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Occupational exposure to livestock and risk of tuberculosis and brucellosis: A systematic review and meta-analysis

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ABSTRACT

Occupational diseases are caused by zoonotic pathogens, which spread to humans through various types and intensities of human-livestock contact at work. In the present era, human brucellosis and tuberculosis remain the predominant occupational diseases throughout the world. However, the actual percentage of reported cases that are acquired from various livestock-related occupational groups is not well known. Therefore, we carried out a systematic review and meta-analysis of previous scatter studies mentioned the occurrence of human brucellosis and tuberculosis. From 2000 to 2021, a computer search of PubMed, Science Direct, Google Scholar, BioMed and Scopus was conducted and finally we found 71 studies (brucellosis = 54, tuberculosis = 17), which were included in this meta-analysis to calculate the aggregate prevalence using the random effects model. Moreover, I^2 statistic, Cochran's Q statistic heterogeneity and subgroup analysis were also performed. The analysis of the data showed that among the various livestock-related occupational groups, the global pooled prevalence of tuberculosis was 19% (95% CI: 09–30), which was higher than brucellosis 14% (95% CI: 10–18). In addition, North America and Africa were reported as the continents of the maximum prevalence rate of 25% (95% CI: −08-58) and 16% (95% CI: 11–21) for tuberculosis and brucellosis than the other continents. Afterwards, the individual's occupation was broken down into the following four groups: farm worker, livestock owner, livestock connected person and abattoir worker. The significant association was found between slaughterhouse workers and brucellosis prevalence (20%; 95% CI: 13–27) as well as the livestock owners and tuberculosis prevalence (28%; 95% CI: 06–50). Likely, a maximum prevalence of tuberculosis was documented among workers ages 20 to 49 years, and of brucellosis among those between the ages of 20 and 25, which suggests that age also had a role. Therefore, it is concluded that the livestock-related occupational groups were found to be at an increased risk of adverse zoonotic disease outcomes. Future studies could be focused on specific occupational group that are in high risk of disease transmission to minimize the effect of these two hazardous pathogens.

1. Introduction

Livestock supports the livelihoods of over 1.7 billion poor people throughout the world, and enormous demand for livestock product spurs the growth of ancillary job opportunities in ailed businesses such as animal husbandry, slaughterhouse, transportation and feed production [1]. However, a large number of livestock stakeholders are in danger due to transmission of zoonotic diseases, particularly bovine tuberculosis and brucellosis. Exposure to *Mycobacterium tuberculosis* (TB) among occupational groups is one of the most serious health risks- nowadays, one out of every four people is affected tuberculosis worldwide [2,3]. Throughout the year of 2016, globally, 147,000 confirmed cases and 12,500 fatalities of tuberculosis affected patients were reported [4]. In addition to TB, *Mycobacterium bovis* (bTB) has also the zoonotic importance due to its chronic nature and survival ability for months or even years within the human host without presenting clinical indications [5]. Therefore, the World Health Organization has categorized bTB as one of the eight dangerous zoonotic diseases with a high potential to infect the human population [6]. Human tuberculosis (HTB) of animal origin, specifically *Mycobacterium bovis*, is becoming more prevalent in both underdeveloped and developed countries because of sharing the same microenvironment with animal, living quarter and breathing during

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livestock handling [2]. According to reliable data from Tanzania, Nigeria and Uganda, >20% of the bacteria found in HTB infections were bTB [7]. Humans are accidental hosts of *Mycobacterium bovis*, with transmission occurring predominantly through the ingestion of contaminated cattle products: such as unpasteurized milk or raw meat products, close contact with infected cattle, aerosol inhalation of infective droplet or tissue, and in the presence of wounds from infected animals [8]. Moreover, human-animal contact at cattle markets and slaughterhouses as well as a lack of proper animal husbandry practices are also acted as the risk factor for tuberculosis transmission [9].

In contrast, brucellosis is one of the seven most neglected diseases in the world, with an estimated 5,000,000 to 12,500,000 cases annually [10,11]. In addition, it is suspected to be a re-emerging disease that affects 500,000 new cases of human infection each year [12]. Presently, human brucellosis is endemic in a number of developing nations, particularly in the Mediterranean, Central and South America, Asia, North and East Africa, and the Middle East: notably in Syria, Iraq, Egypt, Turkey and Iran [13]. In these regions, humans are typically exposed to *Brucella abortus* and *Brucella melitensis* through the consumption of raw milk and unpasteurized dairy products from the infected animal [14]. Consequently, transmission to humans is primarily accomplished through the close contact with contaminated placenta, urine, excrement, blood and aborted fetus [15]. As a result, brucellosis is spreading rapidly among shepherds, milkmen, butchers, knackers, veterinary assistants, and abattoir workers [16].

To summarize, despite taking eradicated or controlled programs, bovine tuberculosis and brucellosis remain endemic in many developing countries, particularly in African and Asian countries where the control measures are not existent in an adequate level [17]. Thus, it is essential to adopt risk management methods to limit human fatalities in order to reduce the danger of human exposure to lethal zoonotic diseases. Keeping this logic, in the present study, we focused on those who work as farmer, cow breeder, slaughterhouse staff and veterinarian since they regularly interact with animals, and are more prone to infection. Subsequently the global scenario of livestock-oriented tuberculosis and brucellosis is still in dearth, it is important to know the global prevalence with associated factors of tuberculosis and brucellosis from livestock-related occupational groups for taking any control measures in the near future. In this regard, meta-analysis is a highly valuable statistical tool whose goal is to synthesize, integrate and contrast the findings of numerous primary studies that investigate the same questions. Thus, we performed a meta-analysis study to calculate the pooled prevalence of these two diseases and provide policymakers with concise facts so they may decide whether to implement any control programs. Future studies could be focused on specific occupational groups which are high risk for the occurrence of tuberculosis and brucellosis and to define appropriate preventive measures.

2. Methods and materials

2.1. Study protocol

In this study, we used PRISMA standards for systematic review and meta-analysis to figure out the prevalence of tuberculosis and brucellosis among livestock-associated occupational groups [16].

2.2. Search strategy

From 2000 to 2021, a comprehensive literature search was undertaken in electronic databases such as Google Scholar, PubMed, Science Direct, BioMed and Scopus using the terms PICO (population, intervention, comparison and outcome)- veterinarians, laboratory staffs, abattoir workers and farmers: population, exposure to *Brucella* species and *Mycobacterium* species: intervention, occupational and job-related factors: comparison, and brucellosis or tuberculosis: outcome. Additionally, we performed manual searching of cross references or bibliography sections to identify the studies that matched the PICO criteria (supplementary file 1). However, the search criterion was restricted to English-language studies. Finally, the eligible studies were retrieved by two reviewers, and we employed a third reviewer to recheck the whole retrieval procedure to ensure that it was bias-free.

2.3. Inclusion criteria

The presented meta-analysis covered all original descriptive studies published in the English language that documented the prevalence of brucellosis and tuberculosis in humans who had come into contact with animals or related products. For further analysis, only studies with a clear contact history for tuberculosis (close contact with infected animal in farm or market or veterinary hospital or slaughterhouse; ingestion of unpasteurized milk or raw meat; and aerosol inhalation of infective droplets) and brucellosis (consumption of raw milk from affected animal and close contact with contaminated placenta, urine, excrement, blood and aborted fetus) were chosen. Then, Personnel from veterinary clinics, slaughterhouses, dairy cow owners, agricultural employees, and pastoralists with at least two years of work experience in their representative field were included.

2.4. Exclusion criteria

We excluded review articles, duplicate studies, qualitative studies, case reports and studies published in non-peer reviewed journals; studies concentrating on animal brucellosis or tuberculosis; studies focusing on immunology, microbiology, drug therapy; and studies focusing on genetics, immunology, microbiology, or drug therapy that did not include a diagnostic tool. Besides, intervention studies that lacked with baseline data on the association between animal exposure and disease were not considered for inclusion in the meta-analysis.

2.5. Quality assessment

For each original study, two authors independently assessed the risk of bias. Then, the study's quality was graded out of ten points using the Newcastle–Ottawa scale specially adapted for cross-sectional studies [18,19]. The tool is divided into three sections, the first of which is methodological quality and is rated with five stars: representativeness of the sample (1 star), sample size (1 star), non-respondents (1 star) and ascertainment of the exposure or risk factor (2 stars); the second section is study comparability: the subject in different outcome groups are comparable based on the study design or analysis (maximum 2 stars); and the third section is outcomes, which is related to statistical analysis: assessment of the outcome (maximum 2 stars), Statistical test (1 star). Following that, the mean score of two authors was applied to make the final decision, and studies with a score of six or higher were included in this systemic review and meta-analysis.

2.6. Screening and data extraction

Studies were included if they investigated occupational categories associated with domestic or household livestock as a risk factor for tuberculosis and brucellosis. Then, two authors independently reviewed and extracted the data before importing it into the pre-prepared form. Data from studies included the author's name, year of study, publication period, type of personnel, geographical area of the study, number of people examined and number of people who tested positive. In the event of a disagreement, the third author evaluated the article to determine its relevancy. A group conversation with the third author helped to establish a consensus.

2.7. Data analysis

The random effect model was used to determine the pooled prevalence of tuberculosis and brucellosis infection in occupational categories using the meta-analysis approach with a 95% confidence interval (CI). Following that, various subgroup studies were undertaken separately based on the type of occupational categories linked with animal species exposures. Afterwards, the results of the meta-analysis were plotted in a forest plot, and the heterogenicity of study level was estimated by Galbraith plot (Fig. 4). Moreover, the Q and I^2 tests were used to determine the studies heterogeneity ($I^2 > 50\%$ indicates significant heterogeneity) [20,21]. Finally, funnel plot and egger's test were performed to confirm the study effect and publication bias. The statistical analysis was done applying the Jamovi software (keeping the significance level at <0.05), while the Galbraith plot and geographic distribution map were generated using RStudio. Additionally, sensitivity analysis was used to examine the robustness of the pooled estimate by removing studies with small sample sizes ($n \leq 200$), studies with intermediate quality that had moderate risk of bias rating score between 6 and 7, and studies with outliers [22]. The presence of outliers was determined via a z-score approach- a score of $> \pm 1.96$ was termed as potential outlier (Supplementary file 2, Figs. 1 and 2) [23].

3. Results

3.1. Characteristics of the articles included in the meta-analysis

The literature search identified a total of 7347 studies (brucellosis: 5204; tuberculosis: 2143) from the databases, and after assessing the inclusion and exclusion criteria, a total of 71 studies (Brucellosis: 54; Tuberculosis: 17) were included in this study (Fig. 1). For tuberculosis, Africa, Asia and America reported 10, 04 and 03 studies, respectively, while 29 studies from Asia, 21 studies from Africa and 04 studies from America (North and South) documented the prevalence of brucellosis (Table 1).

3.2. Results of heterogeneity, publication bias and sensitivity analysis

In this meta-analysis, we evaluated the study's heterogeneity and publication bias. The analysis revealed significant heterogeneity among studies reporting brucellosis (H^2 value = 342.99, I^2 = 99.71%, $p \leq 0.001$) and tuberculosis cases (H^2 value =183.882, I^2 = 99.46, $p \leq 0.001$). Besides, the significant degree of heterogenicity between the studies was made apparent using the Galbraith plot test. Additionally, the Egger's test revealed no indication of bias in studies linked to tuberculosis (p-value = 0.7204); nevertheless, bias in papers connected to brucellosis was significant (p-value = 0.0023). As a result, we carried out sensitivity analysis for studies pertaining to brucellosis. Sensitivity analyses showed that the summary of the pooled estimates was unaffected significantly by the removal of outlier studies and moderate-quality studies (Supplementary file 2, Table 1). The prevalence rate stayed within the 95% CI for the relevant total prevalence [22]. Thus, we can conclude that the pooled estimated prevalence was validated by the reliability and rationality of our analyses. However, it is noted that we could not find any outlayer study for tuberculosis (Supplementary file, Fig. 2).

3.3. Meta-analysis result of tuberculosis

3.3.1. Meta-analysis of the prevalence of tuberculosis regarding continent and country

Total 17 studies obtained from Asia (04 studies), America (03 studies) and Africa (10 studies) were selected for the present meta-

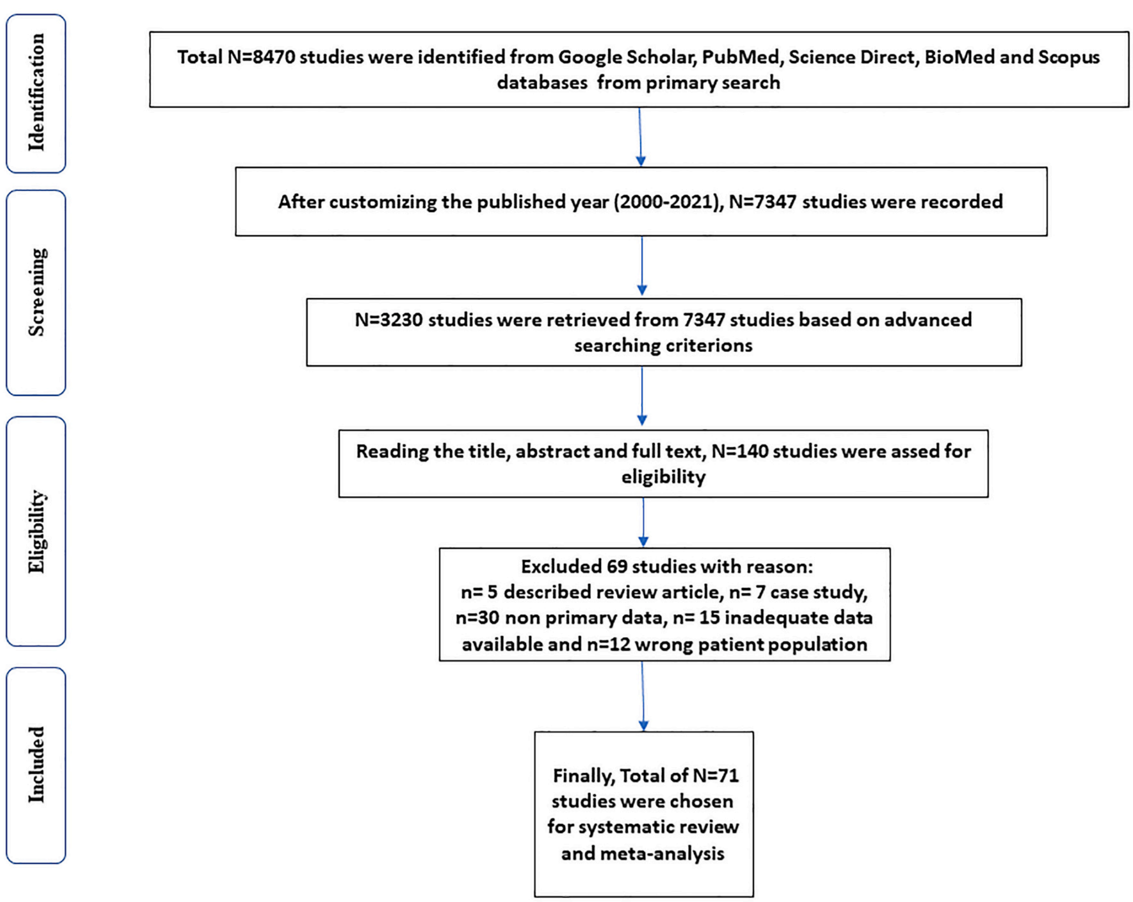

Fig. 1. Flow chart denoting the selection procedures of eligible studies.

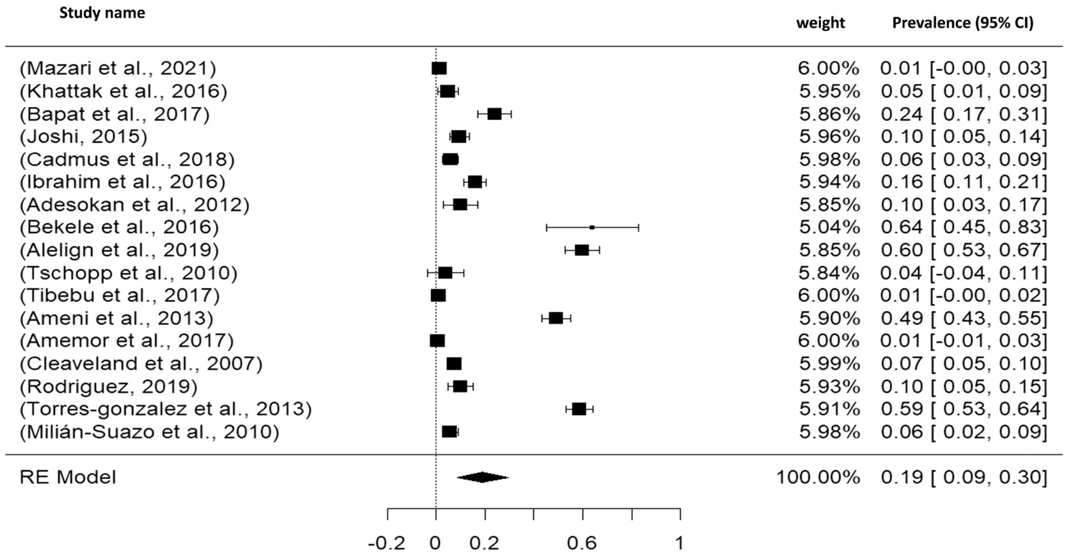

Fig. 2. Visualizing forest plot described mean prevalence of zoonotic tuberculosis from different livestock related occupational groups.

analysis. In this study, we analyzed a total of 3128 samples from the years 2000 to 2021, and found that the global prevalence of tuberculosis was 19% (95% CI: 09–30%), H^2 value = 183.882, I^2 = 99.46, $p \leq 0.001$) (Fig. 2); besides funnel plot of all the studies were showed in Fig. 4. Then analyzing the continent-wise result (Fig. 5), the highest prevalence rate was found in America 25% (95% CI = −08–58%), followed by Africa 21% (95% CI = 06–36%) and Asia 10% (95% CI = 09–19%) (Table 2). After determining the continent-wise results, we analyzed the courtiers and found that Ethiopia, India and Mexico had the highest prevalence, while Ghana and Pakistan had the lowest (Figs. 7 and 11).

3.3.2. Prevalence rate according to causal agent, diagnostic method and knowledge regarding tuberculosis

We found four serotypes of *Mycobacterium bovis* and *Mycobacterium tuberculosis* that are circulating rapidly throughout the world. The majority of studies reported *Mycobacterium bovis* infection, with a pooled prevalence of 15% (95% CI: 03–26), compared to a prevalence rate of 21% (95% CI: 03–38) for *Mycobacterium tuberculosis* (Table 3). Moreover, it is reported that 58% of tuberculosis pathogens were found from raw milk consumption, whereas only 36% of people have knowledge regarding zoonotic tuberculosis transmission.

3.3.3. Rate of prevalence according occupational group, age and sex

We categorized the individual's occupational groups as Farm's worker, livestock owner, livestock related person and abattoir worker. Among all of them, the maximum (28%; 95% CI: 06–50) prevalence rate of tuberculosis was found livestock owner, meanwhile, (21%; 95% CI: 03–38) prevalence rate was found from Farm's worker. However, the prevalence rate of tuberculosis was comparatively lower among the abattoir workers (03%; 95% CI: −01-08) (Table 3). Analyzing the age, the people from 20 to 49 years registered the maximum (34%; 95% CI: 02–66) prevalence rate; meanwhile, the lowest prevalence rate (34%; 06% CI: 01–11) was reported from the individuals between 0 and 19 years age. Moreover, in the term of sex category, Female had the maximum 23% (95% CI: −02-47) prevalence rate rather than male individuals 20% (95% CI: 04–36) (Table 3).

3.4. Meta-analysis result of brucellosis

3.4.1. Continent and country wise prevalence

Total selected 54 studies were obtained from Asia (27 studies), Africa (21 studies), America (04 studies), single study from Egypt and Turkey. The current meta-analysis analyzed a total of 26,403 samples from the years 2000 to 2021, and revealed that the global prevalence of brucellosis was 14% (95% CI: 10–18%), H^2 value = 342.99, I^2 = 99.71%, $p \leq 0.001$) (Fig. 3); besides funnel plot and radial plot of all the studies were showed in Fig. 4. Then analyzing the continent-wise result (Fig. 6), the highest prevalence rate was found in Africa 16% (95% CI = 11–21%), followed by Asia 13% (95% CI = 07–18%) and America 08% (95% CI = −02–17%), (Table 2). Likely, analyzed the courtiers, we found the maximum prevalence range (16–24) % in Egypt, Ethiopia, Ghana and Argentina; meanwhile, the lowest prevalence rate was registered from Kenya, Tanzania, Bangladesh and South Korea (Figs. 8 and 10).

3.4.2. Prevalence rate according diagnostic method

In this study, we categorized the test procedure into six distinct groups, including Rose Bengal Plate Test and enzyme-linked immunoassay (ELISA) (14 studies), Rose Bengal Plate Test (11 studies), ELISA (11 studies), Rose Bengal test/serum and standard agglutination test (07 studies), Standard tube agglutination test (04 studies) and Rose Bengal tests and PCR (03 studies). The maximum prevalence rate was found as 18% (95% CI: 08–29) from the ELISA test; in contrast, the lowest 06% (95% CI: 01–11) prevalence rate was documented in Standard tube agglutination test (Table 4).

3.4.3. Rate of prevalence according to occupational group, age and sex

We categorized the individual's occupation into ten groups: slaughterhouse workers, butchers, farm workers, veterinary assistants, veterinarian, animal handlers, livestock farmers, veterinary students and milker. Among all of them, the maximum (20%; 95% CI: 13–27) prevalence rate of brucellosis was found among slaughterhouse workers. Meanwhile, 19% (95% CI: 09–29) prevalence rate was recorded among the veterinary assistants. However, the prevalence rate of brucellosis was comparatively lower among veterinary students 01% (95% CI: 0–03) and milkers 06% (95% CI: -01-13). Analyzing the age, the people from 20 years to 25 years showed the maximum 09% (95% CI: 06–12) prevalence rate; meanwhile, the lowest prevalence rate 06% (95% CI: 04–07) was reported from the individuals 46 or above 46 years age. Moreover, in the term of sex category, male had 17% (95% CI: 11–24) prevalence rate rather than female individuals 06% (95% CI: 03–09) (Table 4) (Fig. 9).

4. Discussion

The occurrence of zoonotic diseases like tuberculosis and brucellosis

Table 1
Characteristics of the included studies.

Brucellosis						
Reference	Author	Duration	Sample Name	Test Technique	Occupation Group (positive/Total)	Quality score
[33]	Beheshti et al. (2010)	N/A	Blood	Rose Bengal plate test (RBT), standard tube agglutination test (SAT)	Veterinary assistants (6/15), veterinarian students (0/42), butchers (2/52), slaughterhouse workers (2/17), and chefs (1/3)	8
[34]	Nahar and Ahmed (2009)	2007	Blood	Rose Bengal plate test (RBT), standard tube agglutination test (SAT)	Clinical attendant (1/13), animal owner (1/7), butchers (0/4), veterinary science Students (1/26)	8
[35]	Cadmus et al. (2006)	2004	Blood	Rose Bengal test (RBT)	butchers (7/11), herdsmen (0/11)	7
[36]	Nasinyama et al. (2014)	N/A	Blood	Standard Tube Agglutination Test and ELISA	cattle keepers (21/161)	8
[37]	Tasiame et al. (2016)	2011	Blood	Rose Bengal Plate Test and ELISA	Delivery assistants (10/160), cattle drovers (8/18)	8
[38]	Ali et al. (2017)	N/A	Blood	Rose Bengal Plate Test (RBT)	butchers (0/30)	8
[39]	Acharya et al. (2018)	2012	Blood	ELISA	N/A	7
[40]	Holt et al. (2021)	2015–2017	Blood	Rose Bengal Plate Test and ELISA	Dairy Farmers (57/585)	8
[41]	Omer et al. (2002)	2000	Blood	Rose Bengal Plate Test (RBT)	dairy farm workers (10/132), veterinary personnel (1/22), pastoral area (6/156)	8
[42]	Miller et al. (2016)	2011	Blood	ELISA	N/A	6
[43]	Mufinda et al. (2017)	2012	Blood	Rose Bengal Plate Test (RBT)	workers (7/131), cattle breeders (32/192)	8
[44]	Adesiyun et al. (2011)	2006	Blood	ELISA	livestock/farm workers (0/394), abattoir workers (0/99)	7
[45]	Yohannes Gemechu and Paul Singh Gill (2011)	2008–2009	Blood	Rose Bengal test and serum/ standard agglutination test	Veterinarians and pharmacists (43/126), para-veterinarians (3/16), animal attendants and dairy farmers (13/78), miscellaneous (5/21)	8
[46]	Swai and Schoonman (2009)	2004	Blood	Rose Bengal Plate Test (RBT)	Abattoir workers (8/41), livestock farmers (2/67), non-livestock keepers (0/38), veterinary/meat inspectors (0/ 11)	8
[47]	Shome et al. (2017)	N/A	Blood	Rose Bengal Plate Test and ELISA	Animal handlers (15/93), veterinarians (50/833), para-veterinarians (8/49), artificial inseminators (1/18), veterinary students (0/57)	8
[48]	Ebrahimpour et al. (2012)	2010	Blood	Wright Tube Agglutination test	Planter, farmer, housewives, worker, students	6
[49]	Meirelles-Bartoli et al. (2012)	2006	Blood	Rose Bengal test and serum/ standard agglutination test	N/A	6
[14]	Ali et al. (2013)	2011	Blood	Rose Bengal test and serum/ standard agglutination test	Veterinary personnel (0/31), milker (1/53), abattoir worker (10/54), livestock farmer (7/107)	8
[50]	Kumara et al. (2015)	N/A	Blood	Rose Bengal test and serum/ standard agglutination test	Veterinarians (4/75)	8
[51]	Mangtani et al. (2020)	2015–2017	Blood	Rose Bengal Plate Test and ELISA	N/A	7
[52]	Doni et al. (2017)	2013	Blood	Rose Bengal test and serum/ standard agglutination test	Family farmers (42/461), seasonal migratory workers (39/ 246)	8
[53]	Aghaali et al. (2015)	2013	Blood	Standard tube agglutination test	N/A	6
[54]	Priyadarshini et al. (2013)	N/A	Blood	Rose Bengal Plate Test and ELISA	Veterinary officer (0/14), farmer (1/11), exposed animal handler (1/27), slaughter house worker (2/16)	8
[55]	Rahman et al. (2019)	N/A	Blood	Rose Bengal Plate Test (RBT)	Worker (3/437)	7
[56]	Adamu et al. (2015)	N/A	Blood	Rose Bengal Plate Test (RBT)	Animal handlers (5/40), livestock keepers (4/25), butchers (2/20), middle men (0/15)	8
[57]	Shirima and Kunda (2016)	2005–2006	Blood	Rose Bengal Plate Test (RBT)	N/A	7
[58]	Aworh et al. (2013)	2010–2011	Blood	Rose Bengal Plate Test and ELISA	Abattoir workers (54/224)	7
[59]	Al-Haddad et al. (2013)	2009	Blood	Standard tube agglutination test	Farmer (40/456), shepherd (3/47), butcher (0/5)	8
[60]	Rahman et al. (2012)	2007–2008	Blood	Rose Bengal Plate Test and ELISA	Livestock farmer (10/386), milker (10/55), butcher (1/ 40), veterinary practitioner (1/19)	8
[61]	Esmaeili et al. (2016)	2011	Blood	ELISA and standard tube agglutination test	Butchers and slaughterhouse workers (15/190)	7
[62]	Mamani et al. (2018)	2014–2015	Blood	Standard tube agglutination test	Butchers (19/93), slaughterhouse workers (7/79), veterinarians (3/17)	8
[63]	Yoo et al. (2009)	N/A	Blood	Standard tube agglutination test	Handlers of residual products (6/351), slaughterer (6/ 889), inspectors and their assistants (0/190), grading testers and their assistants (0/92)	8
[64]	Schneider et al. (2013)	N/A	Blood	Rose Bengal Plate Test (RBT)	Slaughterhouse workers (6/134)	7
[65]	Khalili et al. (2012)	2011	Blood	ELISA	Slaughterhouse workers (44/75)	8
[66]	Esmaeili et al. (2019)	2017	Blood	ELISA	Butchers and general population (92/289)	7
[67]	Mukhtar and Kokab (2008)	2008	Blood	ELISA	Animal keeper (15/40), loader (4/12), Vet/paravet (3/ 9), slaughterer (23/ 85), meat seller (30/16), cleaner (3/20), driver (0/28)	8
[68]	Amegashie et al. (2016)	2014	Blood	ELISA	Animal contact at work (5/54), meat processing (17/148)	8
[69]	Escobar et al. (2013)	2005–2011	Blood	Serum agglutination test (SAT)	Slaughterhouse workers (32/200)	7
[70]	Zein and Sabahelkhier (2015)	2012	Blood	Rose Bengal Plate Test (RBT)	Veterinarians (2/21), meat-inspectors (6/39), abattoir workers (99/407), animal handlers (76/286)	8
[71]	Theses (2019)	N/A	Blood			8

(*continued on next page*)

Table 1 (*continued*)

Brucellosis						
Reference	Author	Duration	Sample Name	Test Technique	Occupation Group (positive/Total)	Quality score
				Rose Bengal Plate Test and ELISA	Hospital (6/127), veterinarians (4/23), students (0/41), pathological laboratory (8/171)	
[27]	Tsegay et al. (2017)	2013–2014	Blood	Rose Bengal Plate Test (RBT)	Abattoir workers (54/224)	8
[72]	Sadighi et al. (2020)	N/A	Blood	ELISA	Dairy farm workers (2/196)	7
[73]	Amegashie et al. (2017)	2013	Blood	Rose Bengal tests, PCR	Slaughterhouse workers (98/220)	7
[74]	Rezaee et al. (2012)	2010–2011	Blood	Serum agglutination test (SAT)	Butcher (5/32), rancher (6/20), slaughter house worker (12/60), milk product seller (2/18)	8
[75]	El-Moselhy et al. (2018)	N/A	Blood	ELISA	Veterinary doctors (6/23), administrators (5/27), veterinary workers (17/46), peelers (38/115)	8
[76]	Kamga et al. (2021)	2019	Blood	Rose Bengal Plate Test and ELISA	Slaughterhouse workers (8/61), herdsmen (19/101), butchers (7/84), veterinarians (0/11), meat or milk sellers (0/16)	8
[77]	Igawe et al. (2020)	2017	Blood	Rose Bengal Plate Test and ELISA	Slaughterers (27/79), slaughterer/meat sellers (38/98), livestock seller/farmers (3/12), meat inspector/vets (8/20), meat sellers (20/66)	8
[78]	Owowo et al. (2019)	2018	Blood	ELISA	Herdsmen, abattoir, livestock worker	7
[79]	Sagamiko et al. (2019)	2015–2016	Blood	Rose Bengal Plate Test and ELISA	Shepherd (1/75), livestock officer (0/11), butcher men (3/57), abattoir worker (2/186), milking man (0/72), animal product (0/24)	8
[80]	Ron-Román et al. (2014)	2006–2008	Blood	ELISA	N/A	6
[81]	Ali et al. (2021)	N/A	Blood	Rose Bengal tests, PCR	Veterinary students (0/45), shepherds (0/44), veterinarians (1/44), dung cake makers (1/52), milkers (5/63), abattoir workers (13/211)	8
[82]	Madut et al. (2019)	2015–2016	Blood	Rose Bengal Plate Test and ELISA	Vet assistant (12/21), butcher (45/94), health worker (9/14), meat handler (25/57), administrator (2/4)	8
[83]	Proch et al. (2018)	2015–2016	Blood	Rose Bengal Plate Test and ELISA	Veterinarian (2/51), nurse (41/133), handler (21/95)	8
[84]	Nakeel et al. (2016)	N/A	Blood	Rose Bengal Plate Test and ELISA	N/A	6

	Tuberculosis					
Author, Year			Sample name	Test Technique	Occupation Group (positive/Total)	Quality score
[85]	Bekele et al. (2016)	2012–2013	Nasal swab	PCR	Dairy farm worker (16/25)	7
[7]	Alelign et al. (2019)	2015–2018	Sputum	PCR	Farmers (111/186)	7
[17]	Tschopp et al. (2010)	2007–2009	Sputum	Culture (Acid fast staining)	Livestock owner (4/26)	7
[87]	Tibebu et al. (2017)	2010–2011	Sputum	PCR	Dairy farm worker (3/256)	7
[88]	Ameni et al. (2013)	N/A	Sputum	*M. bovis* spoligotype	Cattle owner (141/287)	7
[89]	Amemor et al. (2017)	2011–2012	Sputum	Ziehl- Neelsen staining	Herdsman (0/68)	6
[90]	Bapat et al. (2017)	2014–2015	Blood	PCR	Farmers, dairy workers and livestock keepers (25/105), Zookeepers and animal handlers (11/45)	8
[91]	Torres-gonzalez et al. (2013)	2009–2011	Sputum	Tuberculin skin test (TST) and Interferon-gamma release assay (IGRA)	Dairy farm and abattoir workers (182/311)	8
[92]	Milián-Suazo et al. (2010)	2006–2007	Sputum	*Mycobacterium bovis* spoligotype	Farm worker (11/102), abattoir worker (0/91)	8
[93]	Joshi, (2015)	2002–2003	Sputum	Ziehl- Neelsen staining	Livestock owner and involve person (19/200)	8
[94]	Cadmus et al. (2018)	2014–2015	Sputum	PCR	Traders (7/136/206), butcher (5/70/206)	8
[95]	Ibrahim et al. (2016)	2011–2013	Sputum	Culture and biolin analysis	Livestock related person (40/250)	7
[28]	Adesokan et al. (2012)	N/A	Sputum	PCR	Livestock traders (63), worker in cattle market (7)	8
[96]	Mazari et al. (2021)	N/A	Nasal discharge	ELISA	Farm workers (3/200)	7
[97]	Khattak et al. (2016)	2015	Sputum	PCR	Abattoir workers (4/16), butchers (0/29), livestock farmers (1/50), Vet (0/3), Vet assistant (0/5)	8
[98]	Cleaveland et al. (2007)	N/A	Lymph node biopsies	PCR	TB infected cattle owner (65/457)	8
[99]	Rodriguez (2019)	2016	Blood	Tuberculosis assay	Dairy workers (14/140)	7

in the human population is associated with the presence of these diseases in the local livestock population. Therefore, understanding the different types of liability contact patterns between livestock and humans is extremely crucial in order to reduce disease transmission. As a result, the purpose of this systematic review was to describe the age, gender and diagnostic test variance in brucellosis and tuberculosis transmission patterns to livestock occupational groups. In the present study, a systematic procedure was applied to uncover current literature using preset criteria for two suspected zoonoses (brucellosis and tuberculosis) associated with livestock as well as try to distinguish among

Table 2
Continent wise prevalence of brucellosis and tuberculosis.

Disease	Continent	No. of Studies	Prevalence (%) (95% CI)	I^2 (%)	H^2 Value	Z-Test	Tau^2	Country Included
Brucellosis	Asia	27	13 (07–18)	99.69	319.310	4.27	0.022	Pakistan, Bangladesh, India Iran, South Korea Yemen
	Africa	21	16 (11−21)	99.6	263.08	5.94	0.014	Angola, Cameroon, Ethiopia, Eritrea, Ghana, Kenya, Nigeria, Sudan, Tanzania Uganda
	America	04	08 (−02–17)	98.1	56.20	1.61	0.007	Argentina, Ecuador, Brazil, Trinidad
Tuberculosis	Africa	10	21 (06–36)	99.55	224.61	2.71	0.059	Ethiopia, Ghana, Nigeria and Tanzania
	Asia	04	10 (0–19)	96.14	25.89	2.00	0.086	India, Nepal and Pakistan
	North America	03	25 (−08–58)	99.39	162.63	1.46	0.085	Mexico and USA

Table 3
Prevalence of tuberculosis according to different occupation groups and other risk factors.

Variables		No. of Studies	Prevalence (%) (95% CI)	I^2 (%)	H^2	Z-Test	Tau^2	P-value	Chi-square
Diagnostic method	PCR	08	21 (04–38)	99.47	188.41	2.46	0.058	<0.001	$P = 0.808$
	Other than PCR	09	17 (03–31)	99.35	153.33	2.41	0.045	<0.001	
Age	(0–19) years	04	06 (01−11)	32.11	1.473	2.20	8e-04	0.353	$P = 0.926$
	(20–49) years	05	34 (02–66)	99.19	122.7	2.06	0.133	<0.001	
	>50 years	04	21 (06–37)	87.23	7.832	2.80	0.018	<0.001	
Occupational group	Farm's worker	08	21 (03–38)	99.67	301.23	2.32	0.061	<0.001	$P = 0.563$
	Livestock owner	05	28 (06–50)	98.87	88.88	2.51	0.061	<0.001	
	Livestock related person	04	12 (05–19)	87.10	7.75	3.45	0.004	<0.001	
	Abattoir workers	04	03 (−01–08)	64.46	2.81	1.54	0.001	0.025	
Causal agent	*Mycobacterium bovis*	12	15 (03–26)	99.49	197.84	2.49	0.040	<0.001	$P = 0.251$
	Mycobacterium tuberculosis	07	21 (03–38)	99.06	106.64	2.34	0.053	<0.001	
Sex	Male	07	20 (04–36)	98.61	71.97	2.50	0.0447	<0.001	$P = 1.00$
	Female	07	23 (−02–47)	99.28	139.54	1.81	0.1081	<0.001	

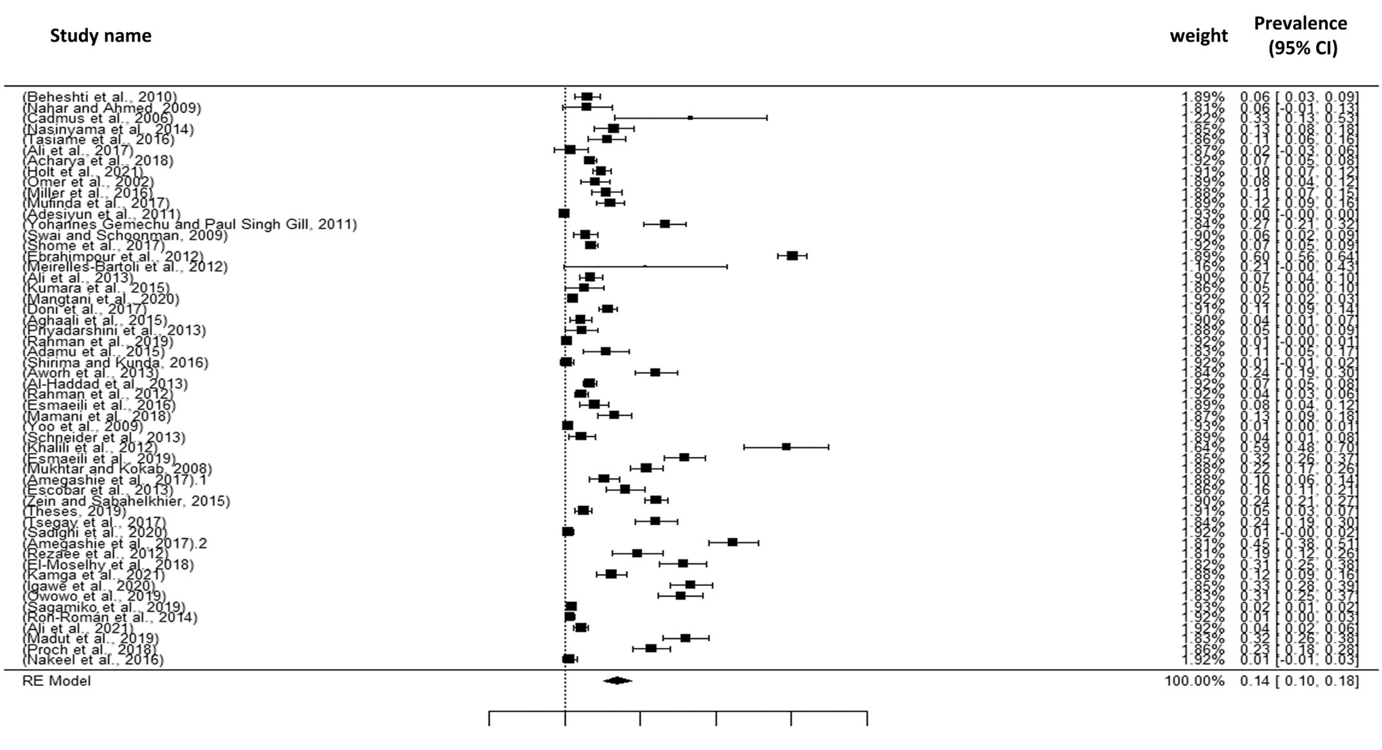

Fig. 3. Visualizing forest plot described mean prevalence of zoonotic brucellosis from different livestock related occupational groups.

separate occupational groups preceding the zoonosis occurrence.

A total of 54 articles were identified for brucellosis as a solely livestock-associated pathogen with significant public health consequences for the livestock occupational groups (farmers, breeders, abattoir workers, veterinarians and veterinary technicians and hunters) as a result of constant aerosol exposure and contact of non-intact skin

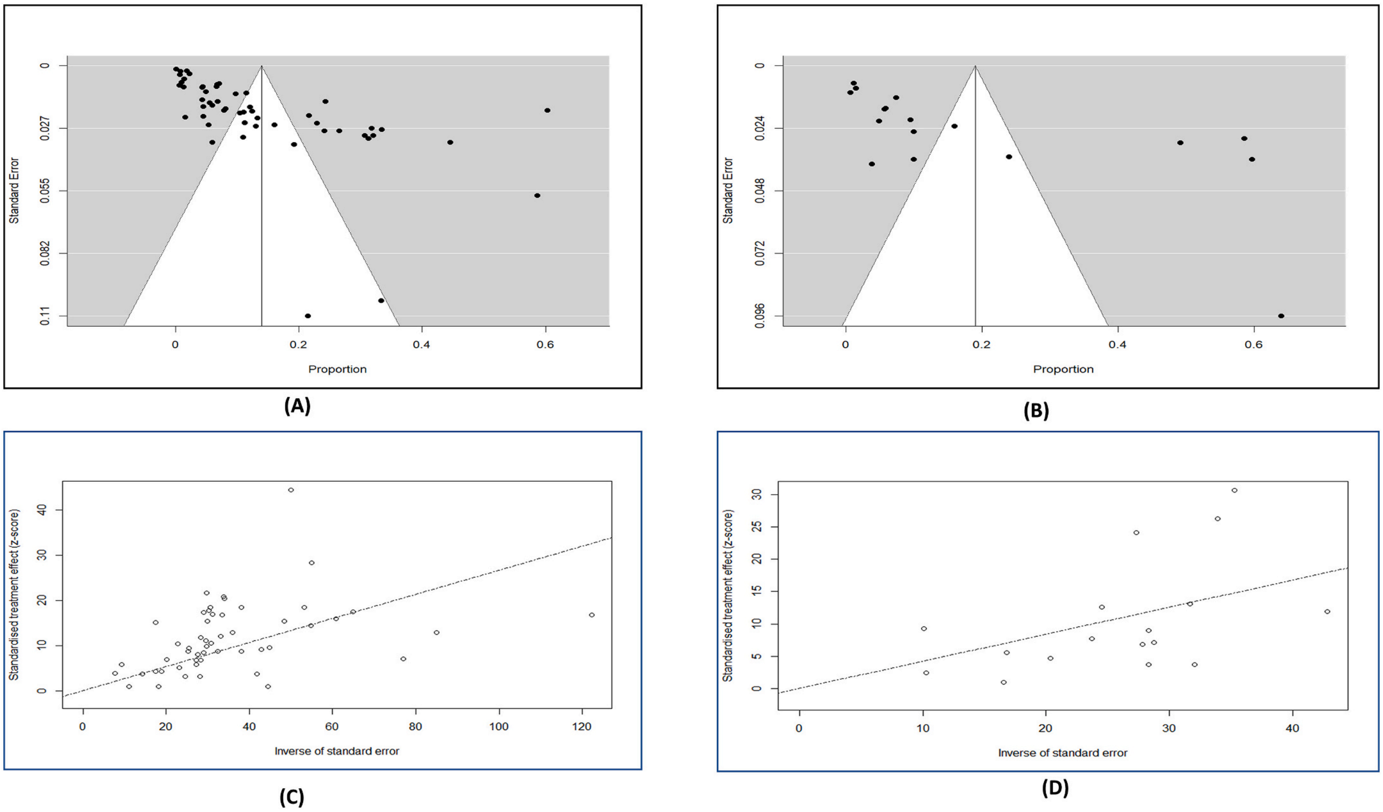

Fig. 4. Visualization of funnel plot described studies heterogenicity: A) Brucellosis; B) Tuberculosis; Galbraith plot: C) Brucellosis; D) Tuberculosis.

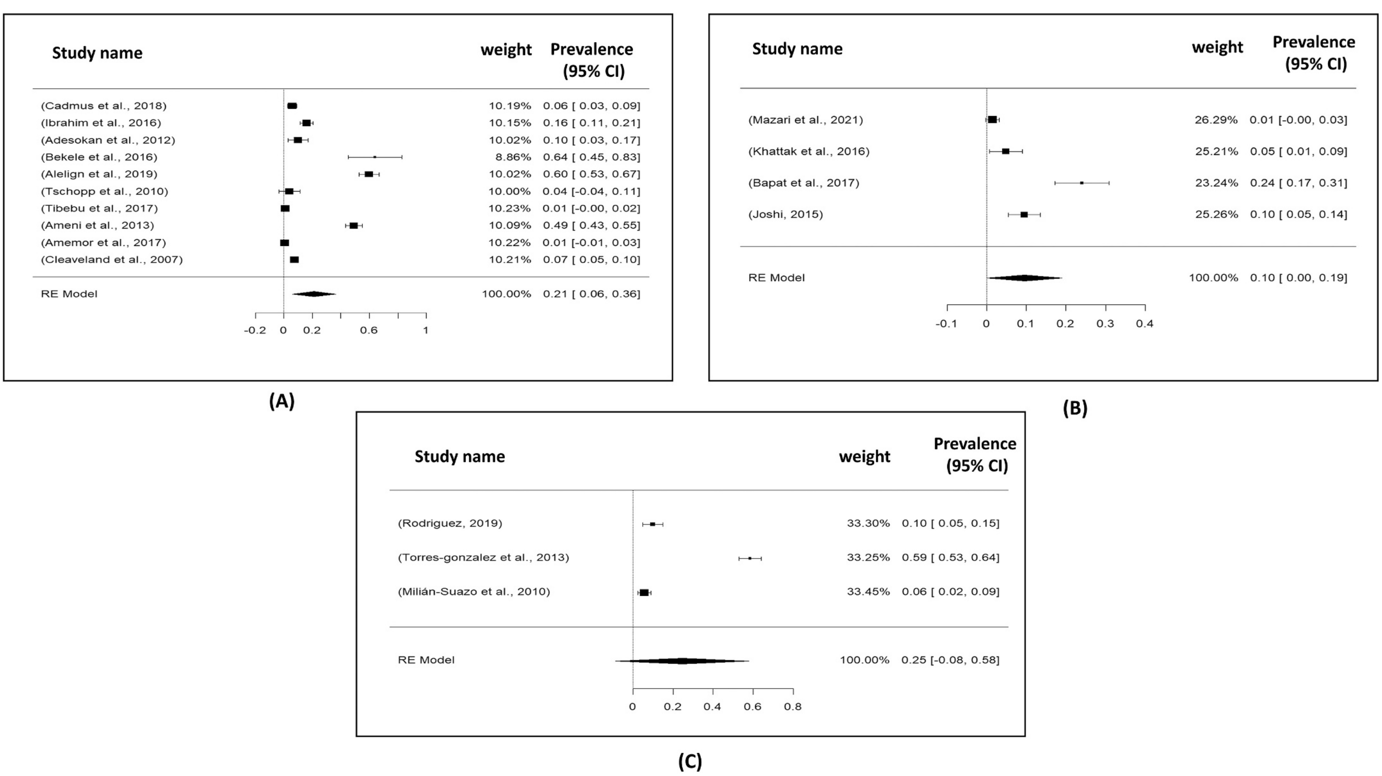

Fig. 5. Forest plot for representation of continent wise prevalence for tuberculosis: A) Africa; B) Asia and C) America (North and South).

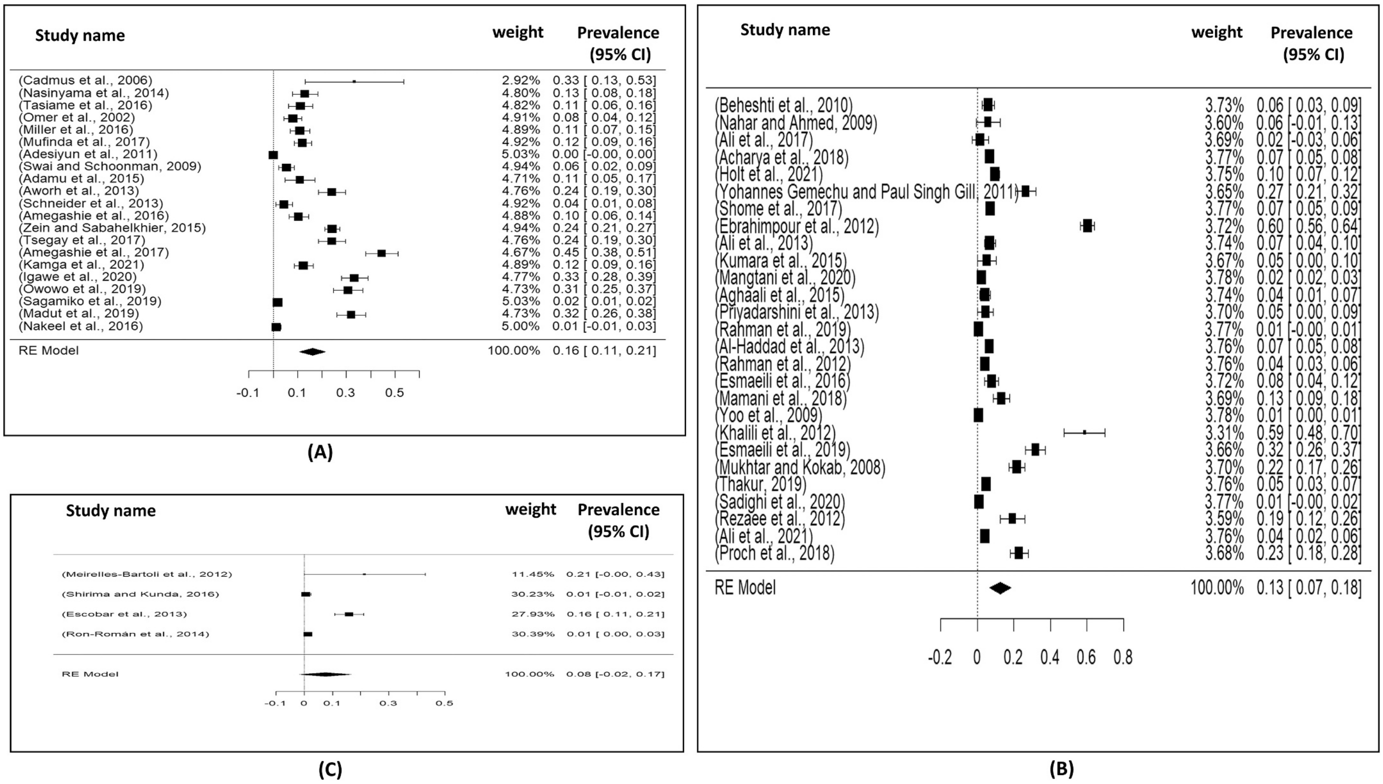

Fig. 6. Forest plot for representation of continent wise prevalence for brucellosis: A) Africa; B) Asia and C) America (North and South).

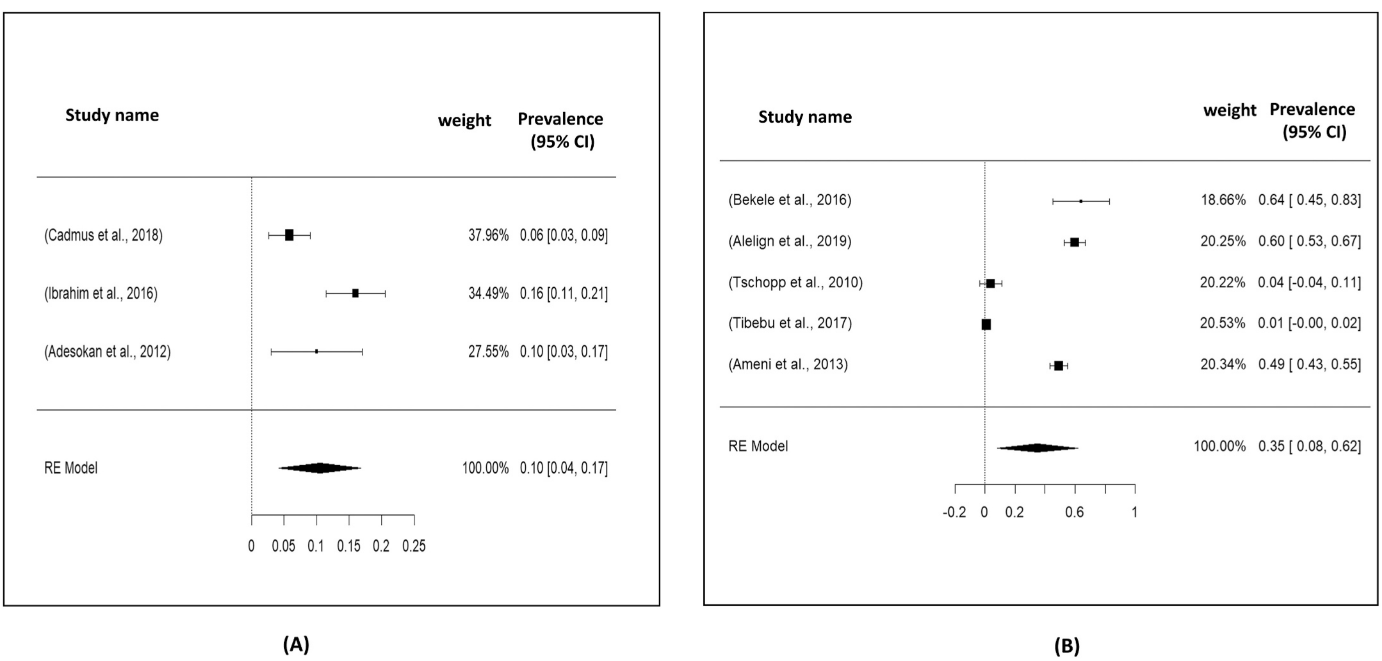

Fig. 7. Forest plot showing the pooled prevalence of tuberculosis: A) Nigeria and B) Ethiopia.

(wounds and abrasion) with infected materials (carcasses, viscera and live attenuated anti-brucellosis vaccines) and low adhesion to personal protective equipment in the work environment [24]. In contrast, 17 studies identified *Mycobacterium tuberculosis* as a zoonotic pathogen, which has gained considerable attention as a public health danger. Presently, *Mycobacterium tuberculosis* infection bears a significant risk in certain occupational groups that work closely with domestic and wild animals, such as livestock farmers, slaughterhouse employees, animal husbandry workers, veterinary staff, butchers, hunters, wildlife workers and live market workers [25]. Moreover, Numerous studies carried out in numerous nations have shown that animal handlers are susceptible to the zoonotic spread of *Mycobacterium bovis* if they have regular and uncontrolled interaction with livestock animals [8]. However, current data on the risk of brucellosis and tuberculosis infection in the workplace are sparse because the majority of studies are on a small magnitude in nature; thus, it is essential to identify the underlying risk factors

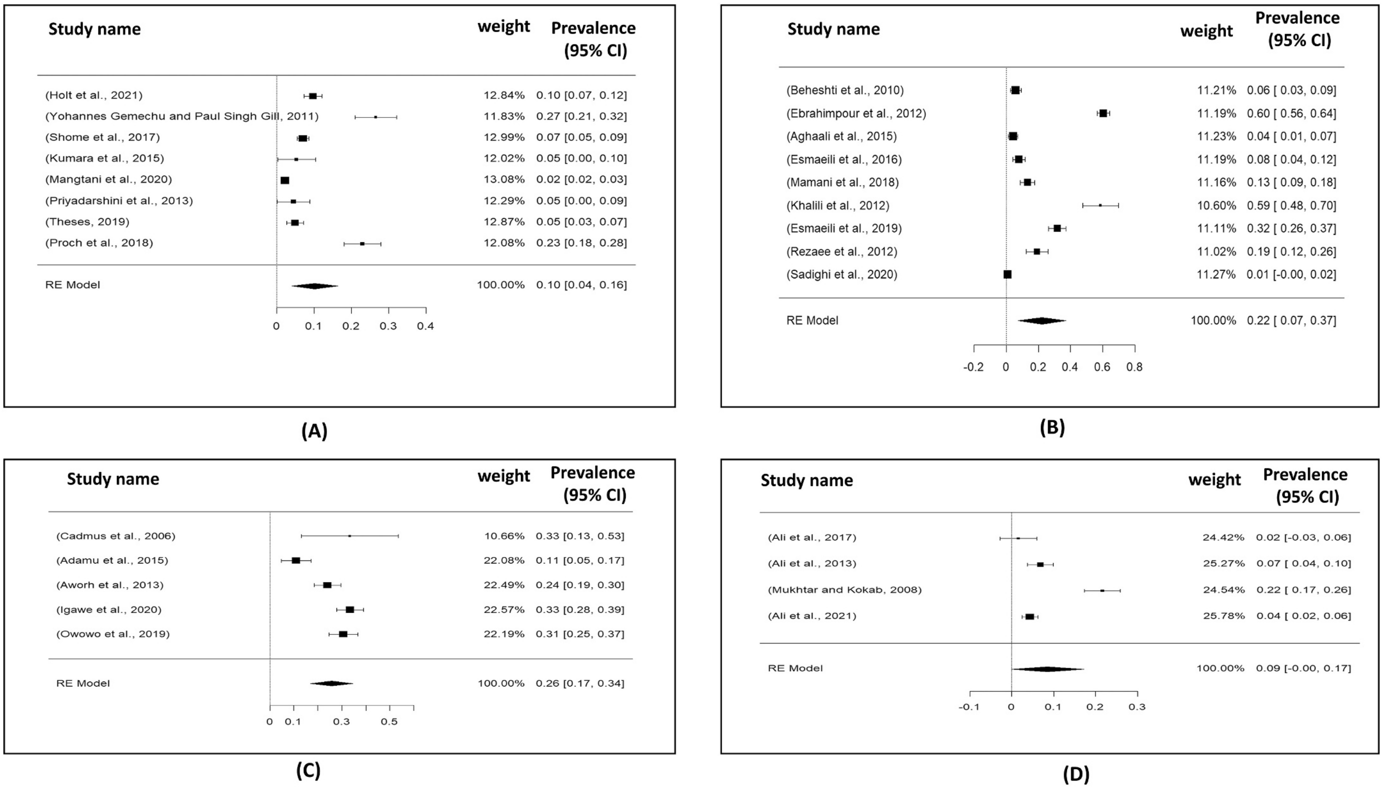

Fig. 8. Forest plot showing the pooled prevalence of brucellosis: A) India; B) Iran; C) Nigeria and D) Pakistan.

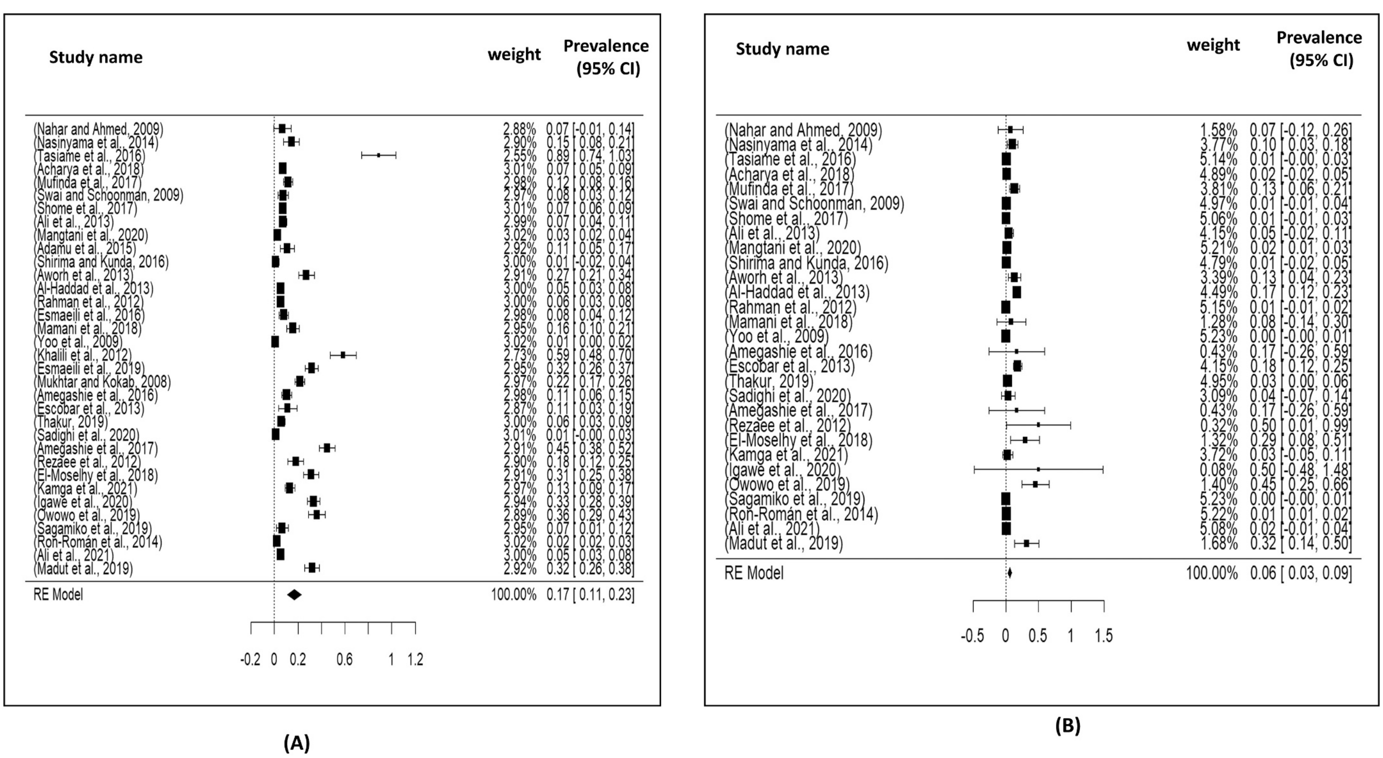

Fig. 9. Visualizing forest plot described mean prevalence of zoonotic brucellosis: A) Male and B) Female.

and pathways associated with transmission of occupational related populations in order to facilitate and implementation of specific preventive measures and guidelines [25]. Therefore, it is crucial to understand the prevalence rate of these two zoonotic diseases among various occupational groups, as well as the association of multiple risk factors. In this regard, our study found a maximum 19% pooled prevalence rate for tuberculosis infection in different occupational categories than the prevalence rate of brucellosis (14%). When the pooled results were

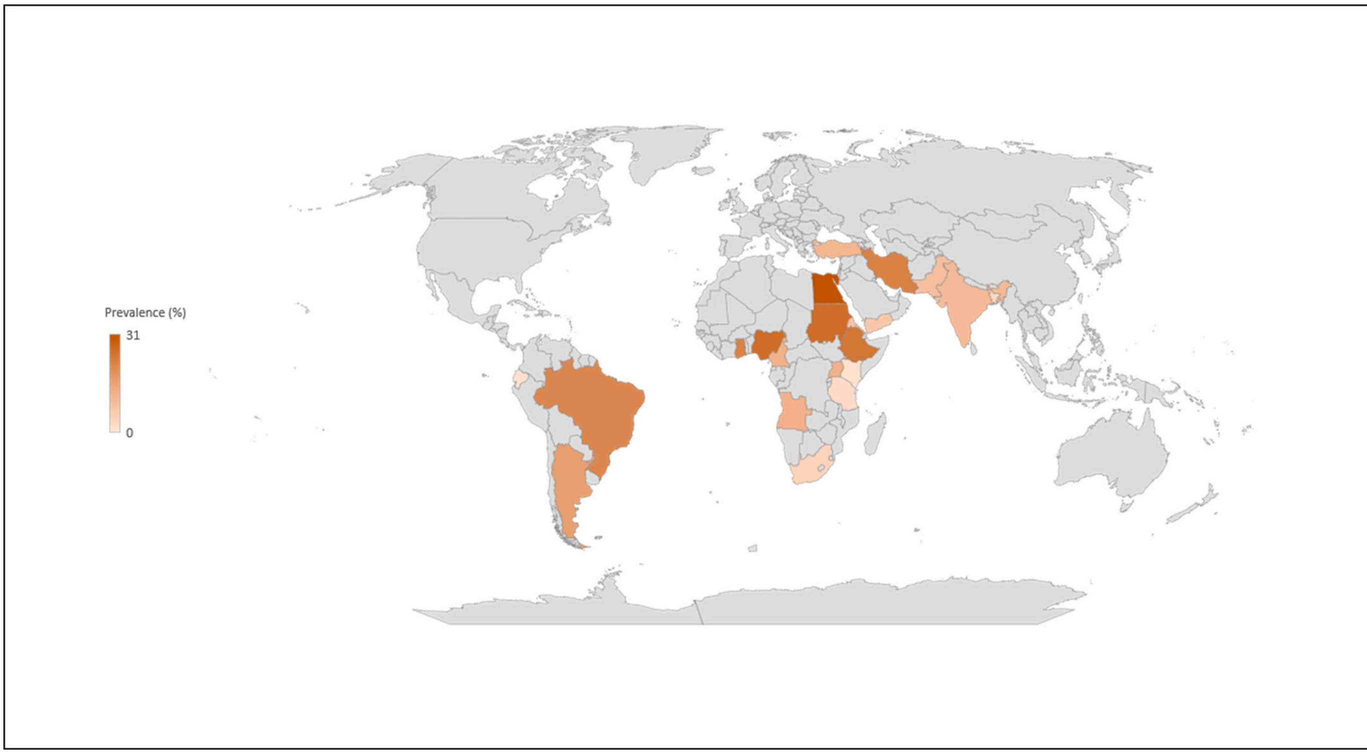

Fig. 10. Visual representation of the prevalence rate of brucellosis from different countries.

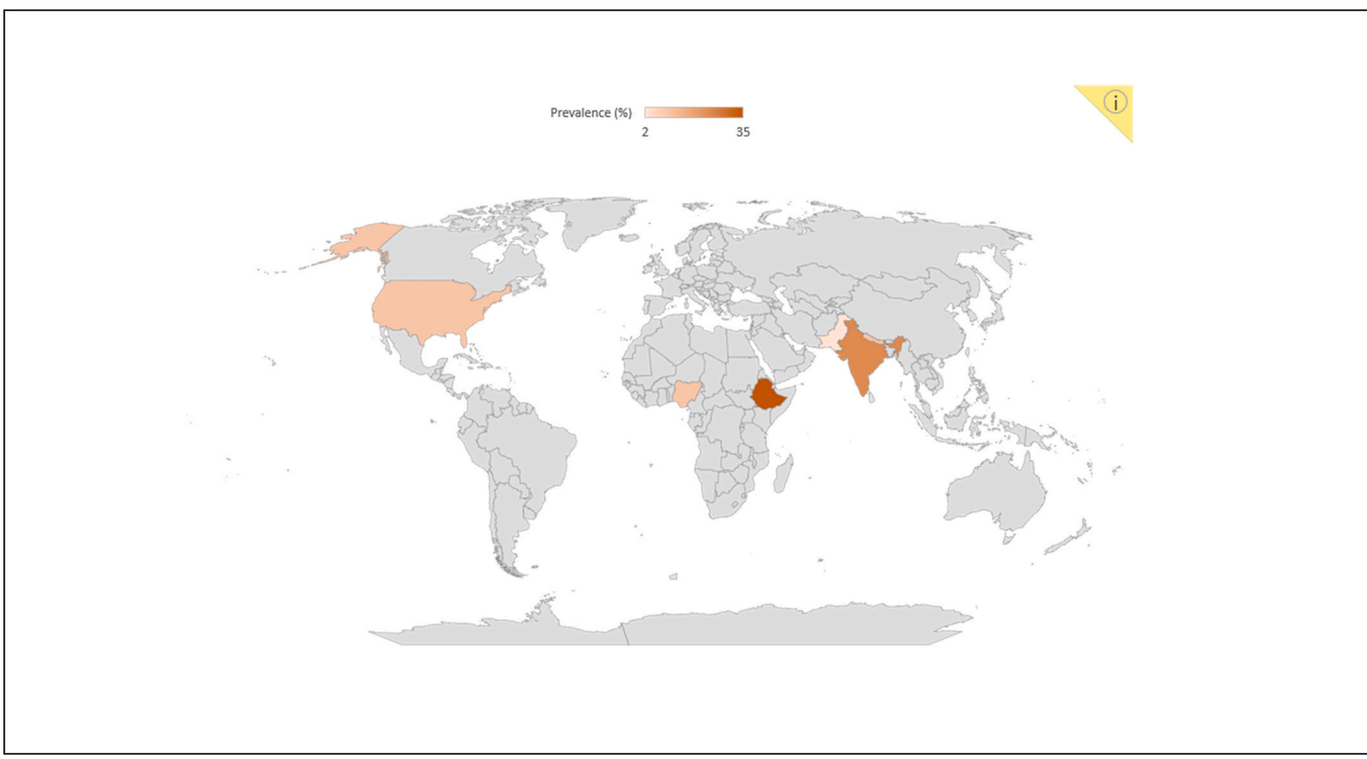

Fig. 11. Graphical representation of prevalence rate of tuberculosis from different countries.

broken down by continent, brucellosis was more prevalent in Africa (16%) and Asia (13%); however, tuberculosis was more predominant in North America (25%) and Africa (21%) (Fig. 12). Immigrants, HIV-infected, and homeless people mostly live in urban areas in developed countries such as the United States of America, where they have a serious influence the predominant tuberculosis epidemiology [26].

Furthermore, the current study documented that the low-income developing countries, such as Ethiopia, Ghana, Egypt and Mexico, are at risk for brucellosis and tuberculosis occurrence rates. Globally, the risks were enhanced in developing countries with a higher prevalence of

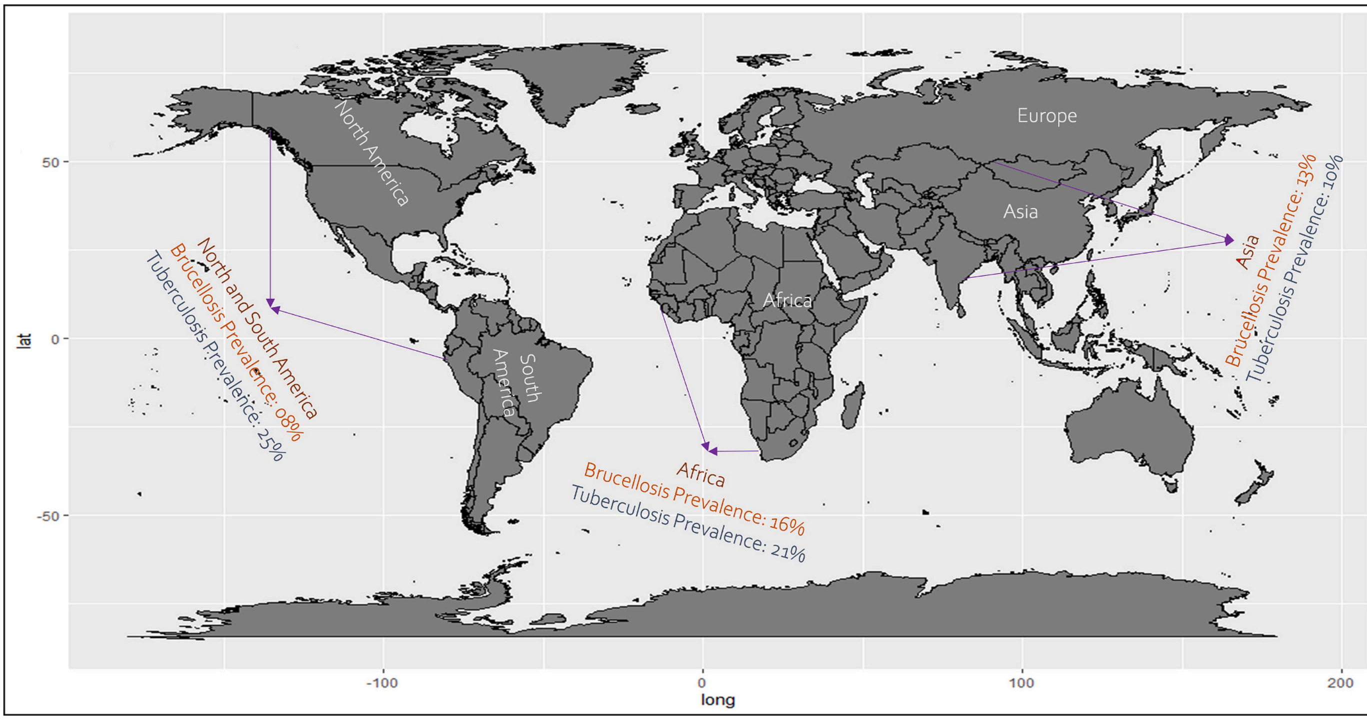

Fig. 12. Continent wise prevalence visualized in world map.

Table 4
Prevalence of brucellosis according to different occupation groups and other risk factors.

Variable	Occupational Group	No. of Studies	Prevalence (%) (95% CI)	I^2 (%)	H^2	Z-Test	Tau^2	P-value	Chi-square test
Occupational group	Slaughterhouse workers	23	20 (13–27)	99.08	108.50	5.79	0.026	<0.001	$P = 0.002$
	Butcher	12	15 (05–24)	94.11	16.98	3.07	0.023	<0.001	
	Farm workers	12	10 (04–17)	99.58	240.83	3.04	0.013	<0.001	
	Veterinary assistants	12	19 (09–29)	99.96	32.91	3.66	0.026	<0.001	
	Veterinarian	11	13 (06–21)	87.61	8.07	3.43	0.012	<0.001	
	Animal handlers	10	16 (09–22)	89.40	9.43	4.98	0.007	<0.001	
	Livestock farmers	07	11 (04–18)	73.35	3.75	3.28	0.004	0.001	
	Shepherd	06	10 (0–19)	94.58	18.45	1.99	0.012	<0.001	
	Veterinarian students	05	01 (0–03)	0	1.00	1.58	2e-04	0.966	
	Milker	04	06 (−01–13)	89.42	9.45	1.70	0.003	0.002	
Age	(20–45) years	03	09 (06–12)	0.0	1.00	6.46	7e-04	0.489	$P = 1.00$
	46 years-rest	03	06 (04–07)	1.34	1.01	6.39	3e-04	0.246	
Sex	Male	32	17 (11–24)	99.68	311.8	5.39	0.032	<0.001	$P = 0.799$
	Female	30	06 (03–09)	98.53	67.989	4.24	0.004	<0.001	
Diagnostic test	Rose Bengal Plate Test and ELISA	14	12 (06–18)	99.48	190.81	4.10	0.011	<0.001	$P = 0.036$
	Rose Bengal Plate Test	11	10 (05–16)	97.87	47.02	3.53	0.008	<0.001	
	ELISA	11	18 (08–29)	99.91	1074.80	3.44	0.030	<0.001	
	Rose Bengal test and serum and standard agglutination test	07	11 (5–17)	92.74	13.77	3.49	0.005	<0.001	
	Standard tube agglutination test	04	06 (01–11)	96.43	27.98	2.36	0.002	<0.001	
	Rose Bengal tests and PCR	03	18 (−07–44)	99.72	355.43	1.43	0.049	<0.001	

the disease. A wide range of breeding techniques, in combination with a lack of veterinary health management to restrict infection in herds, could explain this elevated risk. Besides, proximity between human residences and animal shelters, shared material between farmers without disinfection precautions, consumption of unpasteurized dairy products and milk by farmers, regular physical contact with animals, lack of awareness concerning the disease [27], and inadequate hygienic practices are mainly responsible for rapid spared of these pathogens in the developing countries [28].

Analyzing the different occupational groups, slaughterhouse workers had the maximum prevalence rate of brucellosis (20%), whereas tuberculosis had the lowest prevalence rate (3%) among slaughterhouse workers. The majority of those people were from the United States, Africa, and Europe, with a small number from Asia. Previous research found that in Spain and Ethiopia, respectively, 12.26% and 48.72% of slaughterhouse workers reported cutting themselves with dirty sharp blades and coming into contact with animal fluids, aborted fetus, placenta, and viscera as the most common type of pathogen entry route [27].

Unlikely, in our study, the prevalence of tuberculosis among livestock owners was reported to be as high as 28%. In the same line, Adane et al. [29] found that the prevalence of tuberculosis appears to be higher in the livestock farmer community (59.7%) and this could be due to the lack of understanding about bovine tuberculosis, its transmission channels and prevention approach [30].

Comparing the risk factors including the age and sex, the maximum 34% and 23% prevalence of tuberculosis was reported from female individual and adult aged group (20–49 years). However, young aged group and male individuals have reported the maximum 9% and 17% prevalence rate for brucellosis. Other reports have shown a similar male predominance and this was probably related to the higher occupational exposure of these groups rather than greater ingestion of milk or dairy products. Likely, a previous study reported an increased tuberculosis rate among older adults aged 65 and above, which is in accordance with our study [31]. However, a prior study on the Western Cape's adolescent population's exposure to tuberculosis risk factors found that female adolescents had a 70% higher relative incidence rate of the disease than male adolescents. [32].

5. Conclusion

Infection with brucellosis and tuberculosis on a large scale among livestock-related personnel has become a major public health issue in both developing and developed countries. Working with animals carries a high risk, and yet frequent animal contact in general should also be taken into account for disease transmission. Going deeper, exposure to aborted fetuses, infectious after birth tissues, vaginal discharges, unpasteurized milk, sick animals handling and environmental factors are functioning as risk factors for disease transmission. In the present study we found, 19% and 14% pooled prevalence for tuberculosis and brucellosis among the different livestock related occupational groups. Additionally, brucellosis and tuberculosis were more prevalent in the African region; however, only tuberculosis was more widespread in the American region, and tuberculosis was expanding rapidly in Asian part. Furthermore, conferring to our findings, slaughterhouse workers and farm owners are at risk for getting brucellosis and tuberculosis, respectively. Thus, not only laboratory techniques for precise and rapid diagnosis, isolation and disposal of sick animals can aid in slowing the rapid transmission of these diseases, but also the implementation of proper preventive measures and specific guidelines among high-risk groups of people are also essential to curve the spread.

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Credit author statement

Md. Mukthar Mia and Mahamudul Hasan: Conceptualization, Methodology and Analysis. Mahamudul Hasan and Faija Sadia Pory: Data collection. Md. Mukthar Mia, Mahamudul Hasan and Faija Sadia Pory: Reviewing and Editing.

Declaration of Competing Interest

Authors declare that they have no conflict of interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2022.100432.

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