – | NA |
| Iraq | – | 36 (24–50.1) | – | 0 | – | 0 | – | 0 | – | NA |
| Iran | 3.4 (0.9–11.7) | 14.7 (9.4–22.1) | 51.5 | 7.8 | 3 | 3 | 94.1 | 61.8 | P < 0.001 | P = 0.049 |
| Italy | 21.2 (14.3–30.4) | – | – | – | 0 | – | 0 | – | NA | – |
| Japan | 0.9 (0.1–12.9) | – | – | – | 0 | – | 0 | – | NA | – |
| Malaysia | 14 (0.3–91.3) | 2 (0.1–25.1) | 8.5 | 0 | 1 | 0 | 88.3 | 0 | P = 0.003 | NA |
| Nigeria | – | 1.7 (0.4–6.5) | – | 0 | – | 0 | – | 0 | – | NA |
| Philippines | 13.8 (9.1–20.4) | – | 0 | – | 0 | – | 0 | – | NA | – |
| South Korea | – | 0.6 (0.1–4.4) | – | 0 | – | 0 | – | 0 | – | NA |
| Spain | 1.1 (0.4–3.1) | 1.4 (0.1–19.1) | 0.026 | 0 | 1 | 0 | 0 | 0 | P = 0.087 | NA |
| Sri Lanka | 8.3 (2.8–21.9) | – | 2.3 | – | 1 | – | 57.1 | – | P = 0.127 | – |
| Thailand | 15.4 (1.2–73.7) | 4.2 (0.3–42.5) | 12.7 | 0 | 2 | 0 | 84.3 | 0 | P = 0.002 | NA |
| Turkey | 0.2 (0.3–8.8) | 4.2 (1.3–12.6) | 0 | 21.5 | 0 | 2 | 0 | 90.7 | N.A | P < 0.001 |
obtained from dogs are more reliable because they have been inferred from several studies (10 datasets), in comparison to the results from cats (1 paper). Taken together, when considering the evaluated subgroups, we found that the confidence intervals of reported frequencies were very wide, which is directly related to the limited number of studies and the large differences in reported prevalence rates. This is obviously a major limitation in our study, which can be eliminated by more comprehensive, nation-wide studies.

Another prominent finding of the present study was that dogs are a crucial source of zoonotic Blastocystis subtypes (ST1–ST8) and, therefore, possibly having the potential to transmit such subtypes to humans. However, the number of isolated STs from dogs and cats may increase in the future as not all positive samples in the studies included in this meta-analysis were subtyped. Mixed infections with multiple subtypes are frequently seen in association with Blastocystis infection [70]. Mixed cases were reported in some of the studies, but due to various limitations, we could not estimate their pooled prevalence.

Meta-regression results revealed that in contrast to the sample size in cats and publication year in dogs, the year of publication in cats and the sample size in dogs were considered as a cause of variability in Blastocystis prevalence. Accordingly, there was a direct association between a reduction in Blastocystis infection rate with recently published studies in cats and with an increase in sample size in dogs. A high rate of heterogeneity was reported as publication bias in the present study, which could substantially skew the outcomes [71]. This may originate from differences in geographical region, publication year, number of studies in each area and sample size, as mentioned in Table 2. Other parameters not mentioned in this current review may also represent publication bias, such as the status of animal health, sampling procedures, sample preservation, method of raising owned animals, sensitivity of diagnostic methods, age and sex of the examined hosts and the quality of studies entered. Hence, the results obtained from the present study must be interpreted with caution. In general, despite the valuable epidemiological information we collected in the current study, future studies could, therefore, shed more light on the ST distribution and epidemiological patterns of Blastocystis infection in dogs and cats across the globe.

Table 2 (continued)

| Subgroup variable | Prevalence, % (95% CI) | Heterogeneity (Cochran’s Q) | df (Cochran’s Q) | I² (%) | P-value |
|-------------------|------------------------|-----------------------------|-----------------|--------|---------|
|                   | Dogs | Cats | Dogs | Cats | Dogs | Cats | Dogs | Cats | Dogs | Cats |
| USA               | 9.7 (5.3–17.1) | 11.4 (6.6–19.1) | 0 | 0 | 0 | 0 | 0 | 0 | N.A | N.A |
| Sample size, n    |       |       |       |       |       |       |       |       |       |       |
| ≤ 50              | 18.6 (8.6–35.8) | 14.3 (5.9–30.8) | 35.2 | 45.5 | 10 | 9 | 71.6 | 80.2 | P < 0.001 | P < 0.001 |
| 51–100            | 5.8 (2.2–14.4) | 6.7 (3.5–12.6) | 139.2 | 0 | 11 | 0 | 92.1 | 0 | P < 0.001 | N.A |
| 101–200           | 6.7 (3.7–11.7) | 6.7 (3.5–12.6) | 58.6 | 38 | 8 | 7 | 86.3 | 81.6 | P < 0.001 | P < 0.001 |
| 201–300           | 2.2 (0.8–6) | 37.4 (31.4–43.8) | 2.7 | 0 | 1 | 0 | 63.2 | 0 | N.A | N.A |
| 301–400           | 2.8 (0.3–22.9) | 0.6 (0.1–2.3) | 49.4 | 507.8 | 2 | 0 | 95.9 | 0 | P < 0.001 | N.A |
| > 400             | 5.2 (1.5–16.4) | 6.4 (2.2–17.1) | 305 | 15.3 | 4 | 1 | 98.7 | 93.5 | P < 0.001 | P < 0.001 |

N.A Non-applicable

Conclusion

Currently, many dogs and cats live in the (close) proximity of humans and have the potential to be a threat human health, particularly through zoonotic infections. To the best of our knowledge, we present here the first comprehensive insights into the worldwide epidemiology, subtype distribution and zoonotic potential of Blastocystis infection in dogs and cats. The prevalence of this infection was relatively low among dogs (7%) and cats (9.3%), albeit higher higher in cats. Notably, of the 28 reported Blastocystis STs, 11 were isolated from dogs and six were isolated from cats, with most of these considered to be zoonotic. Consequently, these animals could play a significant role in the transmission of zoonotic subtypes to humans. The present review was designed and conducted solely on the basis of current published literature (up to 8 November 2021), and more extensive studies are needed to elucidate the epidemiology and distribution of dog and cat STs.
**Fig. 5** Weighted frequency of each *Blastocystis* STs in dogs using the random-effects model. Abbreviation: ST, Subtype.
Table 3  Worldwide distribution of Blastocystis subtypes in dogs and cats reported in 19 molecular studies (25 datasets)

| Author, year (n datasets) | Total samples (n) | Infected samples (n) | Prevalence (%) | Subtyping of infected samples<sup>a</sup> | Zoonotic subtypes<sup>d</sup> |
|--------------------------|-------------------|----------------------|----------------|----------------------------------------|-----------------------------|
|                          |                   |                      |                | Subtyped<sup>b</sup> (n/%) | Unidentified<sup>c</sup> (n/%) |

**Dogs**

Boutellis, 2021 (2 datasets) 9 1 11.1 – 1/100 –
Osman, 2015 116 4 3.4 ST2 (2/50), ST10 (2/50) – Feb-50
Udonsom, 2018 (2 datasets) 13 1 7.7 ST3 (1/100) – 1/100
Ramirez, 2014 40 15 37.5 ST2 (15/100) – 15/100
Wang, 2013 (1 dataset) 80 2 2.5 ST1 (2/100) – 2/100
Wang, 2013 (2 datasets) 80 1 1.3 ST2 (1/100) – 1/100
Wang, 2013 (3 datasets) 80 19 24 ST1 (9/47.4), ST4 (2/10.5), ST5 (1/5.3), ST6 (7/36.8) – 19/100
Belleza, 2016 145 20 13.8 ST2 (1/5), ST3 (2/10), ST4 (2/10), ST5 (2/10), ST1/ST3 (1/5), ST2/ST3 (1/5), ST4/ST5 (1/5) Oct-50 Oct-50
Li, 2016 315 6 1.9 ST1 (2/33.3), ST1/ST2 (4/66.7) – 6/100
Ruaux, 2014 (2 datasets) 103 10 9.7 ST1 (2/20), ST10 (2/20) Jan-50 Jan-50
Higuera, 2021 4 2 50 ST23/ST24 (1/50) – 1/100
Gazzonis, 2019 99 21 21.2 ST3 (21/100) – 21/100
Parkar, 2007 (2 datasets) 20 2 10 ST1 (1/50) Jan-50 Jan-50
Parkar, 2007 (3 datasets) 3 3 100 ST5 (3/100) – 3/100
Noradilah, 2017 40 21 52 ST1 (6/20.8), ST3 (7/33.3), ST4 (4/19), ST8 (4/19), ST10 (1/4.8) 20/95.2
Liao, 2020 651 35 5.4 ST1 (6/17.1), ST3 (28/80), ST10 (1/2.8) 34/97.1
Mohammadpour, 2020 (2 datasets) 154 29 18.8 ST2 (8/27.6), ST3 (11/37.9), ST4 (3/10.3), ST7 (3/10.3), ST8 (2/6.9), ST10 (2/6.9) 27/93.1
Wang, 2018 136 4 2.9 ST1 (3/75), ST4 (1/25) – 4/100
Villamizar, 2019 8 1 12.5 ST1 (1/100) – 1/100

**Cats**

Boutellis, 2021 (1 dataset) 19 12 63.1 ST2 (3/25), ST3 (1/8.3) 8/66.7 4/33.3
Can, 2021 465 17 3.6 ST4 (7/41.2) 10/58.8 7/41.2
Li, 2019 346 2 0.6 ST1 (2/100) – 2/100
Ruaux, 2014 (1 dataset) 105 12 11.7 ST1 (1/8.3), ST3 (1/8.3), ST10 (4/33.4) Jun-50 2/16.7
Kwak, 2020 158 1 0.6 ST4 (1/100) – 1/100
Mohammadpour, 2020 (1 dataset) 119 21 17.7 ST1 (5/23.8), ST3 (7/33.3), ST4 (4/19), ST10 (3/14.3), ST14 (2/9.5) 16/76.2

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<sup>a</sup> Out of the positive samples of Blastocystis,
<sup>b</sup> Some have been subtyped
<sup>c</sup> Some have not been subtyped or not determined
<sup>d</sup> The number and percentage of zoonotic subtypes are computed for ST1-ST8
### Overall prevalence of each Blastocystis subtype in cats using a random-effects model

| Group by STs | Study name                  | Statistics for each study | Event rate | Lower limit | Upper limit | p-Value |
|--------------|-----------------------------|---------------------------|------------|-------------|-------------|---------|
| ST1          | Li, 2019                    |                           | 0.999      | 0.000       | 1.000       | 0.758   |
| ST1          | Ruaux, 2014a                |                           | 0.083      | 0.012       | 0.413       | 0.022   |
| ST1          | Mohammadpour, 2020a         |                           | 0.238      | 0.103       | 0.460       | 0.023   |
| ST1          |                              |                           | 0.198      | 0.091       | 0.378       | 0.002   |
| ST10         | Ruaux, 2014c                |                           | 0.334      | 0.131       | 0.625       | 0.260   |
| ST10         | Mohammadpour, 2020d         |                           | 0.143      | 0.047       | 0.362       | 0.004   |
| ST10         |                              |                           | 0.225      | 0.090       | 0.461       | 0.025   |
| ST3          | Boutellis, 2021a            |                           | 0.083      | 0.012       | 0.413       | 0.022   |
| ST3          | Ruaux, 2014b                |                           | 0.083      | 0.012       | 0.413       | 0.022   |
| ST3          | Mohammadpour, 2020b         |                           | 0.333      | 0.168       | 0.553       | 0.134   |
| ST3          |                              |                           | 0.176      | 0.056       | 0.436       | 0.019   |
| ST4          | Can, 2021                   |                           | 0.412      | 0.211       | 0.648       | 0.470   |
| ST4          | Mohammadpour, 2020c         |                           | 0.190      | 0.073       | 0.411       | 0.009   |
| ST4          |                              |                           | 0.295      | 0.125       | 0.549       | 0.110   |

**Fig. 6** Overall prevalence of each *Blastocystis* subtype in cats using a random-effects model

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### Funnel Plot of Standard Error by Logit event rate

**Fig. 7** A funnel plot representing publication bias in the present systematic review and meta-analysis
Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13071-022-05351-2.

Additional file 1: Table S1. JBI critical appraisal checklist applied for included studies

Additional file 2: Figure S1. Sensitivity analysis on the pooled Blastocystis prevalence in dogs.

Additional file 3: Figure S2. Sensitivity analysis on the pooled Blastocystis prevalence in cats.

Additional file 4: Figure S3. Pooled Blastocystis prevalence based on publication year in dogs.

Additional file 5: Figure S4. Pooled Blastocystis prevalence based on publication year in cats.

Additional file 6: Figure S5. Pooled Blastocystis prevalence based on continents in dogs.

Additional file 7: Figure S6. Pooled Blastocystis prevalence based on continents in cats.

Additional file 8: Figure S7. Pooled Blastocystis prevalence based on WHO regions in dogs.

Additional file 9: Figure S8. Pooled Blastocystis prevalence based on WHO regions in cats.

Additional file 10: Figure S9. Pooled Blastocystis prevalence based on countries in dogs.

Additional file 11: Figure S10. Pooled Blastocystis prevalence based on countries in cats.

Additional file 12: Figure S11. Pooled Blastocystis prevalence based on sample size in dogs.

Additional file 13: Figure S12. Pooled Blastocystis prevalence based on sample size in cats.

Additional file 14: Figure S13. Association between Blastocystis prevalence and publication year in dogs using meta-regression.

Additional file 15: Figure S14. Association between Blastocystis prevalence and sample size in dogs using meta-regression.

Additional file 16: Figure S15. Association between Blastocystis prevalence and publication year in cats using meta-regression.

Additional file 17: Figure S16. Association between Blastocystis prevalence and sample size in cats using meta-regression.

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AA and GH conceived and designed the study. LS, AV, AS, BM and SS. extracted the data. AA performed the analyses. AA wrote and revised the paper. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets supporting the conclusions of this article are included in the article (and its additional files).

Declarations

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Competing interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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