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

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A B S T R A C T

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, \textit{I}^2 statistic, Cochran’s \textit{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: farmer 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 \textit{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, \textit{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 \textit{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...
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 heterogeneity 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 heterogeneity 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 outlier 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-
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 ≤ 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 ≤ 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: 05–29) from the ELISA test; in contrast, the lowest 06% (95% CI: 01–11) prevalence rate was documented in Standard tube agglutination test (Table 4).

4. Discussion

The occurrence of zoonotic diseases like tuberculosis and brucellosis
Table 1
Characteristics of the included studies.

| Reference | Author | Duration | Sample Name | Test Technique | Occupation Group (positive/Total) | Quality score |
|-----------|--------|----------|-------------|----------------|-----------------------------------|--------------|
| [35]      | Beheshti et al. (2010) | N/A | Blood | Rose Bengal plate test (RBT), standard tube agglutination test (SAT) | Veterinary technicians (6/15), veterinary students (0/42), butchers (2/52), slaughterhouse workers (2/17), and chefs (3/3) | 8 |
| [34]      | Nahar and Ahmed (2009) | 2007 | Blood | Rose Bengal plate test (RBT), standard tube agglutination test (SAT) | Clinical assistant (1/5), animal owner (1/7), butchers (0/4), veterinary science students (1/26) | 8 |
| [35]      | Cadmus et al. (2006) | 2004 | Blood | Rose Bengal test (RBT), standard tube agglutination test (SAT) | Butchers (7/11), herdmen (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) | Livestock/farm workers (0/394), abattoir workers (0/99) | 7 |
| [44]      | Adesiyan et al. (2011) | 2006 | Blood | ELISA | Veterinary and pharmacists (43/126), para-veterinarians (3/16), animal attendants and dairy farmers (13/78), miscellaneous (5/21) | 8 |
| [45]      | Yoo et al. (2009) | N/A | Blood | Rose Bengal test and serum/standard tube 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]      | Ebrahimipour 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 tube agglutination test | N/A | 6 |
| [50]      | Ali et al. (2013) | 2011 | Blood | Rose Bengal test and serum/standard tube agglutination test | Veterinary personnel (0/31), milkers (1/53), abattoir worker (10/54), livestock farmer (7/107) | 8 |
| [51]      | Kumara et al. (2015) | N/A | Blood | Rose Bengal test and serum/standard tube agglutination test | Veterinarians (4/75) | 8 |
| [52]      | Mangtani et al. (2020) | 2015–2017 | Blood | Rose Bengal Plate Test and ELISA | N/A | 7 |
| [53]      | Doni et al. (2017) | 2013 | Blood | Rose Bengal test and serum/standard agglutination test | Family farmers (42/461), seasonal migratory workers (39/246) | 8 |
| [54]      | Aghaali et al. (2015) | 2013 | Blood | Standard tube agglutination test | N/A | 6 |
| [55]      | Priyadarshini et al. (2013) | 2008–2009 | Blood | Rose Bengal Plate Test and ELISA | Veterinary officer (0/14), farmer (1/11), exposed animal handler (1/27), slaughter house worker (2/16) | 7 |
| [56]      | Rahman et al. (2019) | N/A | Blood | Rose Bengal Plate Test (RBT) | Worker (3/427) | 7 |
| [57]      | Swai and Schoonman (2009) | 2004 | Blood | Rose Bengal Plate Test (RBT) | Animal handlers (5/40), livestock keepers (4/25), butchers (2/20), middle men (0/15) | 8 |
| [58]      | Asworth et al. (2013) | 2010–2011 | Blood | Rose Bengal Plate Test and ELISA | Aboattoir workers (54/224) | 7 |
| [59]      | Al-Haddad et al. (2013) | 2009 | Blood | Rose Bengal plate test and serum/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), milkers (10/55), butcher (1/40), veterinary technician (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/paramedic (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]      | Zin and Sabahehkilner (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]      | Thes et al. (2019) | N/A | Blood | Standard tube agglutination test | (continued on next page) |
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 brucellosis and tuberculosis using preset criteria for two suspected zoonoses (brucellosis and tuberculosis) associated with livestock as well as try to distinguish among

| Table 1 (continued) |
|---------------------|-----------------|-----------------|-----------------|-----------------|

**Brucellosis**

| Reference | Author                  | Duration | Sample Name | Test Technique                      | Occupation Group (positive/Total)                  | Quality score |
|-----------|-------------------------|----------|-------------|-------------------------------------|--------------------------------------------------|--------------|
| [27]      | Tsegay et al. (2017)    | 2013–2014| Blood       | Rose Bengal Plate Test and ELISA    | Hospital (6/127), veterinarians (4/23), students (0/41), pathological laboratory (8/171) | 8            |
| [72]      | Sadighe et al. (2020)   | N/A      | Blood       | Rose Bengal Plate Test (RBT)        | Abattoir workers (54/224)                         | 8            |
| [73]      | Anegashie 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-Mostelby et al. (2018)| N/A   | Blood       | ELISA                               | Veterinary doctors (6/23), administrators (5/27), veterinary workers (17/46), peelers (38/115) | 8            |
| [76]      | Kamba 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                               | Shepherds (1/75), livestock officer (0/11), butcher men (3/57), abattoir worker (2/186), milking man (0/72), animal product (0/24) | 7            |
| [79]      | Sagamiko et al. (2019)  | 2015–2016| Blood       | Rose Bengal Plate Test and ELISA    | Veterinary students (0/45), shepherds (0/44), veterinarians (1/44), dung cake makers (1/52), milkers (5/63), abattoir workers (13/211) | 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              | Veterinarian 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 |
|--------------|-------------|----------------|-----------------------------------|--------------|
| Bekele et al. (2016) | 2012–2013 Nasal swab | PCR | Dairy farm worker (16/25) | 7 |
| [7] Ailegin 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] Tibeau et al. (2017) | 2010–2011 Sputum | M. bovis spoligotype | Cattle owner (141/287) | 7 |
| [88] Ameni et al. (2013) | 2012–2012 Sputum | Ziehl-Neelsen staining | Herdsman (0/60) | 6 |
| [89] Amenour et al. (2017) | 2007–2007 Sputum | M. bovis spoligotype | Farm worker (11/102), abattoir worker (0/91) | 8 |
| [90] Bapat et al. (2017) | 2014–2015 Blood | TST and Interferon-gamma release assay (IGRA) | Tuberculin skin test (TST) and Interferon-gamma release assay (IGRA) | 8 |
| [91] Torres-gonzalez et al. (2013) | 2009–2011 Sputum | M. bovis spoligotype | Farm worker (11/102), abattoir worker (0/91) | 8 |
| [92] Milian-Suazo et al. (2010) | 2006–2007 Sputum | Ziehl-Neelsen staining | Tuberculin skin test (TST) and Interferon-gamma release assay (IGRA) | 8 |
| [93] Joshi, (2015) | 2002–2003 Sputum | PCR | Livestock owner and involve person (19/200) | 8 |
| [94] Cadmus et al. (2018) | 2014–2015 Sputum | Culture and biolin analysis | Livestock related person (40/250) | 7 |
| [95] Ibrahim et al. (2016) | 2011–2013 Sputum | Culture and biolin analysis | Livestock related person (40/250) | 7 |
| [96] Adesokan et al. (2012) | N/A Sputum | PCR | Livestock traders (63), worker in cattle market (7) | 8 |
| [97] Mazari et al. (2021) | N/A Nasal discharge | ELISA | Farm workers (3/200) | 7 |
| [98] 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 |
| [99] Cleaveland et al. (2007) | N/A Lymph node biopsies | PCR | TB infected cattle owner (65/457) | 8 |
| [100] Rodriguez (2019) | 2016 Blood | Tuberculosis assay | Dairy workers (14/140) | 7 |
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.

### Table 2
Continentalwise prevalence of brucellosis and tuberculosis.

| Disease     | Continent | No. of Studies | Prevalence (%) (95% CI) | I² (%) | H² Value | Z-Test | Tau² | 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     | 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) | I² (%) | H² | Z-Test | Tau² | P-value | Chi-square |
|----------------------------|----------------|-------------------------|--------|----|--------|------|---------|------------|
| Diagnostic method          |                |                         |        |    |        |      |         |            |
| PCR                       | 08             | 21 (04-38)              | 99.47  | 188.41 | 2.46 | 0.054 | <0.001 | 0.808      |
| Other than PCR             | 09             | 17 (03-31)              | 99.35  | 153.33 | 2.41 | 0.045 | <0.001 |            |
| Age (0-19years)            | 04             | 06 (01-11)              | 32.11  | 1.473 | 2.20 | 0.018 | 0.353   | P = 0.926 |
| (20-49years)               | 05             | 34 (02-66)              | 99.19  | 122.7 | 2.06 | 0.133 | <0.001 |            |
| >50 years                  | 04             | 21 (05-37)              | 87.37  | 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.
Fig. 4. Visualization of funnel plot described studies heterogenicity: A) Brucellosis; B) Tuberculosis; Galbraith plot: C) Brucellosis; D) Tuberculosis.

| Study name             | weight | Prevalence (95% CI) |
|------------------------|--------|---------------------|
| (Cardmus et al., 2019) | 10.19% | 0.96 [0.87, 1.01]  |
| (Ibrahim et al., 2019) | 10.15% | 1.06 [1.00, 1.19]  |
| (Woldeyesus et al., 2013)| 10.00% | 0.10 [0.06, 0.15] |
| (Selbeke et al., 2016) | 8.88%  | 0.84 [0.66, 1.07]  |
| (Magin et al., 2019)  | 10.02% | 0.95 [0.83, 1.05]  |
| (Tchopp et al., 2010) | 10.00% | 0.96 [0.84, 1.00]  |
| (Tchopp et al., 2010) | 10.00% | 0.96 [0.84, 1.00]  |
| (Mamisi et al., 2013) | 10.09% | 0.95 [0.86, 1.05]  |
| (Kamrani et al., 2017) | 10.22% | 0.98 [0.80, 1.06]  |
| (Kamrani et al., 2017) | 10.22% | 0.98 [0.80, 1.06]  |

RE Model: 100.00% 0.21 [0.08, 0.30]

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

| Study name             | weight | Prevalence (95% CI) |
|------------------------|--------|---------------------|
| (Mazael et al., 2021)  | 26.30% | 0.01 [0.00, 0.03]  |
| (Yarlagadda et al., 2015) | 25.21% | 0.05 [0.01, 0.09] |
| (Bajpai et al., 2017)  | 23.24% | 0.04 [0.01, 0.02]  |
| (Joshi, 2015)          | 26.36% | 0.10 [0.06, 0.14]  |

RE Model: 100.00% 0.10 [0.05, 0.15]
(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.
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. 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.
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
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
livestock farmers 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 live-
stock 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

| Variable             | Occupational Group                  | No. of Studies | Prevalence (%) (95% CI) | I² (%) | H² | Z-Test | Tau² | 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)               | 0.0    | 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      | 07             | 11 (5–17)               | 92.74  | 13.77 | 3.49   | 0.005 | <0.001  |                 |
|                      | standard agglutination test         |                |                         |        |      |        |       |         |                 |
|                      | 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  |                 |
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 curb the spread.

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Declaration of Competing Interest

Authors declare that they have no conflict of interests.

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Appendix A. Supplementary data

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References

[1] F. and A.O. of the U.N. FAO, Decent Rural Employment. https://www.fao.org/ru- nal-employment/agricultural-sub-sectors/livestock/en/, 2022 (accessed April 25, 2022).

[2] M. Bekele, G. Mamo, S. Mulat, G. Amen, G. Beyene, Epidemiology of bovine tuberculosis and its public health significance in Debre-Zeit intensive dairy farm, Ethiopia. J Biomed Nurs. 2 (2016) 9-18.

[3] R.F. Kelly, S.M. Hamman, K.L. Morgan, E.F. Nkwongho, V.N. Ngwa, V. Tanya, W.N. Andu, M. Sander, L. Ndp, I.G. Handel, Others, knowledge of bovine tuberculosis, cattle husbandry and dairy practices amongst pastoralists and small-scale dairy farmers in Cameroon, PLoS One 11 (2016), e0146538, https://doi.org/10.1371/journal.pone.0146538.

[4] S. Cousins, The challenges of preventing bovine tuberculosis, Bull. World Health Organ. 96 (2018) 659-664.

[5] J.B. Nivaguzunwa, A. Michel, C. Byaruhanga, R. Gashururu, F.B. Kolo, et al., Awareness and Occupational Exposure to Brucellosis and Other Zoonotic Diseases Among Abattoir Workers in Rwanda, 2021, pp. 1–23, https://doi.org/10.21203/r7.dz5w.v1.

[6] S. Malama, J.B. Muma, J. Godfroid, A review of tuberculosis at the wildlife-livestock-human interface in Zambia, Infect. Dis. Poverty. 2 (2013) 1–5, https://doi.org/10.1186/2044-9957-2-15.

[7] A. Alejina, A. Zewude, B. Petrie, G. Amen, G. Amerini, Tuberculosis at farmer-cattle interface in the rural villages of South Gonder zone of Northwest Ethiopia, Tuberc. Res. Treat. 2019 (2019), https://doi.org/10.1186/s12890-019-2608-1.

[8] K.R. Devi, I.J. Lee, L.T. Yan, A-N. Syafizah, I. Rosnah, V.K. Chin, Occupational exposure and challenges in tackling M. bovis at human-animal interface: a narrative review, Int. Arch. Occup. Environ. Health 94 (2021) 1147–1171.

[9] A.O. Jenkins, S.L.B. Cadmus, E.H. Venter, C. Pourcel, Y. Hauk, G. Vergnaud, J. Godfroid, Molecular epidemiology of human and animal tuberculosis in Ibadan, southwestern Nigeria, Vet. Microbiol. 151 (2011) 139–147, https://doi.org/10.1016/j.vetmic.2011.02.037.

[10] H.K. Tiwari, V. Proch, B.B. Singh, K. Schemann, M. Ward, J. Singh, J.P.S. Gill, N. A. Khan, Brucellosis in India: comparing exposure amongst veterinarians, Paramedics and animal handlers, One Heal. 14 (2022), 100367.

[11] N.A. Madut, M. Ocan, A. Muwonge, J.B. Muma, G.W. Nasinyama, J. Godfroid, A. S. Junbera, C. Kankya, Sero-prevalence of brucellosis among slaughterhouse workers in Bahr el Ghazal region, South Sudan (2019) 1–8.

[12] K. Nieboer, W.L. Yu, Serological diagnosis of brucellosis, Prilozi. 31 (2010) 65–89.

[13] S. Sabebe, H. Shonaka, M. Syyeyd, Seroprevalence of tuberculosis and Q fever among high-risk occupations in northeast of Iran for first time, Iran. J. Microbiol. 13 (2021) 325.

[14] S. Q. Ali, H. Nehru, F. Melzer, M. Elschen, J. Khan, E.N. Abati, N. Ullah, M. Irfan, S. Akhtar, Seroprevalence and risk factors associated with brucellosis as a professional hazard in Pakistan, Foodborne Pathog. Dis. 10 (2013) 500–505.

[15] L.M. Avila-Granados, D.G. Garcia-Gonzalez, J.L. Zambrano-Varon, A.M. Arenas-Gamboa, Brucellosis in Colombia: current status and challenges in the control of an endemic disease, Front. Vet. Sci. (2019) 321.

[16] G. Guerrier, J.M. Dazonot, L. Morise, J.F. Yvon, G. Pappas, Epidemiological and clinical aspects of human Brucella suis infection in Polynesia, Epidemiol. Infect. 199 (2011) 1621–1625, https://doi.org/10.1017/S0950268811001975.

[17] R. Tschopp, A. Aseff, E. Schelling, S. Berg, E. Hailu, E. Gadisa, M. Habtamu, K. Argaw, J. Zinsstag, Bovine tuberculosis at the wildlife-livestock-human interface in Hamer Woreda, South Omo, Southern Ethiopia, Plaša One 5 (2010), e12205, https://doi.org/10.1371/journal.pone.0012205.

[18] O. Newcastle-Ottawa, Newcastle- Ottawa: Scale Customized for Cross-Sectional Studies. https://static-content.springer.com/esm/articledocs/10.1186%2f4171–13-154/MediaObjects/12889_2012_511_MOESM3_ESM.doc, 2016.

[19] A.J. Rodriguez, V. dos Santos Nunes, C.A. Mastronardi, T. Neeman, G.J. Paz-Filho, Association between circulating adipokine concentrations and microvascular complications in patients with type 2 diabetes mellitus: a systematic review and meta-analysis of controlled cross-sectional studies, J. Diabetes Complicat. 30 (2016) 357–367.

[20] A. Dalimi, F. Fahvildar, Others, molecular study on Cryptosporidium andersonii strains isolated from sheep based on 18S rDNA gene, Infect. Epidemiol. Microbiol. 3 (2017) 100–103.

[21] M. Feller, K. Huwiler, R. Stephan, E. Altpeter, A. Shang, H. Furrer, G.E. Pfiffer, T. Jemmi, A. Baumgartner, M. Egger, Mycobacterium avium subspecies paratuberculosis and Crohn’s disease: a systematic review and meta-analysis, Lancet Infect. Dis. 7 (2007) 607–613.

[22] K. Hajjisa, M.A. Islam, A.M. Sanyang, Z. Mohamed, Prevalence of intestinal protozoan parasites among school children in african: a systematic review and meta-analysis, PLoS Negl. Trop. Dis. 16 (2022), e0009971, https://doi.org/10.1371/journal.pntd.0009971.

[23] K. Howells, C. Sivaratnam, T. May, E. Lindor, J. McGillivray, N. Rinehart, Efficacy of group-based organised physical activity participation for social outcomes in children with autism spectrum disorder: a systematic review and meta-analysis, J. Autism Dev. Disord. 49 (2019) 3290–3308, https://doi.org/10.1007/s10803-019-04050-9.

[24] C.R. Pereira, J.V.F. de Almeida, I.R. de Oliveira, L. de Oliveira, L.J. Pereira, M. G. Zangeronimo, A.P. Lage, E.M.S. Dorneles, Occupational exposure to Brucella spp.: a systematic review and meta-analysis, PLoS Negl. Trop. Dis. 14 (2020), e0008164.

[25] F. Vay, G. Martin-Blondelet, F. Savall, J-M. Soulant, G. Defontaines, F. Herin, Occupational exposure to human Mycobacterium bovis infection: a systematic review, PLoS Negl. Trop. Dis. 12 (2018), e0006208.
M.J. Nakeel, S.M. Arimi, P. Kitala, G. Nduhiu, J.M. Njenga, J.K. Wabacha, A sero-prevalence of human brucellosis and associated risk factors among high risk occupations in Mbeya region of Tanzania. J. Epidemiol. Res. 6 (2020) 1-6, https://doi.org/10.5430/jer.v6n1p1, 688705.

J. Ren-Roman, L. Ren-Garrido, E. Abatih, M. Celi-Erazo, J. Calva-Pacheco, P. Gonzalez-Andrade, D. Berkvens, J. Brandt, et al., Human brucellosis in Northwest Ecuador: typifying Brucella spp., seroprevalence, and associated risk factors, Vector-Borne Zoonotic Dis. 14 (2014) 124-133.

S. Ali, U. Saeed, M. Rizwan, L. Hasson, M.A. Syed, F. Melzer, H. El-Adasy, H. Neubauer, Serosurvey and risk factors associated with Brucella infection in high risk occupations from district Lahore and Kasur of Punjab, Pakistan, Pathogens. 10 (2021) e20.

N.A. Madut, M. Ocan, A. Muwonge, J.B. Muma, G.W. Nasinyama, J. Godfroid, A. V. Proch, B.B. Singh, K. Schemann, J.P.S. Gill, M.P. Ward, N.K. Dhand, Risk factors for occupational Brucella infection in veterinary personnel in India, Transbound. Emerg. Dis. 65 (2018) 791–798.

M.J. Nakeed, S.M. Arimi, P. Kirula, G. Nduhiu, J.M. Njengo, J.K. Wachacha, A sero-epidemiological survey of brucellosis, Q-fever and leptospirosis in livestock and humans and associated risk factors in kajiado county-Kenya, J Trop Dis. 4 (2016) 8.

M. Bekele, G. Beyene, G. Ameen, Epidemiology of Bovine Tuberculosis and its public health significance in Debre- Zeit intensive dairy farms, Ethiopia, Biomed. Nurs. 2 (2016) 7–18, https://doi.org/10.7537/marshn.0201601.

M. Tibebe, W. Mekonnen, T. Awoke, S. Gebre-selassie, L. Yamash, S. Berg, A. Aseffa, A high prevalence of tuberculosis among dairy farmers in Addis Ababa Mycobacterial Diseases a High Prevalence of tuberculosis among dairy farm Workers in Addis Ababa and its surroundings, Mycobact. Dis. 4 (2017), p134, https://doi.org/10.4172/2161-1068.1000139.

G. Ameen, K. Tadesse, E. Hallu, Y. Deresse, G. Medhin, A. Aseffa, G. Hewinson, M. Vordermeier, S. Berg, Transmission of Mycobacterium tuberculosis between farmers and cattle in Central Ethiopia, PloS One 8 (2013) 1–10, https://doi.org/10.1371/journal.pone.0076891.

E.A. Amemor, S.O. Sackey, N. Yebuah, R.D. Folitse, O. Benjamin, E. Afari, F. Wurapa, C. Ohuabunwo, K. Addo, D. Mensah, E. Gaglo, S. Johnson, W. Tasiame, D. Amedzovor, D. Nkunafa, F. Bonsu, THE PREVALENCE OF TUBERCULOSIS IN CATTLE AND THEIR HANDLERS IN NORTH TONGU, School of Veterinary Medicine, Kwame Nkrumah University of Science and Technology, Kumasi. Ghana Tuberculosis Control Programme, Ghana Health Service, 3 Veterinary Services, African J. Infect. Dis. 11 (2017) 12–17.

P.R. Bapat, R.S. Dodkey, S.D. Shekhawat, A.A. Hussain, A.R. Nayak, A.P. Kavle, H. F. Dagianwala, L.K. Singh, R.S. Kashyap, Journal of epidemiology and Global Health prevalence of zoonotic tuberculosis and associated risk factors in central Indian populations, J. Epidemiol. Glob. Health. 7 (2017) 277–283, https://doi.org/10.1016/j.jegh.2017.08.007.

P. Torres-gonzalez, O. Soberanis-ramos, A. Martinez-gamo, B. Chavez-mazari, M. T. Barrios-herrera, M. Torres-rojas, L.P. Cruz-hervert, L. Garcia-garcia, M. Singh, A. Gonzalez-aguirre, A.P. De Leon-gardon, M. Bobadilla-del-valle, Prevalence of latent and active tuberculosis among dairy farm workers exposed to cattle infected by Mycobacterium bovis, PLoS One 7 (2013) 1–6, https://doi.org/10.1371/journal.pone.002177.

F. Milián-Suazo, L. Pérez-Guerrero, Molecular epidemiology of human cases of tuberculosis by Mycobacterium bovis in Mexico, Prev. Vet. Med. 97 (2010) 37–44.

Y.P. Joshi, Prevalence of bovine tuberculosis among livestock and its relation with human tuberculosis in Kanchanpur district prevalence of bovine tuberculosis among livestock and its, 2015, https://doi.org/10.13140/RG.2.1.1613.7441.

S. Cadmus, V. Akimseye, A. Adegbulu, N. Ovwighose, M. Ayoola, J. Ogugua, H. Adoson, E. Cadmus, Isolation of Mycobacterium tuberculosis from livestock workers and implications for zoonoanthropontic transmission in Ibadan, J. Prev. Med. Hyg. 59 (2018) 212–218.

S. Ibrahim, D. Abubakar, A. Usman, F.U. Muhammad, G.A. Musa, Preliminary study on the prevalence of bovine tuberculosis and risk factors among pastoralists in Gombe state, North Eastern Nigeria, J Microbiol Exp. 3 (2016) 81.

M.Q. Mazari, D.H. Kalhoro, H. Baloch, M.S. Kalhoro, S.H. Abro, R. Buriro, A. Kaka, F. Parveen, M.H. Mangi, G.M. Lochi, Others, prevalence and risk factors of bovine tuberculosis in cattle and dairy farm Workers in Mirpurkhas and Badin Districts of Sindh, Pakistan, 2021, https://doi.org/10.1101/20249.9957-213.

I. Khahtak, M.H. Mushagat, S. Ayaz, M.U.D. Ahmad, S.U. Rahman, Occurrence of zoonotic tuberculosis in occupationally exposed high-risk groups in Peshawar, Pakistan, Int. J. Mycobacteriology. 5 (2016) S247.

F. Daginawala, L.K. Singh, R.S. Kashyap, Journal of epidemiology and Global Health prevalence of zoonotic tuberculosis and associated risk factors in central African populations, J. Epidemiol. Glob. Health. 7 (2017) 277–283, https://doi.org/10.1016/j.jegh.2017.08.007.

S. Cleaveland, D.J. Shaw, S.G. Mfinanga, Preliminary study on the prevalence of bovine tuberculosis and risk factors among pastoralists in Gombe state, North Eastern Nigeria, J Microbiol Exp. 3 (2016) 81.

M-Q. Mazari, D.H. Kalhor, H. Baloch, M.S. Kalhor, S.H. Abro, R. Buriro, A. Kaka, F. Parveen, M.H. Mangi, G.M. Lochi, Others, prevalence and risk factors of bovine tuberculosis in cattle and dairy farm Workers in Mirpurkhas and Badin Districts of Sindh, Pakistan, 2021, https://doi.org/10.1101/20249.9957-213.

I. Khahtak, M.H. Mushagat, S. Ayaz, M.U.D. Ahmad, S.U. Rahman, Occurrence of zoonotic tuberculosis in occupationally exposed high-risk groups in Peshawar, Pakistan, Int. J. Mycobacteriology. 5 (2016) S247.

S. Cleaveland, D.J. Shaw, S.G. Mfinanga, Mycobacterium bovis in rural Tanzania : risk factors for infection in human and cattle populations, Tuberculosis. 87 (2007) 30-43, https://doi.org/10.1016/j.tube.2006.03.001.

A. Rodriguez, Tuberculosis among dairy workers in Bailey county, Texas, UT Sch. Public Heal. Diss. 2019 (2019) 24–62.