Brucellosis awareness and knowledge in communities worldwide: A systematic review and meta-analysis of 79 observational studies

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Abstract

Background

Brucellosis is regarded as a major zoonotic infection worldwide. Awareness and knowledge of brucellosis among occupational workers is considered an important aspect of brucellosis control in both humans and animals. The aim of this study was to explore the distributions of the pooled awareness level and the knowledge level of the disease worldwide.

Methods

A meta-analysis was carried out to obtain pooled brucellosis awareness levels and knowledge levels of respondents regarding the zoonotic nature of brucellosis, mode of brucellosis transmission, and brucellosis symptoms in animals and humans. The analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-analyses guidelines.

Results

A total of seventy-nine original articles reporting the brucellosis awareness levels of populations from 22 countries were assessed. The total pooled awareness level of brucellosis was 55.5%, and the pooled awareness levels regarding the zoonotic nature of brucellosis, mode of brucellosis transmission, signs of human brucellosis and signs of animal brucellosis were 37.6%, 35.9%, 41.6%, and 28.4% respectively. The pooled awareness level was higher than the brucellosis-related knowledge level. Subgroup analyses showed that no obvious differences in brucellosis awareness levels between high-risk populations in Asia and Africa. Health workers (including human health workers and veterinarians) had the greatest overall awareness and knowledge of human brucellosis. The overall awareness levels and knowledge levels of livestock owners (farmers) and herders were higher than those of dairy farmers and abattoir workers. In addition, awareness and knowledge levels were higher among people who were involved in bovine, caprine and ovine animal...
production or in caprine and ovine animal production than among people who were involved in only bovine animal production.

**Conclusions**

Insufficient awareness and knowledge of brucellosis were observed in the original studies conducted mainly in Asia and Africa. Interventions to improve public knowledge about brucellosis are urgently needed.

**Author summary**

Brucellosis is considered a neglected zoonotic disease that creates a very large obstacle to the development of animal production and is a great threat to human health. High brucellosis awareness and knowledge is critical for the implementation of correct practices and habits and consequently the control and prevention of brucellosis. The aim of this study was to estimate the awareness and knowledge of brucellosis, specifically regarding its zoonotic nature, mode of transmission, and signs in humans and in animals as well as awareness information sources. To this end, a meta-analysis of data from 79 studies was performed. The included studies on the awareness and knowledge of brucellosis were mainly from Africa and Asia. There were no significant differences in the awareness levels of brucellosis among high-risk groups in Asia and Africa. Overall, people’s awareness and knowledge of brucellosis were low and insufficient. Health workers had the highest pooled levels of awareness and knowledge regarding brucellosis. In addition, livestock stock owners (farmers) had notably higher awareness and knowledge levels than dairy farmers and abattoir workers. Neighbors and friends were the most common sources of brucellosis information for farmers. The low and insufficient awareness and knowledge about brucellosis is an obstacle for public health. Raising awareness and increasing detailed knowledge of brucellosis are of great significance for the control of brucellosis and the protection of human health. The potential of the media and health workers in the dissemination of knowledge about the disease needs to be fostered.

**Introduction**

Brucellosis is considered as one of the most important zoonoses in the world with more than 500,000 human cases occurring globally every year [1,2]. Despite a high burden of infection in many areas of the world, brucellosis is rarely prioritized by health systems and is considered a neglected zoonosis by the World Health Organization (WHO) [3] and World Organisation for Animal Health (OIE) [4]. Brucellosis causes abortion, infertility and milk production decline in animals [5,6]. It is transmitted to humans through consumption of unpasteurized dairy products and uncooked meat or through direct contact with infected animals, placentas or aborted fetuses [7]. Clinically, human disease is characterized by fever, fatigue, sweating, joint pain, headache, loss of appetite, muscular pain, lumbar pain, weight loss, and arthritis [8,9] and is often misdiagnosed as other febrile syndromes, such as malaria and typhoid fever, resulting in mistreatments and underreporting [6,10,11].

Generally, poor hygiene, prevalence of the disease in animals and practices that expose humans to infected animals or their products can significantly increase the risk of the occurrence of the disease in humans [12]. Therefore, farmers, pastoralists, abattoir workers, animal health personnel, laboratory personnel and other people involved in the livestock value chain...
are considered the highest occupational risk groups [13]. Vaccination is an important control tool particularly where there is no compensation for livestock owners for test-and-slaughter, there is no individual identification system and mobile livestock keeping is practiced. And the control and eradication of brucellosis cannot be achieved by vaccination and test-and-slaughter only; the cooperation of relevant occupational groups is an important component in achieving this goal [14]. Therefore, adequate knowledge of the epidemiology of brucellosis is of great public health importance, particularly among high-risk groups, as knowledge promotes people to take protective measures at work and actively participate in disease control programs, thus greatly assisting the development of brucellosis control strategies.

Although there are many original studies that evaluate the knowledge and awareness of brucellosis, the overall awareness and detailed knowledge of the disease and the distribution of the literature remain unclear. To this end, we conducted this meta-analysis study to pool brucellosis awareness and knowledge levels worldwide as well as to seek out factors associated with the levels of awareness and knowledge.

Materials and methods

Search strategy

This review was reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) guidelines [15], and the PRISMA checklist is appended as S1 Appendix. Between March and June 2018, a literature search was conducted in PubMed, Web of Science, China National Knowledge Infrastructure (CNKI), Wan Fang and Yahoo search engines to identify the relevant articles about people’s brucellosis awareness and knowledge globally. The search string applied a combination of related words and was applied to each database separately, using Boolean operators. Searches used in all databases are shown in S2 Appendix. To identify additional relevant citations as much as possible, reference lists of included papers as well as “cited by” and “related information” tools in PubMed were searched. Not only English terms but also corresponding Chinese terms were applied to the Chinese databases.

Inclusion and exclusion criteria

All primary study designs were considered eligible, thus secondary reports, nonoriginal research, comments, editorials and reviews were directly excluded. Studies were included if they were related to brucellosis awareness or knowledge assessment. Studies conducted to evaluate the awareness and knowledge levels of zoonotic diseases were included as long as they reported data about brucellosis, but only data related to brucellosis were considered and analyzed.

Studies containing any of the following criteria were included: (i) studies reporting the awareness of brucellosis, where the original expression was similar to “Have you heard of brucellosis?”, “Do you know about brucellosis?” or “be aware of brucellosis”; (ii) studies reporting brucellosis knowledge about the mode of transmission to people, the zoonotic nature, and signs in humans and animals; (iii) studies reporting knowledge about consumption of unpasteurized milk and uncooked meat as high-risk practices for brucellosis infection in humans; and (iv) studies providing the information sources of people who had heard of brucellosis.

Screening of the identified publications

All citations were imported and duplicates were removed using the software EndNote X8. Two team members independently screened the literature in two stages. In the first stage, titles and abstracts were screened to exclude duplicates and ineligible studies based on relevance. In the second stage, the two reviewers independently evaluated the full text of the selected literature
to ensure full compliance with the inclusion criteria. At each stage, the selected papers were compared by the two investigators for analysis consistency. At the event of a disagreement, a third investigator joined the discussion and made a decision. The screening and selection of studies were promoted by the creation of appropriately labeled subgroups in EndNote.

**Data extraction**

A data abstraction form was constructed after screening the selected articles. For each included study, we extracted the following basic information: author, publication year, geographic region, study design, study population, sampling method, number of participants, education distribution, gender distribution and main livestock contacted by the studied population. Furthermore, the number of participants who answered positively (n) and sample size (N) were the two necessary parameters for the calculation of the pooled levels of brucellosis awareness and knowledge in the meta-analysis. In particular, the number of participants who answered positively (n) was obtained directly from these studies or by multiplying the sample sizes (N) with the proportions (%) associated with the investigated items reported in the studies. All the data extraction work was performed independently and then compared by two investigators. In the event of a disagreement, a third person joined the discussion and made a decision.

**Data analyses**

All available data were pooled in the present meta-analysis. The subgroups and categories considered included geographic regions (classified into five regions, Asia, Africa, South/Central America, North America and Oceania), animal species (bovine, ovine and caprine), human populations (occupational and nonoccupational groups; farmers, abattoir workers, traders, human and animal health workers, pastoralists and livestock transporters were identified as the occupationally exposed population) and countries. Additional subgroup analyses were performed for specified occupations (animal and human health workers, livestock owners (farmers), dairy farmers, abattoir workers, pastoralists, patients, students and residents).

Meta-analysis was performed based on a random-effect model. To stabilize the variance, the original rates were transformed by arcsine transformation. Cochran’s chi-square (Q-test) and the I² statistic were used to estimate the heterogeneity of the results. A funnel plot was constructed to visually examine the publication bias, and Begger’s rank test was used to test the significance of the plot’s asymmetry. R statistical software (Version 3.0.0) was applied for all the aforementioned calculations.

**Risk of bias assessment**

The quality and risk of bias of studies were assessed comprehensively as outlined in Hoy et al. [16] and Crombie et al. [17]. The risk of bias in the included studies was evaluated with a total of ten risk-biased items regarding external validity (items 1 to 4 assessed domain selection and nonresponse bias) and internal validity (items 5 to 9 assessed the domain of measurement bias, and item 10 assessed the bias related to the analysis). For each item, the study was classified as “Yes” or “No”, which meant “Low risk” or “High risk”, respectively. At the end of the overall risk assessment of study bias, studies with a “No” score ≤3 were classified as low risk, studies with a “No” score 4–6 were classified as moderate risk and studies with a “No” score ≥7 were classified as high risk. The risk bias and assessment results are provided in S3 Appendix. Studies with overall high risk of study bias were still included in this present meta-analysis as long as the research purpose and design were reasonable and the numerator and denominator for the parameter of interest were appropriate.
Results

Characteristics of the included studies

The search and selection process of related studies is presented in Fig 1. After the removal of articles published before 2010, articles with data that could not be interpreted, articles with duplicated data and studies without full-text, seventy-nine studies were included in the meta-analysis.
The characteristics of the included studies are provided in Table 1. Among the included publications, 52 studies were from Asia, 24 were from Africa, one each from Europe, South/Central America and North America, respectively. Among the included studies, one was published in Portuguese, one was published in Turkish, 31 were published in Chinese, and 56 were published in English.

The target populations of the studies included human health workers, high-risk occupational populations (farmers, traders, abattoir workers, livestock transporters, and animal health workers.), students and residents. Main animal species reared by the respondents were cattle and buffalo, sheep and goats, pigs, camels and dogs. The sample sizes of the studies ranged from 26 to 2,491 respondents. A questionnaire-based survey was administered in all the included studies; five studies adopted a self-administered questionnaire, while 74 studies collected the data during face to face interviews.

### Risk of bias assessment result
A low risk of bias was found in 63 studies, a moderate risk of bias was found in 15 studies and a high risk of bias was indicated in one study, which was included due to its reasonable research purpose and study design. The detailed risk of bias of each study is shown in S3 Appendix. In addition, with Begger’s test, no evidence of publication bias was found (Table 2).

### Awareness of brucellosis, its zoonotic nature and its transmission mode
An awareness of brucellosis was reported in 52 studies, with a pooled awareness level of 55.5%. An awareness of the zoonotic nature of brucellosis and its transmission mode were reported in

| Geographical region | First author, Publication year | Country | Investigation time | Questionnaire administration | Characteristics of participants | Illiterate level (%) | Main animal | Sampling method |
|---------------------|--------------------------------|---------|-------------------|-----------------------------|--------------------------------|---------------------|-------------|----------------|
| Africa              | Mosalagae, 2010 [18]          | Zimbabwe | Oct, 2009-Mar, 2010 | Interviewed                  | Dairy farmers                   | 119                  | 25.2         | Cattle         | Convenience |
|                     | Holt, 2011 [19]               | Egypt   | Dec, 2000-Feb, 2010 | Interviewed                  | Livestock owners               | 214                  | 30.0         | Cattle and buffalo | Random    |
|                     | Moafilo, 2011 [20]            | Angola  | Nov, 2009         | Interviewed                  | Breeders and abattoir workers  | 170                  | 7.3          | Cattle, goat, sheep, pig | Random    |
|                     | Adeolu, 2012 [21]             | Nigeria | Jan-Nov, 2013     | Interviewed                  | Livestock owner, traders      | 157                  | 16.6         | Cattle         | Cluster    |
|                     | Chakuma, 2013 [22]            | Zambia  | Oct-Nov, 2013     | Interviewed                  | Livestock owners               | 126                  | 15–44+       | Livestock      | Random     |
|                     | Tesfaye, 2013 [23]            | Ethiopia | Nov, 2013-Apr, 2014 | Interviewed                  | High-risk population          | 175                  | 15.0         | Livestock      | Random     |
|                     | Kamnoon, 2014 [24]            | Uganda  | Jan-Aug, 2012     | Interviewed                  | Members                       | 271                  | 40 (18–68)    | Cattle         | Random     |
|                     | Tebeg, 2014 [25]              | Malawi  | Feb, 2013-Dec, 2013 | Interviewed                  | Dairy farmers                  | 180                  | 40.8         | Cattle         | Random     |
|                     | Bax, 2015 [26]                | Tanzania | Nov, 2013-Sep, 2014 | Interviewed                  | Farmers, health workers        | 280                  | 100.0        | Cattle, sheep and goat | Random   |
|                     | Bethi, 2015 [27]              | Nigeria | -                 | Interviewed                  | Pastoralists                   | 62                   | 15–64+       | Cattle         | Random     |
|                     | Derwi, 2015 [28]              | Ethiopia | -                 | Interviewed                  | Farmers, traders               | 320                  | 79.2         | camel          | Random and Convenience |
|                     | Malinda, 2015 [29]            | Angola  | -                 | Interviewed                  | Abattoir workers, Breeders    | 122                  | 36.5         | Cattle         | Random     |
|                     | Ohaya, 2015 [30]              | Kenya   | Oct-Nov, 2013     | Interviewed                  | Pastoralists                   | 120                  | 25.0         | sheep and goat | Random     |
|                     | Tebeg, 2015 [31]              | Senegal | Aug-Nov, 2013     | Interviewed                  | Livestock owners               | 222                  | 15–65        | Cattle         | Random     |
|                     | Adebi, 2016 [32]              | Tanzania | Jan-Aug, 2013     | Interviewed                  | Livestock owners               | 280                  | -            | Livestock      | Random     |
|                     | Hegazy, 2016 [33]             | Egypt   | Feb-Jul, 2014     | Interviewed                  | Pastoralists                   | 96                   | -            | sheep and goat | Census     |
|                     | Zhang, 2016 [34]              | Tanzania | -                 | Interviewed                  | Human and animal health workers | 62                   | 23–81        | camel          | Census     |
|                     | Elderly, 2017 [35]            | Kenya   | -                 | Interviewed                  | Livestock owners               | 10                   | -            | Livestock, buffalo, sheep, goat | p |
|                     | Madari, 2017 [36]             | Sudan   | -                 | Interviewed                  | Abattoir workers, patients     | 830                  | -            |                       | Purposive, snowball |
|                     | Marin, 2017 [37]              | Sudan   | Dec, 2016-Jan, 2017 | Interviewed                  | Abattoir workers and animal health workers | 77 | 29–9 (15–58) | 3.1 | 53.2 | - |
|                     | Nabirye, 2017 [38]            | Uganda  | May, 2016-Feb, 2017 | Interviewed                  | Pastoralists                   | 231                  | 10–94        | Cattle         | Convenience |
|                     | Awate, 2017 [39]              | Kenya   | Dec, 2015-May, 2016 | Interviewed                  | Cattle owners                  | 80                   | 70.0         | Cattle         | Random     |
|                     | Wehane, 2017 [40]             | Ethiopia | Oct, 2016–Apr, 2017 | Interviewed                  | Pastoralists and human health personnel | 126 | - | 26–80 | Cattle Random |
|                     | Njukah, 2018 [41]             | Kenya   | -                 | Interviewed                  | High-risk population           | 154                  | -            | Cattle, camel, sheep, goat | Purposive, snowball |

(Continued)
| Geographical region | First author, Publication year | Country | Investigation time | Questionnaire administration | Characteristics of participants | Sample size | Age (yrs, mean, range) | Female (%) | Malaria level (%) | Main animal | Sampling method |
|---------------------|-------------------------------|---------|-------------------|-----------------------------|--------------------------------|-------------|-----------------------|------------|-----------------|-------------|----------------|
| Asia               | Chen, 2011 [65]               | China   | Jan-Oct, 2013     | Interviewed                 | High-risk population            | 237         | 15–60                | 28.3       | –               | Cattle, sheep and goat | Random         |
|                    | Rivera, 2013 [66]             | India   | 2010–2013         | Self-administered           | Human health workers            | 717         | 18–60                | 46.6       | –               | Cattle, sheep and goat | Random         |
|                    | Adhikari, 2014 [67]           | Nepal   | 2014–2016         | Interviewed                 | High-risk population            | 400         | 19–80                | 35.0       | –               | Cattle, sheep and goat | Random         |
|                    | Chaudhary, 2015 [68]          | Nepal   | 2015–2016         | Self-administered           | Human health workers            | 1076        | 19–50                | 33.2       | –               | Cattle, sheep and goat | Random         |
|                    | Chandra, 2016 [69]            | Nepal   | 2016–2017         | Interviewed                 | High-risk population            | 160         | 19–80                | 40.5       | –               | Cattle, sheep and goat | Random         |
|                    | Mohapatra, 2017 [70]          | India   | 2017–2018         | Self-administered           | Human health workers            | 1000        | 19–80                | 38.0       | –               | Cattle, sheep and goat | Random         |
|                    | Mahapatra, 2018 [71]          | India   | 2018–2019         | Interviewed                 | High-risk population            | 150         | 19–80                | 38.0       | –               | Cattle, sheep and goat | Random         |
| Europe             | Sierra, 2010 [72]             | Portugal| Apr, 2012         | Interviewed                 | Livestock farmers              | 154         | –                    | 14.3       | –               | Cattle          | Random         |
|                    | Chaves, 2011 [73]             | Portugal| Nov-Dec, 2011     | Interviewed                 | High-risk population            | 154         | –                    | 14.3       | –               | Cattle          | Random         |
|                    | Vazquez, 2012 [74]            | Portugal| Apr–Jul, 2012     | Interviewed                 | High-risk population            | 154         | –                    | 14.3       | –               | Cattle          | Random         |

(Continued)
33 and 30 studies, respectively, with respective pooled awareness levels of 37.6% and 35.9%, as shown in Table 2.

### Awareness of the symptoms of brucellosis in humans and animals

An awareness of the clinical signs and symptoms of human brucellosis and animal brucellosis were reported in 23 and 16 studies, respectively, and the pooled awareness levels were 41.6% and 28.4%, respectively. In addition, we explored the distribution of brucellosis symptoms that were mentioned in the included studies. Fever, fatigue, joint pain, sweating and urogenital disease were the most commonly mentioned and studied symptoms in humans, but the pooled

| Studied items                               | Number of studies | Level (95%CI) | I²(%) | P-value | Begger’s test (P-value) |
|---------------------------------------------|-------------------|---------------|-------|---------|------------------------|
| Heard of (aware of) brucellosis              | 52                | 55.5 (45.4, 65.4) | 99.4% | <0.0001 | 0.85                   |
| Zoonotic nature of brucellosis              | 33                | 37.6 (25.7, 50.4) | 99.4% | <0.0001 | 0.76                   |
| Mode of transmission                        | 30                | 35.9 (25.3, 47.3) | 99.0% | <0.0001 | 0.97                   |
| Clinical signs of human brucellosis         | 23                | 41.6 (33.0, 50.4) | 98.8% | <0.0001 | 0.25                   |
| Fever                                       | 17                | 34.4 (19.5, 51.1) | 98.9% | <0.0001 | 0.43                   |
| Fatigue                                     | 10                | 30.7 (12.6, 52.6) | 99.1% | <0.0001 | 0.33                   |
| Joint pain                                   | 17                | 32.1 (21.2, 44.1) | 98.2% | <0.0001 | 0.41                   |
| Sweating                                     | 11                | 21.8 (12.5, 32.9) | 97.0% | <0.0001 | 0.94                   |
| Urogenital diseases                          | 6                 | 9.3 (1.9, 21.5)   | 96.5% | <0.0001 | 0.85                   |
| Symptoms of animal brucellosis              | 16                | 28.4 (21.9, 35.5) | 97.4% | <0.0001 | 0.69                   |
| Abortion                                     | 16                | 37.2 (23.7, 51.8) | 98.5% | <0.0001 | 0.75                   |
| Reduction in milk production                | 5                 | 18.5 (4.0, 40.2)  | 97.8% | <0.0001 | 1                     |
| Animal source for brucellosis infection     |                   |                |       |         |                        |
| Sheep and goat                              | 9                 | 54.1 (47.3, 60.8) | 92.1% | <0.0001 | 0.53                   |
| Cattle                                      | 9                 | 29.1 (17.4, 42.5) | 97.6% | <0.0001 | 1                     |
| Pig                                         | 8                 | 17.5 (10.3, 26.2) | 95.6% | <0.0001 | 0.22                   |
| Dog                                         | 7                 | 12.8 (7.0, 20.0)  | 94.8% | <0.0001 | 0.88                   |
| High-risk practices for infection           |                   |                |       |         |                        |
| Consumption of raw milk                     | 21                | 44.5 (30.0, 59.4) | 99.2% | <0.0001 | 0.67                   |
| Consumption of raw meat                     | 19                | 34.6 (23.2, 47.1) | 98.9% | <0.0001 | 0.28                   |
| Direct contact with aborted fetuses and abortion material | 14          | 54.9 (37.0, 72.1) | 99.4% | <0.0001 | 0.78                   |
| Vaccination as a preventive measure of brucellosis | 15          | 26.1 (12.1, 43.3) | 99.4% | <0.0001 | 0.07                   |
| Information sources of awareness of brucellosis |                 |                |       |         |                        |
| Neighbor relative or friends                | 9                 | 58.7 (31.9, 82.9) | 99.3% | <0.0001 | 1                     |
| TV and radio                                | 9                 | 23.1 (8.4, 42.4)  | 98.2% | <0.0001 | 0.40                   |
| Local health workers                        | 7                 | 17.8 (9.7, 27.6)  | 93.4% | <0.0001 | 0.76                   |
| Lecture                                     | 5                 | 7.9 (3.6, 13.6)   | 87.0% | <0.0001 | 0.33                   |
Awareness level was lower than 35.0%. Abortion was the most commonly mentioned symptom of animal brucellosis, with a pooled awareness level of 37.2%, followed by a reduction in milk production (18.5%), as shown in Table 2.

**Awareness of zoonotic infection and high-risk practices for human infection**

Nine included studies explored the awareness of infected animals as the source of human infection, with a pooled awareness level of 54.1%; respondents listed sheep and goats as an animal source, followed by cattle, pigs and dogs as an infection source. The pooled awareness levels of raw milk consumption and the consumption of infected meat as risk factors for brucellosis were 44.5% and 34.6%, respectively. The pooled knowledge level of direct contact with aborted fetuses and abortion materials as high-risk practice was 54.9% (Table 2).

**Awareness regarding the vaccination and brucellosis information sources**

Fifteen studies explored the awareness regarding the vaccination of animals against brucellosis, and the pooled awareness was only 26.1% (Table 2). Nine studies analyzed the information sources of those respondents who had heard of brucellosis. People mainly acquired knowledge of brucellosis from the following four sources: neighbors/friends, mass media (TV/radio), health workers and health education-related lectures. Overall, 58.7% of respondents acquired the information about brucellosis through their neighbors or friends, which was notably higher than those that acquired information through TV/radio, health workers and lectures (Table 2).

**Subgroup analyses by occupation, animal species and geographic region**

Regarding the awareness of brucellosis, no obvious differences were found between the occupation-related population and students and residents. Subgroup analysis by occupation showed that animal health workers had the greatest awareness of brucellosis (100.0%). Pastoralists had higher awareness of brucellosis (72.0%) than livestock owners/farmers (57.0%), abattoir workers (24.3%), dairy farmers (29.5%) and livestock (product) traders (30.3%). We also found that people who were involved in bovine, ovine and caprine production (72.5%) and ovine and caprine production (74.3%) had higher awareness levels than those people who were involved in only bovine production (35.6%), as shown in Tables 3 and 4.

Regarding the zoonotic nature of brucellosis, people involved mainly in bovine, ovine and caprine production had an awareness level of 54.7% and people involved in ovine and caprine had an awareness level of 62.2%, while people involved in only bovine production had an awareness level of 21.2%. The pooled awareness level of the zoonotic nature of brucellosis in the African population (17.8%) was notably lower than that in the Asian population (44.0%). The results indicated that there was no clear difference in the brucellosis awareness levels between Asia (56.5%) and Africa (53.4%) (Table 3). Livestock owners (farmers) showed relatively higher awareness of the zoonotic nature of brucellosis than dairy farmers (15.4%) and abattoir workers (2.6%) (Table 4).

Regarding the mode of transmission from infected animal to human, a low awareness level (37.4%) was found in the occupationally exposed population, whereas a relatively higher awareness level was found in human health care providers (80.9%) and animal health workers (75.9%). Abattoir workers and dairy farmers had extremely low awareness levels (Tables 3 and 4).

Regarding awareness of the symptoms of human brucellosis, higher awareness levels were found in human health care providers (75.8%), animal health workers (50.5%) and pastoralists...
Table 3. Subgroup analysis of awareness and knowledge of brucellosis.

| Items                        | Subgroups                      | Population       | Number of studies | Level (95%CI) | I²  | P-Value |
|------------------------------|--------------------------------|------------------|-------------------|---------------|-----|---------|
| Heard of brucellosis         | Population                     | Occupational population | 48               | 55.2 (44.4, 65.8) | 99.4% | <0.0001 |
|                              | Resident                        | 1                | 78.8             | -             | -   |         |
|                              | Student                         | 2                | 45.5 (35.2, 55.9) | 95.9% | 0.02 |         |
|                              | Animal                          | Bovine           | 20               | 35.6 (19.2, 54.0) | 99.5% | <0.0001 |
|                              |                                | Bovine, caprine and ovine | 15          | 72.5 (52.3, 88.8) | 99.6% | <0.0001 |
|                              |                                | Caprine and ovine | 9                | 74.3 (58.7, 87.2) | 98.8% | <0.0001 |
|                              | Dog                             | 1                | 88.0             | -             | -   |         |
|                              | Camel                           | 1                | 7.7              | -             | -   |         |
|                              | Region                          | Africa           | 20               | 53.4 (36.3, 70.2) | 99.2% | <0.0001 |
|                              |                                | Asia             | 30               | 56.5 (43.0, 69.5) | 99.5% | <0.0001 |
| Zoonotic disease             | Population                     | Occupational population | 32               | 39.4 (27.5, 52.0) | 99.3% | <0.0001 |
|                              | Resident                        | 1                | 0.7 (0.1, 1.9)   | -             | -   |         |
|                              | Animal                          | Bovine           | 10               | 21.2 (6.2, 42.0) | 99.2% | <0.0001 |
|                              |                                | Bovine, caprine and ovine | 8            | 54.7 (35.3, 73.4) | 99.7% | <0.0001 |
|                              |                                | Caprine and ovine | 9                | 62.2 (53.5, 70.5) | 93.2% | <0.0001 |
|                              | Dog                             | 1                | 58.7             | -             | -   |         |
|                              | Region                          | Africa           | 9                | 17.8 (2.7, 42.1) | 99.2% | <0.0001 |
|                              |                                | Asia             | 22               | 44.0 (30.8, 57.6) | 99.3% | <0.0001 |
|                              |                                | Europe           | 1                | 74.7           | -   |         |
|                              | South America                   | 1                | 58.7             | -             | -   |         |
| Mode of transmission         | Population                     | Occupational population | 17               | 37.4 (27.0, 48.5) | 99.0% | <0.0001 |
|                              | Resident                        | 1                | 13.3             | -             | -   |         |
|                              | Animal                          | Bovine           | 4                | 26.4 (16.8, 37.4) | 95.8% | <0.0001 |
|                              |                                | Bovine, caprine and ovine | 8            | 43.2 (23.4, 64.2) | 99.3% | <0.0001 |
|                              |                                | Caprine and ovine | 5                | 28.3 (12.2, 47.9) | 99.2% | <0.0001 |
|                              | Region                          | Africa           | 6                | 45.1 (30.2, 60.4) | 96.5% | <0.0001 |
|                              |                                | Asia             | 11               | 32.0 (18.2, 47.7) | 99.5% | <0.0001 |
|                              | South America                   | 1                | 58.7             | -             | -   |         |
| Symptoms of human            | Population                     | Occupational Population | 22               | 41.6 (32.7, 50.8) | 98.9% | <0.0001 |
|                              | Student                         | 1                | 40.0             | -             | -   |         |
|                              | Animal                          | Bovine           | 4                | 14.8 (2.8, 33.8) | 98.7% | <0.0001 |
|                              |                                | Bovine, Caprine and ovine | 10          | 46.6 (35.2, 58.2) | 98.4% | <0.0001 |
|                              |                                | Caprine and ovine | 6                | 46.2 (33.8, 58.8) | 96.4% | <0.0001 |
|                              | Region                          | Africa           | 2                | 18.7 (0.0, 58.7) | 99.0% | -       |
|                              |                                | Asia             | 20               | 45.1 (36.1, 54.1) | 98.7% | <0.0001 |
|                              | South America                   | 1                | 23.4             | -             | -   |         |
| Symptoms of animals          | Population                     | Occupational Population | 15               | 29.4 (22.6, 36.8) | 97.5% | <0.0001 |
|                              | student                         | 1                | 15.1             | 15.0% | - |
|                              | Animal                          | Bovine           | 5                | 28.9 (22.6, 35.6) | 90.5% | <0.0001 |
|                              |                                | Bovine, Caprine and ovine | 6            | 31.3 (21.1, 42.4) | 97.3% | <0.0001 |
|                              |                                | Caprine and ovine | 4                | 27.4 (13.9, 43.6) | 97.3% | <0.0001 |
|                              | Region                          | Africa           | 3                | 30.4 (19.2, 42.9) | 94.4% | <0.0001 |
|                              |                                | Asia             | 12               | 27.9 (19.5, 37.3) | 98.0% | <0.0001 |
|                              | South America                   | 1                | 29.8             | -             | -   |         |

(Continued)
(74.3%) than in abattoir workers (18.3%) and dairy farmers (3.1%). The awareness among people involved in bovine, ovine and caprine production (46.6%) and ovine and caprine production (46.2%) were notably higher than people involved in only ovine production (14.8%). Regarding regions, the awareness of human brucellosis symptoms was higher in Asia (45.1%) than in Africa (18.7%). An extremely low awareness level of animal symptoms was observed, and no obvious differences were found among geographic regions and people involved in different animal production methods. (Tables 3 and 4).

Regarding the awareness of vaccination of animals against brucellosis, the pooled awareness level in the African population (4.6%) was notably lower than that in the Asian population (46.3%) (Table 3). And the high awareness level of vaccination as a preventive measure for brucellosis was only found in dairy farmers (88.4%) (Table 4).

For the awareness level of brucellosis among the high-risk population (animal health workers, farmers, abattoir workers, traders and transporters other related populations, not including human health workers), no significant difference (P = 0.8) was observed between Asia and Africa. The results showed extremely low awareness of brucellosis in India (13.7%), Sri Lanka (11.6%), Angola (23.9%), Ethiopia (17.3%), Zimbabwe (21.0%) and Senegal (0.0%) (Table 5).

Discussion

Raising the awareness of brucellosis and brucellosis-related knowledge in occupation-related groups is an important aspect for the effective control of brucellosis [97]. Health education about the disease for high-risk groups was essential in gaining support for a control program [98,99]. Therefore, assessing the overall disease awareness level of the occupational population is a basis for the development and implementation of more efficient health education activities and brucellosis control programs that should fit the needs and perceptions of local communities [100].

This is the first systematic review and meta-analysis aimed at exploring the brucellosis awareness level worldwide. Most of the original studies that assessed the awareness and knowledge of brucellosis were conducted in Asia and Africa, and with less from Europe, America and Oceania, which is generally consistent with the geographical distribution of brucellosis. Brucellosis is endemic to Asia and Africa, and countries in central and southwestern Asia are currently seeing the greatest increase in cases [101,102].

Overall, only approximately half of the occupation-related groups knew about brucellosis, which means that awareness and knowledge of brucellosis were insufficient. The knowledge levels regarding the zoonotic nature, mode of transmission and symptoms in humans and animals of brucellosis were lower than the awareness level of brucellosis, which means that people had heard of brucellosis but did not necessarily have a clear understanding of brucellosis. This might suggest that people in Asia and Africa have superficial and inadequate knowledge about
Table 4. Subgroup analyses of awareness and knowledge among occupations.

| Items                                           | Occupations                  | Number of studies | Level (95%CI)          | $I^2$  | $P$-Value |
|------------------------------------------------|------------------------------|-------------------|------------------------|-------|-----------|
| Heard of brucellosis (aware of brucellosis)    | Abattoir worker              | 7                 | 24.3 (15.2, 34.8)      | 81.1% | <0.0001   |
|                                                | Dairy farmer                 | 8                 | 29.5 (11.4, 51.8)      | 99.0% | <0.0001   |
|                                                | Animal health worker         | 3                 | 100.0 (98.6, 100.0)    | 0%    | 1         |
|                                                | Human health worker          | 3                 | 78.6 (7.29, 100.0)     | 98.8% | <0.0001   |
|                                                | Livestock (product) trader   | 3                 | 30.3 (24.9, 36.0)      | 0.0%  | 0.4950    |
|                                                | Livestock owner (farmer)     | 14                | 57.0 (39.1, 74.0)      | 99.6% | <0.0001   |
|                                                | Pastoralist                  | 5                 | 72.0 (30.5, 98.3)      | 99.4% | 0.0010    |
|                                                | Brucellosis patient          | 3                 | 55.1 (45.4, 64.7)      | 78.9% | 0.0087    |
|                                                | Resident                     | 1                 | 78.8                   | -     | -         |
|                                                | Transporter                  | 1                 | 71.4                   | -     | -         |
|                                                | Student                      | 2                 | 45.5 (35.2, 55.9)      | 82.1% | 0.0180    |
| Zoonotic disease                               | Abattoir worker              | 3                 | 2.6 (0.0, 11.2)        | 87.2% | <0.0001   |
|                                                | Dairy farmer                 | 8                 | 15.4 (2.1, 37.8)       | 99.5% | <0.0001   |
|                                                | Livestock owner (farmer)     | 10                | 59.9 (38.2, 79.7)      | 99.1% | <0.0001   |
|                                                | Pastoralist                  | 3                 | 34.8 (17.3, 54.7)      | 93.2% | 0.0004    |
|                                                | Resident                     | 1                 | 0.7                    | -     | -         |
| Mode of transmission                           | Abattoir worker              | 3                 | 2.4 (0.0, 20.3)        | 93.3% | <0.0001   |
|                                                | Dairy farmer                 | 2                 | 7.4 (0.7, 20.5)        | 97.0% | <0.0001   |
|                                                | Animal health worker         | 2                 | 75.9 (0.4, 100.0)      | 96.2% | <0.0001   |
|                                                | Human health worker          | 2                 | 80.9 (58.2, 96.0)      | 92.2% | 0.0003    |
|                                                | Livestock (product) trader   | 1                 | 39.8                   | -     | -         |
|                                                | Livestock owner (farmer)     | 6                 | 27.2 (16.7, 39.2)      | 97.2% | <0.0001   |
|                                                | Patient                      | 2                 | 30.1 (1.0, 76.1)       | 96.1% | <0.0001   |
|                                                | Resident                     | 1                 | 13.3                   | -     | -         |
| Human brucellosis symptoms                     | Abattoir worker              | 2                 | 18.3 (3.5, 41.2)       | 79.6% | 0.0270    |
|                                                | Dairy farmer                 | 1                 | 3.1                    | -     | -         |
|                                                | Animal health worker         | 2                 | 50.5 (45.5, 55.5)      | 5.9%  | 0.3025    |
|                                                | Human health worker          | 1                 | 75.8                   | -     | -         |
|                                                | Livestock (product) trader   | 1                 | 7.8                    | -     | -         |
|                                                | Livestock owner (farmer)     | 7                 | 31.9 (19.2, 46.1)      | 98.2% | <0.0001   |
|                                                | Pastoralist                  | 2                 | 74.3 (72.2, 76.3)      | 88.8% | 0.7530    |
|                                                | Patient                      | 2                 | 48.1 (34.3, 62.1)      | 60.7% | 0.1107    |
|                                                | Student                      | 1                 | 40.0                   | -     | -         |
| Animal brucellosis symptoms                    | Patient                      | 1                 | 4.3                    | 96.4% | <0.0001   |
|                                                | Student                      | 1                 | 37.9                   | -     | -         |
|                                                | Livestock owner (farmer)     | 6                 | 26.4 (13.6, 41.5)      | 98.8% | <0.0001   |
|                                                | Pastoralist                  | 1                 | 19.4                   | -     | -         |
|                                                | Patient                      | 1                 | 53.1                   | -     | -         |
|                                                | Student                      | 1                 | 15.1                   | -     | -         |
| Vaccination as a preventive measure            | Abattoir worker              | 2                 | 9.5 (1.1, 25.1)        | 82.5% | 0.0168    |
|                                                | Dairy farmer                 | 1                 | 88.4                   | -     | -         |
|                                                | Animal health worker         | 1                 | 30.0                   | -     | -         |
|                                                | Human health worker          | 1                 | 1.9                    | -     | -         |
|                                                | Livestock owner (farmer)     | 7                 | 19.3 (1.9, 48.5)       | 99.6% | <0.0001   |
|                                                | Pastoralist                  | 2                 | 25.9 (0.0, 82.3)       | 99.2% | <0.0001   |

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brucellosis. Poor knowledge about brucellosis is an obstacle for brucellosis control and elimination [103]. The low awareness and knowledge levels elucidated in this study are therefore of great importance, particularly considering the zoonotic nature and the public health significance of brucellosis.

Due to the low awareness and knowledge of brucellosis, the health of occupationally exposed populations and public food safety need more attention. It has been reported that a lack of knowledge about the disease could potentially lead to a delay in seeking medical support and, hence, a delay in the diagnosis and treatment of the disease [104,105]. Misdiagnosis often leads to a delay in treatment and can result in long-term complications from the disease [106]. In addition, the low brucellosis awareness and knowledge level of people involved in the livestock value chain could lead to a neglect in disease prevention and incorrect practices in handling, cooking and preserving animal-based food, which poses a great threat to public food safety [97]. Knowing the high-risk behaviors associated with brucellosis infections can also promote individuals to take protective measures, such as avoiding the consumption of raw milk and uncooked meat and wearing gloves when delivering or handling abortion materials.

Many factors are thought to be related to the level of awareness and knowledge of brucellosis. Several studies in the meta-analysis have indicated that education is positively associated with awareness and knowledge levels [28, 29, 39, 62, 80, 81, 92, 93, 95, 96]. It has been shown that previous experience with brucellosis in livestock and brucellosis prevalence levels are positively correlated with awareness and knowledge levels of brucellosis [107]. A study in southwestern Ethiopia [108] suggested that the lack of awareness of zoonotic diseases in the study area might have been due to the lack of awareness-creating activities provided by public health agencies and veterinary departments in the region. In summary, a low level of awareness could

### Table 5. Brucellosis awareness of high-risk populations in countries in Asia and Africa.

| Geographic regions | Country     | Number of studies | Level (95%CI) | F² | P-Value |
|--------------------|-------------|-------------------|---------------|----|---------|
| Overall            |             | 47                | 55.3 (44.3, 66.0) | 99.4% | <0.0001     |
| Between Asia and Africa |       | 0.822             |               |     |         |
| Asia               | China       | 13                | 63.0 (45.6, 78.8) | 99.5% | <0.0001     |
|                    | India       | 5                 | 13.7 (0.4, 40.7) | 98.7% | <0.0001     |
|                    | Tajikistan  | 3                 | 53.6 (5.6, 97.2) | 97.7% | <0.0001     |
|                    | Turkey      | 2                 | 78.2 (53.5, 95.2) | 94.2% | <0.0001     |
|                    | Jordan      | 1                 | 100.0          |     |          |
|                    | Pakistan    | 1                 | 70.0           |     |          |
|                    | Palestine   | 1                 | 100.0          |     |          |
|                    | Sri Lanka   | 1                 | 11.6           |     |          |
| Africa             | Angola      | 2                 | 23.9 (3.4, 55.2) | 98.0% | <0.0001     |
|                    | Egypt       | 2                 | 77.1 (62.6, 88.8) | 77.2% | 0.0361     |
|                    | Ethiopia    | 3                 | 17.3 (8.7, 28.2) | 98.7% | <0.0001     |
|                    | Kenya       | 3                 | 72.8 (54.2, 88.0) | 92.6% | <0.0001     |
|                    | Nigeria     | 2                 | 63.2 (30.1, 100.0) | 98.7% | <0.0001     |
|                    | Susan       | 2                 | 48.8 (26.8, 71.1) | 93.4% | <0.0001     |
|                    | Tanzania    | 2                 | 95.1 (68.1, 100.0) | 82.6% | 0.0164     |
|                    | Uganda      | 2                 | 88.2 (35.1, 100.0) | 99.5% | <0.0001     |
|                    | Zimbabwe    | 1                 | 21.0           |     |          |
|                    | Senegal     | 1                 | 0.0            |     |          |

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be due to remoteness, a lack of health facilities, poor extension services, little training on the rearing and handling of animals, a lack of health education programs and low literacy rates, which have been reported as major contributors to the low level of awareness among dairy farmers [109]. Currently, cross-sectoral and disciplinary cooperation in the control of zoonoses is encouraged by the “One Health” framework [110,111]. Communication and cooperation between the animal and human health sectors, the agricultural sector, the education sectors, animal producers and other relevant occupational groups are very important to improve the awareness and control of brucellosis.

In the present study, greater brucellosis awareness and knowledge were reported in the respondents involved in both bovine and small ruminant production, and the awareness and knowledge level in the respondents involved in small ruminant production was higher than that in people involved in only bovine animal production. This might be because brucellosis seropositivity was higher in goats than in other species [112].

Health workers play an important role in health education and disease knowledge advocacy for occupational groups. In this study, the greatest awareness was reported in health care providers, including both animal and human health workers. This can be explained by their medical background and the training and experience they receive over their career, which proves the importance of education and training to improve the awareness of brucellosis in high-risk groups [113,114].

The results showed that the main brucellosis information sources were friends and neighbors. A low proportion of participants mentioned mass media (radio/TV) as a source of information about brucellosis; this fact may suggest that the role of television/radio as a mass media outlet for the dissemination of knowledge about brucellosis has not received much attention. This should be considered in the development of education programs regarding brucellosis control.

The strength of our meta-analysis was that the evaluation of recent studies on about brucellosis awareness and knowledge among high-risk populations, health workers, general residents and students worldwide offered the evidence-based guidance for the implementation of education services and brucellosis control measures. However, there were several limitations in this study. Obvious heterogeneity existed in the meta-analysis. Although a theoretical framework was designed for this study, it was difficult to ensure that a reasonable design and rigorous questionnaire and sampling methods were used in all original studies to complete the investigations.

In summary, mainly in Asia and Africa, an insufficient proportion of the populations in rural communities is aware of brucellosis and a low knowledge level of brucellosis was observed. Since the occupationally exposed population’s perception of brucellosis influences the development and implementation of disease control strategies as well as the adoption of best practices and habits during work and life, it is very important to raise the awareness level of brucellosis in occupationally exposed populations.

Supporting information

S1 Appendix. PRISMA checklist.
(DOC)

S2 Appendix. Studies search strategies in the meta-analysis.
(DOCX)

S3 Appendix. Risk of bias assessment.
(XLSX)
S4 Appendix. Pooled forest and funnel plots of meta-analysis.
(DOCX)

S5 Appendix. Data for meta-analysis.
(XLSX)

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