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Prevalence of brucellosis in sheep and goats in the regions of Central America and the Caribbean and South America in the period 2010-2021. Systematic review and meta-analysis

Prevalencia de brucelosis en ovinos y caprinos en las regiones de Centroamérica y el Caribe y Sudamérica en el período 2010- 2021. Revisión sistemática y meta-análisis

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Abstract

In order to determine through a systematic review and meta-analysis the combined prevalence of brucellosis in sheep and goats in the regions of Central America, the Caribbean and South America and to identify if there are differences in their behavior over time, the species studied, the geographic region and the species of the genus *Brucella* investigated, articles published in the electronic databases PubMed/PubMed Central, Science Direct, Scielo, Ebsco, Springer Link, Elsevier and Google Scholar in the period 2010-2021 were retrieved. Individual brucellosis seroprevalence was calculated for each study and a meta-analysis was performed to estimate pooled prevalence and for subgroup analysis a meta-regression analysis was performed for each variable included in the study separately and variables with *P-values*<0.01 were used in the multivariate meta-regression analysis. Forty-eight articles were identified that met the criteria for inclusion in the study from 14 countries and territories in the regions studied, six from the Central America and Caribbean region and eight from South America, showing that there are few articles reporting on the seroprevalence of brucellosis in sheep and goats in the regions studied. It was found that there is a high combined prevalence of the disease and that it is higher for *B. ovis* with respect to *Brucella* spp. and in the period from 2010 to 2016 with respect to the period from 2017 to 2021. No differences were found in the combined prevalence between sheep and goats or between the regions studied.

Keywords: brucellosis, small ruminants, prevalence, meta-analysis.

Resumen

Con el objetivo de determinar mediante una revisión sistemática y meta-análisis la prevalencia combinada de brucelosis en ovinos y caprinos en las regiones de Centroamérica y el Caribe y Sudamérica e identificar si existen diferencias en su comportamiento en el tiempo, las especies estudiadas, la región geográfica y en las especies del género Brucella investigadas, se recuperaron artículos publicados en las bases de datos electrónicas: PubMed/PubMed Central, Science Direct, Scielo, Ebsco, Springer Link, Elsevier y Google Scholar en el período 2010-2021. Se calculó la seroprevalencia individual de brucelosis para cada estudio y se realizó un meta-análisis para estimar la prevalencia combinada y para el análisis de subgrupos se realizó un análisis de meta-regresión para cada variable incluida en el estudio por separado y las variables con valores de P<0,01 se utilizaron en el análisis de meta-regresión multivariada. Se identificaron 48 artículos que cumplían los criterios para ser incluidos en el estudio de 14 países y territorios de las regiones estudiadas, seis de la región de Centroamérica y el Caribe y ocho de Sudamérica, demostrándose que existen pocos artículos que informen sobre la seroprevalencia de brucelosis en ovinos y caprinos en estas regiones. Se comprobó que existe una elevada prevalencia combinada de la enfermedad y que la misma fue mayor para B. ovis con respecto a Brucella spp. y en el período de 2010 al 2016 con respecto al período del 2017 al 2021. No se encontraron diferencias en la prevalencia combinada entre los ovinos y caprinos ni entre las regiones estudiadas.

Palabras clave: brucelosis, pequeños rumiantes, prevalencia, meta-análisis.

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Introduction

Brucellosis is an infectious disease caused by the *Brucella* genus bacteria (Alves de Oliveira et al., 2016) that affects a great number of animal species and is considered to be one of the most common zoonetic disieases worldwide, with more than half a million cases a year (Ran et al., 2018), the *Brucella melitensis* and *B. ovis* species are primary agents of brucellosis in small rumiants (Rossetti et al., 2022), although *B. abortus* can also affect these animal species (Akhvledian et al., 2010, Sorsa et al., 2022).

Brucellosis from *B. melitensis* causes abortions. Stillbirth crisis and weak offsprings are clinical signs of this disease as well, and they are associated with a negative impact of productivity in cattle. The *Brucella* species is the most biral for humans and is responsible for chronic and sometimes crippling diseases (Rossetti et al., 2017).

The *B. ovis* is the ethiological agent of the contagious epydimitis of rams which causes important economic loosses for bovine production. The disease is associated with genital injuries and reduced fertility in males sometimes also causing embryionic mortality, abortion or reduced fertility in sheeps, and an increase in stillbirth mortality in goats (Fiorentino et al., 2017).

Brucellosis occurs endemically in developing countries, including Latin American nations (Moreno, 2002; Lucero et al., 2008), and in small ruminants it is characterized by causing abortions, retained placenta, infertility, orchitis, epididymitis, among other conditions (Shome et al., 2021).

The production of small ruminants has increased in recent years (Farias et al., 2013), with reported populations of sheep and goats in the Americas in 2020 totaling 82,740,751 and 39,194,276 heads, respectively (FAO, 2022). A large percentage of these animal populations is concentrated in poor countries that lack the necessary resources for the diagnosis and control of brucellosis (Geresu and Kassa, 2016), which poses a significant public health challenge, as these animals serve as reservoirs of the disease (Ran et al., 2018), and humans can become infected through the consumption of unpasteurized milk, products made from it, or through the handling of infected animals (Mazlan et al., 2021).

The control of brucellosis in small ruminants can contribute to reducing the incidence of the disease in humans; however, understanding the behavior and epidemiology of the disease is a fundamental prerequisite for the development of an effective control campaign (Ran et al., 2018). Between 2010 and 2020, a total of 16 countries from the regions of Central America, the Caribbean, and South America reported cases of brucellosis in sheep and goats (OIE, 2022), highlighting the significance of this disease in these areas. Evaluating the prevalence of the disease in different species through meta-analysis has enabled the establishment of an evidence-based framework for improved prevention, control, and eradication strategies (Dahl, 2020; Dadar et al., 2021). Therefore, this study aimed to determine, through a systematic review and meta-analysis, the pooled prevalence of brucellosis in sheep and goats in Central America, the Caribbean, and South America, based on information from articles published in electronic databases between 2010 and 2021. Additionally, the study sought to identify whether there were differences in disease patterns over time, between studied species, geographic regions, and *Brucella* species investigated.

Materials and methods

Literature search strategy

The study included articles published in the electronic databases PubMed/PubMed Central, Science Direct, SciELO, EBSCO, SpringerLink, Elsevier, and Google Scholar during the period 2010-2021. The article search was conducted using Medical Subject Headings (MeSH) terms. The key search terms were: (Brucellosis OR *Brucella*) AND (Sheep OR Goat) AND (Seroprevalence OR Prevalence OR Seroepidemiology) AND (South America OR Central America OR Caribbean OR Specific country). These same terms were also used in Spanish. In addition to scientific articles, master's and doctoral theses were included in the study.

Inclusion adn exclusion criteria

The following inclusion criteria were used to confirm the elegibility of the retrieved articles: 1) published articles between 2010 and 2021; 2) original peer-reviewed research articles and postgraduate theses conducted in South America, Central America, and the Caribbean; 3) cross-sectional studies reporting the seroprevalence of brucellosis in sheep and goat species under any management system (intensive or extensive); 4) studies with full texts available; 5) studies that used serological diagnostic techniques recommended by the

World Organisation for Animal Health (OIE, 2021); 6) studies that reported both sample size and number of positive samples. In addition, the references of the selected articles were manually checked to identify relevant studies that may not have been retrieved during the database search.

Quality assessement

For the quality assessment, two reviewers were selected, and the "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) methodology was applied. This methodology includes 22 items, covering aspects such as study objectives, various components of the materials and methods (study design, sample size, study population, bias, calibration methods), results, and limitations. Scores ranged from 0 to 44, and the reviewed articles were categorized into three quality levels: low quality (<15.5), moderate/good quality (15.5-29.5), and high quality (30.0-44.0) (Von Elm et al., 2007). Only articles classified as high or good quality were included in the study, while those rated as low quality were excluded.

Selection of studies and data analysis

The BIVET software (Romero, 2019) was used to index the identified records. Duplicate records were documented and removed. Titles and abstracts were independently screened based on predefined inclusion criteria, and full texts were independently retrieved and assessed for final eligibility. A data extraction form was developed, including the following variables: first author, year of publication, year of the study, geographical location (countries), study design, sampling method, sample size, diagnostic test, animal species sampled, *Brucella* species sampled (*B. abortus* and *B. melitensis* were reported as *Brucella* spp. since conventional serology cannot differentiate them), number of positive samples, and corresponding negative cases. The individual seroprevalence of brucellosis was calculated by dividing the number of positive cases by the total number of individuals included in the study within a given population and time frame, and multiplying by 100. The effect size of each study and corresponding confidence intervals were calculated based on the extracted data. A Microsoft Excel spreadsheet was used to code and manage all the data extracted from the relevant studies. The PRISMA methodology (Shamseer et al., 2015) was used to report the study results.

Statistical analysis

A meta-analysis was conducted to estimate the pooled prevalence, using the formula provided by Barendregt et al. (2013). A diagram was used to present variations among studies, and the meta-analysis results included seroprevalence estimates with corresponding confidence intervals for all included studies, along with the pooled effect size. Similarly, a subgroup analysis was performed to determine the effect of variables such as country, geographic region (South America and Central America & the Caribbean), animal species (sheep and goats), *Brucella* species investigated (*Brucella* spp. and *B. ovis*), and publication period (2010-2016 and 2017-2021) on the pooled prevalence of brucellosis.

Cochran's Q statistic and inverse variance index (I^2) were calculated to assess heterogeneity and inconsistency (true variation) among studies, respectively. I^2 values of 25, 50, and 75% were interpreted as low, moderate, and high heterogeneity, respectively (Higgins and Thompson, 2002). The variance of effect size estimates in the study population was evaluated using the tau-squared (τ^2) statistic. A Galbraith plot was also constructed to assess heterogeneity in effect size estimates at the study level. Based on the heterogeneity assessment, the DerSimonian and Laird random-effects model was used when the Q-test *P*-value was <0.05 and I^2 was >50%; otherwise, the Mantel-Haenszel fixed-effects model was applied to pool the estimates (Tufanaru et al., 2015).

Subsequently, the effects of small-study bias and the presence of publication bias were assessed using funnel plots and Egger's and Begg's asymmetry tests (Borenstein et al., 2009). A funnel plot was generated using the logarithm of the effect size and its corresponding standard error.

The meta-analysis was performed using the meta package version 4.18-1 in R software (R Development Core Team, R, 2020). Heterogeneity between subgroups was further tested through meta-regression analysis, which also examined the relationship between prevalence and variables such as geographic region, study period, and animal species. A separate meta-regression analysis was conducted for each variable included in the study, and variables with *P*-values <0.01 were included in the multivariate meta-regression analysis.

Results and discussion

A total of 48 articles met the criteria for inclusion in the study. Reports on the prevalence of brucellosis were available for only 14 countries and territories within the studied regions—six from Central America and the Caribbean and eight from South America—representing 18.75 and 61.53%, respectively, of the countries in these regions. Notably, 70.83% of the studies were concentrated in just three countries: Brazil, Mexico, and Argentina (Table 1; Figure 1)

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Tabla 1. Distribution of articles included per Geographic area

Geographic area	Included articles	References	Research	Positives	% de positives	IC 95%
Central American and the Caribbean	16**		13,243	825	6.23	5.83-6.55
Dominica	1	Johnson et al., 2020	194	0	0	0.00-1.94
El Salvador	1	Linderot de Cardona et al., 2016	731	0	0	0.00-0.52
Granada	1	Johnson et al., 2020	184	0	0	0.00-2.05
Mexico	11	Ortega-Sánchez et al., 2012; Carrera Chávez et al., 2013; Oseguera Montiel et al., 2013; García-Juárez et al., 2014; Banda Castillo, 2015; Flores et al., 2015; Gutiérrez Hernández et al., 2015; Marin et al., 2015; Hernández et al., 2016; Román-Ramírez et al., 2017; Román-Ramírez et al., 2020	11,616	825	7.10	6.65-7.58
Montserrat	1	Johnson et al., 2020	168	0	0	0.00-2.24
Saint Kitts and Nevis	1	Johnson et al., 2020	350	0	0	0.00-1.09
South America	35		52,890	2,841	5.37	5.18-5.57
Argentina	6	Mancebo et al., 2011; Gaido et al., 2013; Russo et al., 2016; López et al., 2018; Martinez et al., 2018; Simonetti et al., 2019	37,853	2,157	5.70	5.47-6.31
Bolivia	2	Beltrán-Saavedra et al., 2010; Zambriski et al., 2010	271	0	0.00	0.00-1.40
Brazil	17	Alves et al., 2010; Juliano et al., 2011; Costa et al., 2012; Marinho et al., 2012; Martins et al. 2012; Ribeiro Araújo et al., 2013; Santos et al., 2013; Ximenes Martins et al., 2013; Rizzo et al., 2014; Machado et al., 2015, Alves de Oliveira et al., 2016; De Moraes Peixoto et al., 2016; dos Santos et al., 2016; Santos et al., 2016; Alexandre Alves et al., 2017; Alves da Silva et al., 2017; de Araújo Teixeira et al., 2021	9,876	565	5.72	5.28-6.20
Chile	1	Troncoso et al., 2014	40	5	12.50	5.46-26.11
Colombia	1	Tique et al., 2010	329	0	0.00	0.00-1.15
Ecuador	5	Zabala et al. 2012; Poulsen et al., 2014; Purtschert Barahona et al., 2017; Ron-Román et al., 2017; Moscoso Gómez et al., 2019	2,827	38	1.34	0.98-1.84
Peru	1	Campos y Morales-Cauti, 2020	926	1	0.11	0.02-0.61
Venezuela	2	Valeris-Chacín et al., 2012; Vargas et al., 2016	768	75	9.77	7.86-12.07
Total	48		66,133	3,666	5.54	5.37-5.72

** an article that presents information of four countries

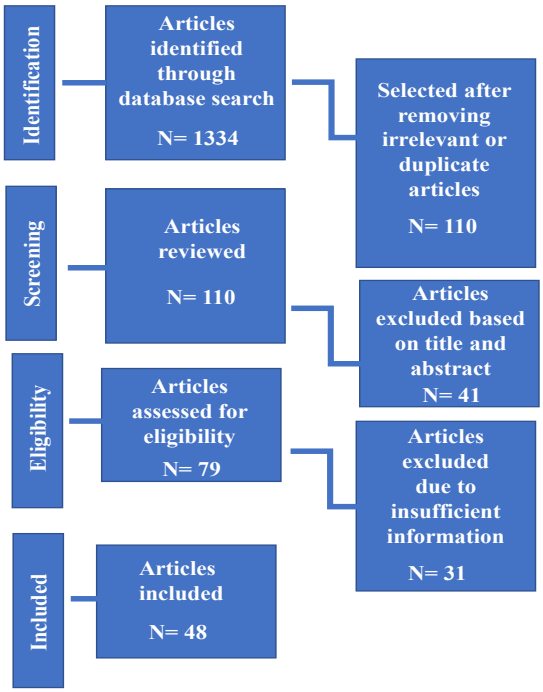

Figure 1. Flow diagram of the article selection process for inclusion in the study.

According to the animal species, it was found that out of the 48 available articles, 31 reported data on the prevalence of brucellosis in sheep and 23 in goats (Table 2).

Table 2. Distribution of included articles by animal species.

Especie animal	Included articles	References	Research	Positives	% of positives	IC 95%
Ovinos	31	Alves et al., 2010; Beltrán-Saavedra et al., 2010; Tique et al., 2010; Juliano et al., 2011; Costa et al., 2012; Marinho et al., 2012; Martins et al. 2012; Carrera Chávez et al., 2013; Ximenes Martins et al., 2013; Ribeiro Araújo et al., 2013; Santos et al., 2013; Rizzo et al., 2014; Troncoso et al., 2014; Machado et al., 2015; Gutiérrez Hernández et al., 2015; Marin et al., 2015; Alves de Oliveira et al., 2016; De Moraes Peixoto et al., 2016; dos Santos et al., 2016; Linderot de Cardona et al., 2016; Russo et al., 2016; Santos et al., 2016; Vargas et al., 2016; Alexandre Alves et al., 2017; Alves da Silva et al., 2017; López et al., 2018; Martínez et al., 2018; Campos y Morales-Cauti, 2020; Johnson et al., 2020; Román-Ramírez et al., 2020; de Araújo Teixeira et al., 2021	17,281	873	5.05	4.74-5.39

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Table 2. Distribution of included articles per animal species. Continuation

Caprinos	23	Tique et al., 2010; Zambriski et al., 2010; Mancebo et al., 2011; Ortega-Sánchez et al., 2012; Valeris-Chacín et al., 2012; Zabala et al. 2012; Gaido et al., 2013; Oseguera Montiel et al., 2013; García-Juárez et al., 2014; Poulsen et al., 2014; Banda Castillo, 2015; Flores et al., 2015; Hernández et al., 2016; Linderot de Cardona et al., 2016; Russo et al., 2016; Vargas et al., 2016; Purtschert Barahona et al., 2017; Román-Ramírez et al., 2017; Ron-Román et al., 2017; Martínez et al., 2018; Moscoso Gómez et al., 2019; Simonetti et al., 2019; Johnson et al., 2020	48,852	2,793	5.72	5.51-5.93
Total	48*		66,133	3,666	5.54	5.37-5.72

*Six articles discuss both species

Of the articles retrieved, 35 corresponded to the period 2010-2016 and 13 to the period 2017-2021 (Table 3). It was observed that during the latter period, a limited number of publications reported on the prevalence of brucellosis in sheep and goats, with 70.83% of these studies concentrated in Brazil, Mexico, and Argentina—countries that, according to FAO reports, had the largest goat and sheep populations in the region (FAO, 2022). This situation was reflected in the evidence of bias and high heterogeneity, which may be attributed to the limited availability of articles on the prevalence of brucellosis in sheep and goats, and the fact that most of them were restricted to a few countries in the region. For this reason, outlier cases were not excluded, as doing so would have left too few studies to calculate the required estimates. Similar findings have been reported by other authors (Adetunji et al., 2019), and this was considered one of the main limitations of the present study, and of prevalence studies of this nature in general.

The results underscored the need to increase research efforts to better understand the actual status of the disease. A successful strategy for the prevention, control, and eradication of brucellosis requires comprehensive national-level surveillance and follow-up studies in countries where the disease is prevalent, in order to accurately assess its magnitude (Khuranaa et al., 2021).

Table 3. Distribution of articles per period included in the analysis.

Period	Included articles	References	Research	Positives	% of positives	IC 95%
2010-2016	35		58,437	3.548	6,07	5,88-6,27
2010	4	Alves et al., 2010, Beltrán-Saavedra et al., 2010, Tique et al., 2010, Zambriski et al., 2010	680	6	0,88	
2011	2	Juliano et al., 2011, Mancebo et al., 2011	6,403	1,743	27.22	0.40-1.19
2012	6	Costa et al., 2012, Marinho et al., 2012, Martins et al. 2012, Ortega-Sánchez et al., 2012, Valeris-Chacín et al., 2012, Zabala et al., 2012	2,625	147	5.60	4.78-6.55

Table 3. Distribution of included articles in the analysis per period. Continuation..

2013	6	Carrera Chávez et al., 2013, Gaido et al., 2013, Oseguera Montiel et al., 2013, Ribeiro de Araújo et al., 2013, Santos et al., 2013, Ximenes Martins et al., 2013	8,355	563	6.74	6.22-7.30
2014	4	García-Juárez et al., 2014, Poulsen et al., 2014, Rizzo et al., 2014, Troncoso et al., 2014	566	94	16.61	11.87-17.24
2015	5	Banda Castillo, 2015, Flores et al., 2015, Gutiérrez Hernández et al., 2015, Machado et al., 2015, Marin et al., 2015	8,813	236	2.68	2.36-3.04
2016	8	Alves de Oliveira et al., 2016; De Moraes Peixoto et al., 2016; dos Santos et al., 2016; Hernández et al., 2016; Linderot de Cardona et al., 2016; Russo et al., 2016; Santos et al., 2016; Vargas et al., 2016	30,995	759	2.45	2.28-2.63
2017-2021	13		7,696	118	1.53	1.28-1.83
2017	5	Alexandre Alves et al., 2017; Alves da Silva et al., 2017; Purtschert Barahona et al., 2017; Román-Ramírez et al., 2017; Ron-Román et al., 2017	3,759	36	0.96	0.69-1.32
2018	2	López et al., 2018; Martínez et al., 2018;	1,250	59	4.72	3.68-6.04
2019	2	Moscoso Gómez et al., 2019; Simonetti et al., 2019	351	1	0.28	0.05-1.60
2020	3	Campos y Morales-Cauti, 2020; Johnson et al., 2020; Román-Ramírez et al., 2020;	2,236	5	0.22	0.10-0.52
2021	1	de Araújo Teixeira et al., 2021	100	17	17.00	10.89-25.55
Total	48		66,133	3,666	5.54	5.37-5.72

An analysis of the *Brucella* species investigated revealed that 28 studies assessed the seroprevalence of *Brucella* spp., while 20 focused specifically on *B. ovis* (table 4). The limited number of studies and the challenges associated with the surveillance of species such as *B. melitensis* were of major concern, particularly due to the reemergence of these pathogens in South America (Tique et al., 2010).

Out of the articles analyzed, 31 evaluated the prevalence of brucellosis in sheep and 23 in goats. Sheep and goats were primarily affected by *B. melitensis*, with sheep also being affected by *B. ovis*. Both species were also susceptible to *B. abortus* and other species of the Brucella genus (Saxena et al., 2018).

Although it was not possible to differentiate *B. melitensis*, B. abortus, and B. suis using conventional serological methods, B. melitensis was recognized as the main Brucella species affecting sheep and goats (Sorsa et al., 2022), and it posed the greatest zoonotic risk, accounting for the highest percentage of human brucellosis cases (Abedi et al., 2019).

In the case of B. ovis, although it is not considered a zoonotic agent unlike other species of the genus, it was noted to have a less severe impact on ruminant health. However, it was still responsible for significant losses related to subfertility and had a considerable impact on genetic selection at the farm level (Praud et al., 2012).

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Table 4. Distribution of the articles included in the analysis by species of the *Brucella* genus

Agent species	Included articles	References	Research	Positives	% of positives	IC 95%
Brucella spp.	28	Beltrán-Saavedra et al., 2010; Tique et al., 2010; Zambriski et al., 2010; Ortega-Sánchez et al., 2012; Zabala et al. 2012; Valeris-Chacín et al., 2012; Gaido et al., 2013; Oseguera Montiel et al., 2013; Ximenes Martins et al., 2013; García-Juárez et al., 2014; Poulsen et al., 2014; Banda Castillo, 2015; Flores et al., 2015; Marin et al., 2015; dos Santos et al., 2016; Hernández et al., 2016; Linderot de Cardona et al., 2016; Russo et al., 2016; Santos et al., 2016; Vargas et al., 2016; Purtschert Barahona et al., 2017; Román-Ramírez et al., 2017; Ron-Román et al., 2017; Martínez et al., 2018; Moscoso Gómez et al., 2019; Simonetti et al., 2019; Campos y Morales-Cauti, 2020; Johnson et al., 2020; Román-Ramírez et al., 2020	50,087	1.327	2.65	2.51-2.79
B. ovis	20	Alves et al., 2010; Mancebo et al., 2011; Juliano et al., 2011; Marinho et al., 2012; Costa et al., 2012; Martins et al. 2012; Ribeiro Araújo et al., 2013; Santos et al., 2013; Ximenes Martins et al., 2013; Carrera Chávez et al., 2013; Troncoso et al., 2014; Rizzo et al., 2014; Gutiérrez Hernández et al., 2015; Machado et al., 2015; Marin et al., 2015; Alves de Oliveira et al., 2016; De Moraes Peixoto et al., 2016; Alves da Silva et al., 2017; Alexandre Alves et al., 2017; López et al., 2018; de Araújo Teixeira et al., 2021	16,046	2,339	14.58	14.04-15.13
Total			66,133	3,666	5.54	5.37-5.72

The random-effects meta-analysis indicated a high degree of variability among studies (τ^2= 0.0305; I^2= 99%, Q-test= 6,765.86, df= 63, and P<0.000). The studies were weighted approximately equally, with individual study weights ranging from 1.2 to 1.6%, due to the high heterogeneity observed. The forest plot derived from the meta-analysis is presented in figure 2.

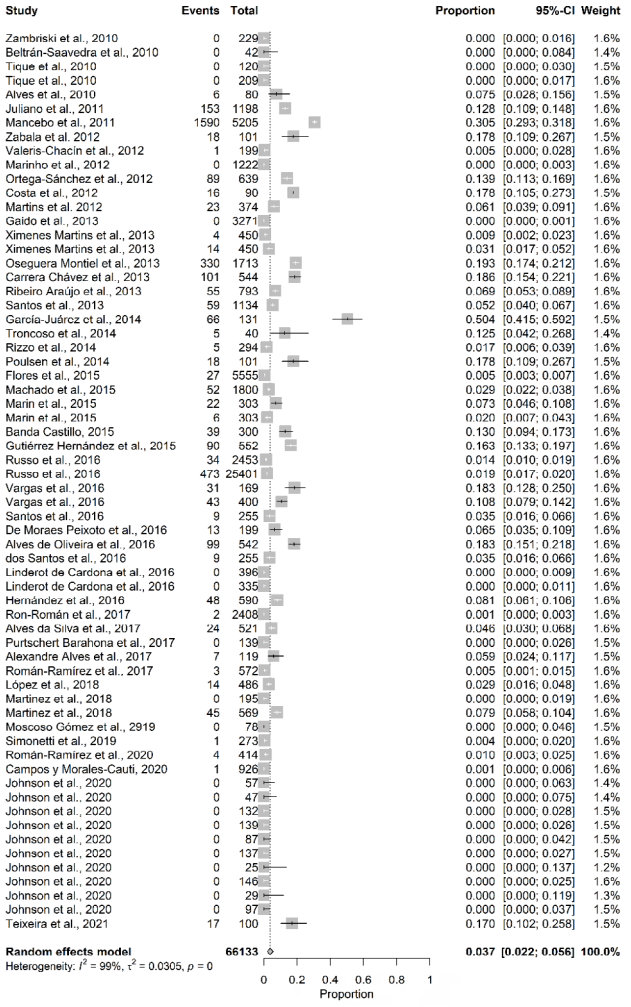

Figure 2. Forest plot of the systematic review and meta-analysis based on the overall pooled prevalence according to the records included in the study.

The Galbraith plot (figure 3) revealed a high degree of heterogeneity. The assessment of bias and small-study effects, using the funnel plot along with Egger's and Begg's tests, indicated evidence of publication bias in the studies reporting the prevalence of brucellosis in sheep and goats in the regions analyzed (figure 4).

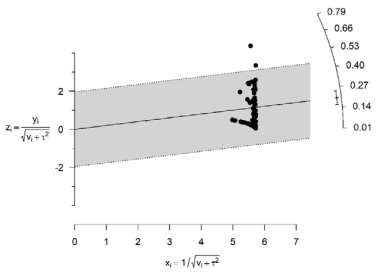

Figure 3. Galbraith chart for the analysis of the included studies.

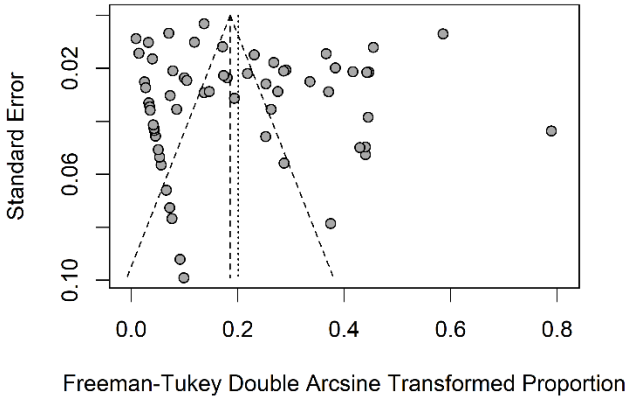

Figure 4. Analysis of the publication bias of the articles included in the analysis.

The estimated prevalences in individual studies ranged from 0.0 to 50.4%, with an overall pooled prevalence of 3.70% (95% CI: 2.20-5.60). The meta-analysis revealed a high combined prevalence of the disease, indicating that, despite the measures implemented in various countries, controlling brucellosis remains a significant challenge for veterinary and public health authorities in the studied regions (Ávila-Granados et al., 2019).

In the subgroup meta-analysis, the pooled prevalence in South America was 4.0% (95% CI: 2.0-6.6), and in Central America and the Caribbean, it was 3.2% (95% CI: 0.8-6.7) (table 5). However, when the multivariate meta-regression analysis was performed, no statistically significant differences in pooled prevalence between the regions were found.

Table 5. Comparison of the combined individual prevalence of brucellosis in sheep and goats in the regions of Central America and the Caribbean and South America.

Regions	Prevalence (95% CI)	I2	Q	Heterogeneity	
				GL	P
Central America and the Caribbean	0.032 (0.008 - 0.067)	98.6%	1,602.64	23	0,000
South America	0.040 (0.020 - 0.066)	99.2%	5,160.04	39	0,000
General	0.037 (0.022 - 0.056)	99.1%	6,765.86	63	0,000

Legend IC= Confidence interval, GL= degree of freedom, I2= inverse variance index, Q= Cochrane's Q statistics , P= *P-value*.

The pooled prevalence in sheep and goats was similar, at 3.7% (95% CI: 2.2-5.6) and 3.7% (95% CI: 1.2-7.3), respectively (table 6). Although no comparable studies in small ruminants were identified within the regions and period analyzed, studies conducted in cattle and buffaloes revealed a similar prevalence pattern of the disease (Zamora et al., 2022).

Studies from China also reported a comparable pooled prevalence of 3.20% (Ran et al., 2018), while pooled prevalences of 5.3% in sheep and goats were reported in other studies conducted in Ethiopia (Tadesse, 2016).

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Table 6. Analysis per subgroups comparing the combined individual prevalence of brucellosis in the different studied species.

Species	Prevalence (95% CI)	I2	Q	Heterogenity tests	
				GL	*P*
Ovines	0.037 (0.022 - 0.056)	96.8%	1,120.11	36	0.000
Caprines	0.037 (0.012 - 0.073)	99.5%	5,641.00	26	0.000
General	0.037 (0.022 - 0.056)	99.1%	6,765.86	63	0.000

Legend IC= Confidence interval, GL= degree of freedom, I2= inverse variance index, Q= Cochrane's Q statistics , *P*= *P*-value.

An analysis of the pooled prevalence of smooth *Brucella* strains and *B. ovis* revealed a higher prevalence for *B. ovis* (7.7%, 95% CI: 3.6-13.3) compared to smooth strains (2.2%, 95% CI: 1.2-3.5) (table 7). Based on this subgroup meta-analysis and the multivariate meta-regression, significant differences were found in the pooled prevalence of brucellosis among the different *Brucella* species studied, with *B. ovis* showing a higher prevalence than *Brucella* spp. (7.7 vs. 2.2%, respectively).

This result may be associated with the fact that the disease caused by *B. ovis* is not considered zoonotic, and thus field detection data remain scarce and often incomplete—particularly in traditional sheep farming, where infection is frequently underestimated due to its subclinical presentation (Galluzzo et al., 2021). This concerning situation underscores the need for increased awareness and enhanced surveillance (Elderbrook et al., 2019).

Tabla 7. Analysis of combined prevalence of different *Brucella* species in the studied period.

Brucella species	Prevalence (95% CI)	I^2	Q	Heterogeinity test	
				GL	*P*
B. ovis	0.077 (0.036 - 0.133)	99.2%	2,416.79	20	0.000
Brucella spp.	0.022 (0.012 - 0.035)	98.0%	2,051.45	42	0.000
General	0.037 (0.022 - 0.056)	99.1%	6,765.86	63	0.000

Legend IC= Confidence interval, GL= degree of freedom, I2= inverse variance index, Q= Cochrane's Q statistics , *P*= *P*-value.

During the period 2010 to 2016, a higher pooled prevalence of 6.1% (95% CI: 3.6-9.1) was reported, compared to 0.7% (95% CI: 0.1-1.8) in the period 2017-2021 (table 8). Although the number of studies retrieved from the latter period was small—and thus the results should be interpreted with caution—this notable reduction in pooled prevalence may be strongly attributed to the vaccination programs implemented by the countries (Román-Ramírez et al., 2017).

Table 8. Analysis per subgroup comparing the combined individual prevalence of Brucellosis in ovines and caprines during the studied period.

Period	Prevalence (95% CI)	I^2	Q	Heterogeneity test	
				GL	*P*
2010 - 2016	0.061 (0.036 - 0.091)	99.4%	6,219.64	40	0.000
2017 - 2021	0.007 (0.001 - 0.018]	91.1%	247.32	22	0.000
General	0.037 (0,022 - 0.056)	99.1%	6,765.86	63	0.000

Legend IC= Confidence interval, GL= degree of freedom, I2= inverse variance index, Q= Cochrane's Q statistics , *P*= *P*-value.

The multivariate meta-regression analysis showed that, among the variables studied, the *Brucella* species investigated and the study period were statistically significant ($P<0.01$) (table 9).

Tabla 9. Results of multivariate regression analysis at an individual level.

Variables	Categories	Coeficient (IC 95%)	*P*
Region	Central America and The Caribbean	1 (ref)	
	South America	-0.04 (-0.13-0.04)	0.3079
Animal species	Ovines	1 (ref)	
	Caprines	-0.08 (-0.17-0.01)	0.0869
Brucella genus	*B. ovis*	1 (ref)	
	Brucella spp.	**-0.15 (-0.25 a -0.05)**	**0.0027**
Period	2010 - 2016	1 (ref)	
	2017 - 2021	**-0,13 (-0,21 a -0,04)**	**0,0029**

Abortive diseases are recognized as one of the major challenges to animal health in sheep and goats, highlighting the need for robust prevalence studies to assess threats to both animal and public health (Haif et al., 2021).

Through the use of systematic review and meta-analysis, more detailed information on the distribution of the disease within a given territory can be obtained, allowing for the evaluation of the effectiveness of implemented control programs (Musallam et al., 2016).

Although the present study had some limitations, it contributed to a better understanding of the prevalence of brucellosis in sheep and goats in the regions of Central America, the Caribbean, and South America. While several individual studies had been published during the study period in different countries reporting on the disease situation, there was no prior comprehensive study that consolidated this information to provide a regional overview.

Conclusions

The study demonstrates that there are few articles reporting on the seroprevalence of brucellosis in sheep and goats in the regions analyzed. It also confirms a high pooled prevalence of the disease, with *Brucella ovis* showing a higher prevalence compared to *Brucella* spp., and a greater prevalence during the period 2010-2016 compared to 2017-2021. No significant differences were found in the pooled prevalence between sheep and goats, nor between the regions studied.

Conflict of interests

The authors declare that they have no conflicts of interest in any phase of this publication.

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