

Epidemiological Aspects of Brucellosis in Saudi Arabia: A Narrative Review

Ali H. AlQahtani¹, Raniah E. Zamzamy¹, Saeed Mahdi Algarni¹, Hayel Mohammed Qudsi¹, Soha Abdulgader Alghamdi¹, Emad Lafi Almohammadi²

¹Executive Department of Zoonotic, Vector-Borne and Environmental Diseases, Public Health Authority, Riyadh, Saudi Arabia

²Department of Communicable Diseases, Public Health Authority, Riyadh, Saudi Arabia

Email: drali50505@gmail.com

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Abstract

Brucellosis is a zoonotic disease of considerable public health importance due to its ability to spread from animals to humans and its impact on health and agricultural sectors. In Saudi Arabia, brucellosis poses a significant challenge, with numerous cases attributed to the consumption of raw dairy products and close contact with livestock. Method: Data in this review was gathered through an extensive literature search on PubMed and Google Scholar using the terms “Brucellosis” and “Saudi Arabia.” This search yielded more than 67 articles, and duplicate studies and irrelevant papers were excluded. Results: The presence of brucellosis in the Saudi population has been acknowledged since the 1950s; however, formal documentation was not established until 1983. The recent yearbook from the Ministry of Health was 2022, indicating the incidence rate decreased from 2018 from 18.07 until 2022 to 7.9 per 100,000 population, and Riyadh had the highest incidence rate. Seasonal trends were noted as the increase in cases occurred during spring and summer. *B. melitensis* is the most virulent and prevalent strain of *Brucella*. As for the zoological aspect, studies reported brucellosis in camel, sheep, and goats with various incidence rates according to the time and location, despite that older animals and females were reported with higher seroprevalence of brucellosis. Conclusion: Research indicated varying incidence rates of brucellosis in humans and animals across Saudi regions, with specific population segments and occupations being more susceptible. This underscores the need for continued vigilance, public health education, and veterinary control measures to reduce the risk of transmission to humans.

Keywords

Brucellosis, Saudi Arabia

1. Introduction

Brucellosis is a significant zoonotic disease known for its impact on both human health and agricultural economies worldwide, as the World Health Organization (WHO) recognizes brucellosis as a disease of considerable public health importance due to its ability to spread from animals to humans primarily affecting those in close contact with infected livestock [1] [2]. The genus *Brucella* is the bacteria that causes brucellosis, which can infect cattle, goats, sheep, and other animals, leading to considerable economic losses due to reduced productivity in affected herds [1] [2]. Human brucellosis often results from ingesting unpasteurized dairy products, direct contact with infected animals, or inhaling aerosols containing the bacteria [1] [3]. The disease presents a wide range of clinical symptoms, making it difficult to diagnose without specific laboratory tests [4]. For example, fever, sweats, malaise, anorexia, pain in muscles and joints, and fatigue, often leads to chronic conditions if not adequately treated [5]. Globally, brucellosis remains endemic in many countries, especially in the Mediterranean region, parts of Asia, Africa, Latin America, and the Middle East, including Saudi Arabia [3]. In Saudi Arabia, the disease poses a significant public health challenge particularly in education, and veterinary control measures, as most of the reported cases resulted from the consumption of raw dairy products and close contact with livestock [2] [6] [7].

The economic impact of brucellosis is profound, affecting not only the health sector due to the cost of treatment and diagnosis but also the agricultural sector through losses in animal productivity and trade restrictions [6] [8] [9]. Hence, the control of brucellosis in animals, through vaccination and other biosecurity measures, is the most efficacious approach to reducing the incidence of the disease in humans [6] [10] [11]. International and local health organizations advocate for One Health approach as comprehensive strategies to combat brucellosis, emphasizing the importance of surveillance, public awareness campaigns, and collaboration between human and animal health sectors [6] [12]. In conclusion, brucellosis remains a significant zoonotic disease with widespread health and economic implications. The collaborative efforts of health professionals, veterinarians, and policymakers are essential to address the challenges of brucellosis and achieve significant progress in its control and prevention. In the present narrative review, we aimed to review the literature about brucellosis in Saudi Arabia, the history of the disease, epidemiologic aspects, high-risk populations, hard-to-reach areas, and zoological aspects of brucellosis transmission.

2. Materials and Methods

Data presented in this review was gathered through an extensive literature search on PubMed and Google Scholar using the terms “Brucellosis” and “Saudi Arabia.” This search yielded more than 67 articles that were filtered to meet the purpose of the current work. Duplicate studies and irrelevant papers are excluded. The current

narrative review summarizes the main findings of research conducted locally.

3. Results

History of brucellosis was first identified as a zoonotic disease by Marston in Malta in 1859 brucellosis has also been known by names such as Mediterranean Fever, Malta Fever, and Bang's disease. The pathogen responsible, *Brucella melitensis*, was isolated by David Bruce in 1886. Subsequently, five distinct strains of the bacterium were identified: *B. abortus*, *B. suis*, *B. ovis*, *B. neotomae*, and *B. canis*. In a more recent discovery from 1994, *Brucella* isolated from marine mammals was found to be potentially pathogenic to humans, and informally named "*B. maris*", for Saudi Arabia, the most recorded strain of the bacterium is *Brucella melitensis* followed by *B. abortus* after confirming 30 cases over 2 years study from a sample of 209 patients [13] [14]. The presence of brucellosis in the human population of Saudi Arabia has been acknowledged since the 1950s; however, formal documentation of the disease in humans was not established until the year 1983, which resulted in an increased number of reported cases from 1985 until 1992, followed by a noticeable decrease until 2006 [15] **Figure 1**. Moreover, Seroepidemiological surveys showed that imported animals have a greater prevalence of brucellosis infection compared with domestically raised animals, which were slaughtered during the 1977 Hajj [16]. This is directly linked to the late 1970s, when the country's economic boom, the government promoted and provided financial support for the creation of numerous dairy farms/industries and extensive sheep/cattle breeding initiatives, despite limited veterinary services; this resulted in the indiscriminate importation of inadequately tested animals, thereby facilitating the entry and spread of brucellosis within the Kingdom [17].

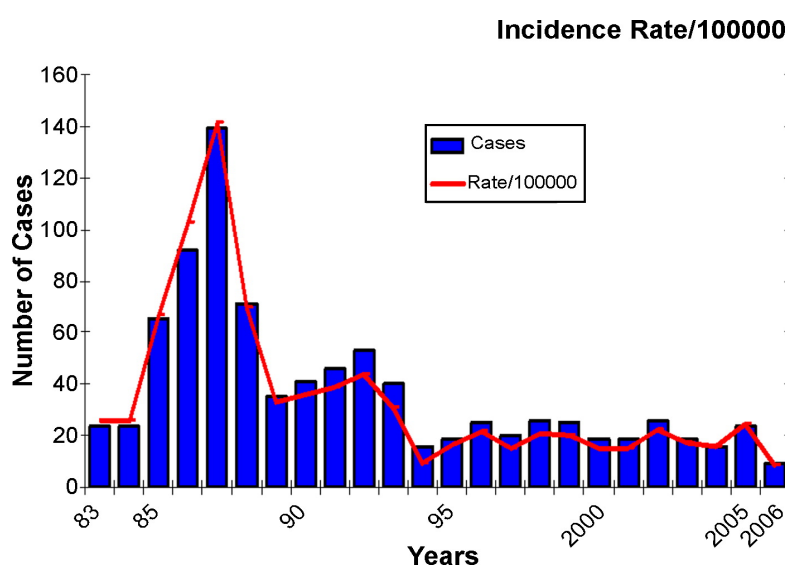


Figure 1. Incidence rate per 100,000 from 19,983 This information indicates the trend in brucellosis incidences in Saudi Arabia from Anazi, M., AlFayyad, I., AlOtaibi, R., & Abu-Shaheen, A. (2019). Epidemiology of brucellosis in Saudi Arabia. Saudi Medical Journal, 40(10), 981.

3.1. Epidemiology of Brucellosis in Saudi Arabia

A systematic review conducted by Anazi *et al.* (2019), who focused on the epidemiology, etiology, distribution, impact, and burden of brucellosis in the Saudi population, through a collaborative effort, two researchers reached a common consensus to include 51 articles for further evaluation; 17 articles met the inclusion criteria, covering studies published between 1984 and 2011. These studies spanned various geographic areas within Saudi Arabia and touched on the prevalence of brucellosis among pregnant women, children, and workers with animals. For example, Anazi *et al.* (2019) reported that the incidence rate for pregnant women during 2005-2007 was 12.2% from a study with a sample of 450 pregnant women. Male children at 12 years or less have the highest incidence rate [18]. Butchers had the highest rate 8.9% among other jobs such as abattoir workers and veterinarians [19]. Notably, a study highlighted a significant decline in brucellosis incidence from 22.9 in 2004 to 12.5 in 2012, marking a notable public health achievement [20]. **Table 1** shows the declining trend in incidence rate from 2018 until 2022 which was shared MOH [21]. Key factors in disease transmission were identified, such as the ingestion of raw milk and occupational animal contact at the forefront, signaling critical areas for intervention. The current review also underscored the heightened risk associated with the consumption of unpasteurized dairy products and illuminated demographic patterns in susceptibility to brucellosis, with certain age groups and Saudi nationals more affected. **Table 2** shows data about brucellosis distribution according to age group, with the most recent trend from 2018-2022 which highlighted the age group from 15 - <45 as the highest one, while **Table 3** indicates that Saudi male is the highest recorded group with 1176 case for the same period [21]. Seasonal variances observed, indicating higher disease rates in the spring and summer months. **Figure 2** highlights the most recent pattern in the case of reporting according to the months, as 309 cases were reported during June 2022, while 211 cases were reported in February 2022 which is the lowest record [21]. Another systematic review by Aljohani (2022) examined articles published between 1990 and 2022. 17 articles were deemed relevant after a meticulous screening process. The selected studies reveal a persistent risk of brucellosis transmission, intertwined with animal husbandry practices and specific socio-cultural behaviors that promote the disease's spread. Aljohani (2022) emphasizes the crucial need for widespread awareness campaigns aimed at the intersection of human, livestock, and wildlife health. Such initiatives are vital for producing accurate estimates of brucellosis prevalence, identifying reservoirs of the *Brucella* bacterium, and formulating control measures of proven effectiveness. Research over the decades has indicated varying prevalence rates of brucellosis across Saudi regions; **Figure 3** shows the recent cases distribution in KSA regions as Riyadh is the first region to record cases [21]; also, specific population segments and occupations are more susceptible. Moreover, the review points to a gender disparity in brucellosis cases, this is could be due to different levels of exposure to risk factors like direct animal handling and the consumption of unpasteurized dairy products [22]. *B. melitensis* is considered the most infectious and predominant

strain of *Brucella* globally, including in the Kingdom of Saudi Arabia (KSA), and is almost transmitted through contact with animals or their products [22]. According to Al Jindan (2021), conversely, *B. Abortus*, while being the most widespread, is less virulent for both animals and humans. *B. Suis* poses a significant threat to human health, whereas *B. Canis* is connected with milder infections [23]. These species are further categorized into biovars based on physiologic and biochemical differences, with *B. Abortus*, *B. Melitensis*, and *B. Suis* classified into 7, 3, and 5 biovars, respectively [24]. In Saudi Arabia's desert climate, various studies have reported the occurrence of different *Brucella* species in humans:

- Jokhdar *et al.* (2009) Found *B. melitensis* and *B. Abortus* in a blood sample analysis in their case report [25].
- In Taif, Nemenqani *et al.* (2009) recognized *B. melitensis* as the infectious agent in breast brucellosis [26].
- In 2013, Kamal *et al.* studied a sample of 101 patients in Tabuk and Jeddah, all diagnosed with an acute febrile illness (AFI) of indeterminate origin, the results for most of them were positive for both *B. Abortus* and *B. melitensis* [15].
- According to Al Shaalan *et al.* (2014) most Saudi children are infected with *Brucella melitensis* followed by *Brucella Abortus* [27].
- In the central region particularly in Dawadmi Governatec *B. melitensis* pathogen is the most prevalent as Alrheam *et al.* (2015) noted [28].
- One case of prenatal transmission of *B. Abortus* and *B. melitensis* was reported in Saudi Arabia, the pathogens were detected in both mother and infant blood samples as reported by Alnemri *et al.* (2017) [29].

Table 1. Reported cases and incidence rates of brucellosis in the last five years.

2018G		2019G		2020G		2021G		2022G	
Cases	Incidence rate per 100,000 population	Cases	Incidence rate per 100,000 population	Cases	Incidence rate per 100,000 population	Cases	Incidence rate per 100,000 population	Cases	Incidence rate per 100,000 population
5455	18.07	4257	14.16	2372	7.52	2400	7.80	2543	7.9

Source: Statistical Yearbook. Ministry of Health, Kingdom of Saudi Arabia, 2022, There is notable decrease in incidence rates from 2018 until 2022 with almost 10-fold.

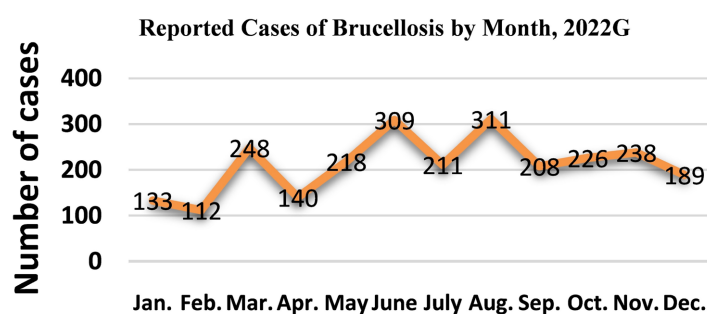


Figure 2. Statistical Yearbook. Ministry of Health, Kingdom of Saudi Arabia, 2022, Ministry of Health. The trend of case reporting during 2022 show that June has the highest reported cases with 309 cases, while February Has 112 cases which is the lowest record.

Table 2. Reported cases of brucellosis by age group, 2022G.

Age group (years)					
<1	1 - <5	5 - <15	15 - <45	≥45	Total
0	66	233	1451	793	2543

Source: Statistical Yearbook. Ministry of Health, Kingdom of Saudi Arabia, 2022, Ministry of Health. The highest age group reported with brucellosis was 15 - <45.

Table 3. Reported cases of brucellosis by nationality, sex & incidence rate, 2022G.

Saudi			Non-Saudi			Total
M	F	T	M	F	T	
1176	545	1721	761	61	822	2543

Source: Statistical Yearbook. Ministry of Health, Kingdom of Saudi Arabia, 2022, Ministry of Health. Saudi males are the most infected group with brucellosis in 2022.

Reported Cases of Brucellosis by Health Region, 2022G

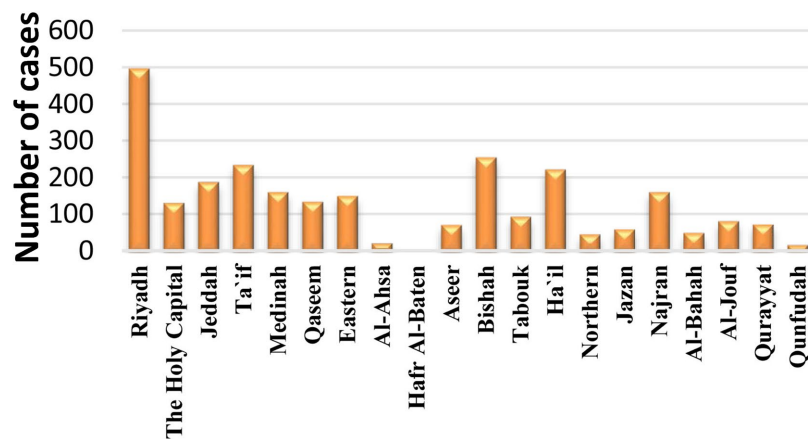


Figure 3. Reported cases of brucellosis by health region, ministry of health, Riyadh is the highest reporting region in 2022.

3.2. Studies According to the Geographical Distribution of the Kingdom of Saudi Arabia

3.2.1. Central Regions of Saudi Arabia

Al Mofleh *et al.* (1996) worked through a comprehensive national survey to establish baseline statistics for the prevalence of human brucellosis [2]. The survey involved 5507 people, representing 2 per 1000 of the population in the central region of Saudi Arabia, with 75% residing in urban settings and males constituting 51% of the surveyed group. Utilizing the microplate agglutination test (MAT), a seropositivity rate of 48.5% (2715 out of 5597) was recorded. Al Mofleh *et al.* (1996) went for further analysis using the Standard Tube Agglutination Test (STAT) and the 2-Mercaptoethanol test (2-MET) diagnosed 142 individuals (2.5%) with active brucellosis, with 80 identified by STAT and 62 by 2-MET. The analysis revealed a correlation between increasing age and brucellosis prevalence, peaking in the fifth

and sixth decades. Gender did not significantly affect the distribution of active cases, although females showed a higher seropositivity rate than males. A marked difference was noted in the prevalence of active brucellosis between Saudi nationals and non-nationals, with the former significantly more affected. Factors such as rural living, smaller living spaces, animal contact, and farming are linked to active brucellosis. The study also highlighted additional risk factors, including a history of undulant fever, consumption of raw dairy products, animal milking, and close contact with animals during birth and their afterbirth [2]. Qasim (2020) conducted a study aimed to explore the epidemiological and clinical characteristics, laboratory findings, treatment approaches, complications, and outcomes of brucellosis in children. Using a retrospective design, the study reviewed the medical records of 153 pediatric patients treated at King Abdullah Specialist Children's Hospital in Riyadh from January 2015 to January 2019 [3]. For Qasim (2020) findings indicated a predominance of male patients (69.6%, $n = 107$), with an average age of 7.75 ± 3.28 years. The main route of transmission was identified as the consumption of unpasteurized camel dairy products. Constitutional and musculoskeletal complaints emerged as the most common initial symptoms. Amongst the patients, 3.9% ($n = 6$) presented with complicated brucellosis, including neurobrucellosis in three cases. Roughly 15% of the children required hospitalization. Nearly all patients (99.35%, $n = 152$) exhibited an SAT titer of $\geq 1:160$. Blood cultures were positive in 34% ($n = 52$) of the 111 tested individuals. The most commonly administered treatment involved a combination of rifampicin and co-trimoxazole, prescribed to 52.9% ($n = 81$) of the cases. A minority of patients (4.6%, $n = 7$) experienced relapse, while a significant majority (95.4%, $n = 146$) achieved complete remission [3].

3.2.2. Eastern Regions of Saudi Arabia

In 2009, Al-Tawfiq & AbuKhamsin Started a study delved into the epidemiologic characteristics of human brucellosis over 24 years in the health-care system of Saudi Aramco, located in Eastern Saudi Arabia, analyzing cases from 1983 to 2007; throughout this period, 913 patients diagnosed with brucellosis, comprising 608 males and 305 females, establishing a male to female ratio of 2:1. Al-Tawfiq & AbuKhamsin (2009) significantly observed fluctuation in the annual incidence rate per 100,000 population, which peaked at 70 in 1987 from an initial rate of 13 in 1983, before decreasing to 9 by 2006. Patient ages ranged widely from 1 to 83 years, averaging at 35.8 ± 17.9 years, with a median age of 36 years; the data revealed that the majority of cases occurred in individuals between 20 to 40 years, with those aged 20 - 30 and 31 - 40 years comprising 21% and 17% of the cases, respectively. Children aged 10 years or younger accounted for 5% of the patient group [30]. The adjusted incidence rate per 100,000 population highlighted that individuals aged 40 - 49 years experienced the highest infection rate (100/100,000), whereas those under 10 years had the lowest rate (2.9/100,000). Disease's occurrence changed according to the seasons, with the highest number of cases

(39.5%, n = 361) reported during April to June, and the fewest in January. Among 219 patients with family-owned animals, camels were the most common (57.1%), followed by sheep (22.4%), goats (11%), and cows (9.6%). Blood culture tests were positive in 80.7% (201/247) of cases, indicating a high prevalence of bacteremia among the patients [30]. No significant correlation was found between age groups and the rate of positive blood cultures ($P = 0.244$). Serology titers varied, with 1:320 observed in 34.3% of patients, 1:640 in 31%, 1:1280 in 24.7%, and $\geq 1:2560$ in 10%, showcasing a significant association between higher *Brucella* titers and increased rates of positive cultures ($P = 0.0002$). This comprehensive analysis offers valuable insights into the epidemiologic trends and characteristics of human brucellosis in Eastern Saudi Arabia over two decades [30].

3.2.3. Northern Regions of Saudi Arabia

Al-Sekait (2000) studies the prevalence of brucellosis in the Al-Medina region of Saudi Arabia utilizing a cross-sectional survey method. In 1997, the study involved random multistage cluster sampling of 500 households, encompassing 4000 individuals. Al-Sekait (2000) method to analyze blood samples was through the Tube Agglutination Test (TAT) and 2-mercapto-ethanol (2ME) to detect brucellosis; the findings indicated a 2.6% prevalence rate of brucellosis among the population. Notably, the prevalence increased with age and was more significant in rural communities and among individuals of low socio-economic status [6]. The study identified eight key factors that predispose individuals to brucellosis: consumption of raw milk and milk products, livestock ownership, milking of animals, direct contact with animals, butchering of raw meat, handling animals at birth, and contact with the placental membrane; moreover, the prevalence of brucellosis in livestock, determined through the examination of blood samples from a random selection of animals, estimated at 17.4% [6]. This study underscores the significant health challenge posed by brucellosis in this region, highlighting the need for targeted public health interventions and education to mitigate the risks associated with these predisposing factors [6]. In a study conducted at the Northern Area Armed Forces Hospital in Hafr Al-Batin, Kingdom of Saudi Arabia, a thorough analysis of the clinical features, laboratory findings, treatments, and complications of brucellosis patients conducted by Fallatah *et al.* (2005), used a retrospective review spanned from January 1995 to December 2001. The age distribution showed that 20.8% of patients were 12 years old or younger, 60.3% were between 13 and 40 years, 16.4% were between 41 and 60 years, and 2.5% were over 60 years old [31]. Common symptoms included fever in 79.2% of cases, joint pain in 70.4%, and bone pain in 48.4%. Less common symptoms were abdominal pain, vomiting, anorexia, splenomegaly, hepatomegaly, and lymphadenopathy [31]. The *Brucella* tube agglutination titers ranged from 1:160 to 1:5120. Anemia and lymphocytosis were noted in 35.8% and 9.8% of patients, respectively, and bacteremia was identified in 6.2% [31]. According to Fallatah *et al.* (2005), relapses were recorded in 11.3% of cases, and complications included pneumonia, epididymal-orchitis, abortion, and threatened abortion, each contributing to the complexity of

brucellosis management in this population. This study underscores the endemic nature of brucellosis in Northern Saudi Arabia, mirroring the clinical presentation, laboratory features, and response to therapy observed in other regions of the Kingdom [31].

3.3. Southern Regions of Saudi Arabia

Alkahtani *et al.* (2020), conducted a comprehensive cross-sectional seroepidemiological study at Aseer Central Hospital in southern Saudi Arabia, spanning from 2014 to 2018, a total of 7567 patients suspected of having febrile illnesses were evaluated for brucellosis; the assessment involved the analysis of serum samples for *Brucella* antibodies utilizing the slide agglutination test; the findings indicated a 12.8% prevalence of brucellosis among the suspected cases, with a confidence interval (CI) of 95% ranging between 10.4% to 15.7%. The year 2015 saw the highest prevalence rate according to Alkahtani *et al.* (2020), which then showed a decreasing trend over the subsequent three years, reaching the lowest levels ($p < 0.05$). The study also revealed a significant gender disparity in brucellosis rates, with males exhibiting a higher prevalence than females ($p < 0.05$). Seasonal variations were apparent, as most cases were recorded during summer ($p < 0.05$). Demographic age analysis showed the highest prevalence among individuals aged 21 - 40 (40.5%), followed by those aged 41 - 60 (27.7%). Conversely, the lowest prevalence rates were observed among the elderly and young children, at 15% and 3% respectively. Interestingly, cross-transmission of brucellosis within families was documented in 1% of cases, and high antibody titers (>1280) were identified in 22% of hospitalized patients. The main symptoms reported by affected individuals included fatigue, hyperhidrosis, fever, and joint pain, highlighting the clinical impact of brucellosis among the patient population in southern Saudi Arabia [32]. In a retrospective study conducted at King Abdullah Hospital in Bisha, Southern Saudi Arabia, from January 2015 to December 2019, researchers explored the incidence and clinical presentations of human brucellosis among patients; this investigation, encompassing 6,586 patients, identified a brucellosis infection rate of 15.8% ($n = 1041$), with affected individuals ranging in age from five to 95 years and an average age of 35.1 ± 21.2 years [33]. Most of the infected patients were male (72.3%), and young adults aged 26 - 44 were the most affected age group (34.1%). Ibrahim & Al-Shahrani, (2021) observed a significant decline in the annual infection rate from 33.2% in 2015 to 12.5% in 2019 ($p < 0.0001$). Seasonal trends were recognized, with an increase in brucellosis cases during spring, reaching a peak in the summer; the most common clinical symptoms associated with brucellosis were fever (35.3%), joint pain (25.5%), generalized body ache (10.7%), and neurological symptoms (10.0%) [18]. Among children, joint pain was particularly prevalent (44.4%), while adult patients more frequently exhibited neurological symptoms; the findings suggest that brucellosis remains endemic in Southern Saudi Arabia, emphasizing the need for local health authorities to implement preventative and educational programs [33].

3.4. High-Risk Populations

In a study aimed at assessing the prevalence of brucellosis among abattoir workers in Saudi Arabia, Abdulaziz Al-Sekait (1993) conducted research involving a randomized multi-stage sampling of 1200 workers in such facilities. According to Abdulaziz Al-Sekait (1993), brucellosis can be diagnosed through both blood culture and the standard tube agglutination test. The findings revealed an overall brucellosis prevalence of 4.0% among the abattoir workers, and the rate of infection varied significantly across different job roles, with butchers showing the highest prevalence at 8.9%, followed by veterinarians and veterinary assistants at 5.4%, and administrative personnel at 1.1% [19]. In a study focused on children, AlShaa-lan *et al.* (2002) explored the signs, symptoms, and risk factors associated with brucellosis. The findings indicated that consuming unpasteurized camel milk was the primary mode of transmission among the participants [18]. Arthritis emerged as the most common presentation, affecting 70% of the cases, followed by 20% of the children exhibiting non-specific febrile illness without any localizing signs, and 10% showing febrile illness with rare presentations [18]. Additionally, 45% of the cases were associated with bacteremia, and a significant majority (96%) of the infections were due to *B. melitensis* [18] in a prospective study conducted from August 2005 to December 2007, involving 450 pregnant women, it was reported that the incidence of brucellosis among the participants was 12.2% [34]. Within this group, the rate of abortion was observed in 27.27% of the cases. Moreover, intrauterine fetal deaths occurred in 12.72% of the cases, and preterm labor was reported in 10.90% of the instances. A comparative analysis among women with positive and negative brucellosis titers revealed statistically significant differences in the rates of abortion and intrauterine fetal deaths, the differences in preterm labor rates were not found to be statistically significant [34].

3.5. Zoological Aspects of Brucellosis Transmission

In a comprehensive epidemiologic study aimed at assessing the seroprevalence of brucellosis among domestic animals in the Al-Qassim region of Saudi Arabia, Al-muzaini, (2023) conducted research using a cross-sectional study design. The study encompassed 690 farm animals, including 274 camels, 227 sheep, and 189 goats, representing a variety of ages and both sexes. Diagnostic serological methods such as the Rose Bengal test (RBT), complement fixation test (CFT), and enzyme-linked immunosorbent assay (ELISA) were employed to detect brucellosis in these animals; the RBT results indicated that out of 65 sera found positive for brucellosis, camels had a 5.47% positivity rate, sheep had a 14.09% rate, and goats had a 9.50% rate. Subsequent confirmatory tests using c-ELISA and CFT on RBT-positive samples showed that 60 serum samples were confirmed positive with c-ELISA, including 5.10% camels, 13.21% sheep, and 8.46% goats. Correspondingly, CFT confirmed 59 serum samples as positive, with 5.11% of camels, 12.77% of sheep, and 8.46% of goats affected [11]. The study revealed that sheep exhibited the highest seroprevalence of brucellosis. In contrast, camels showed the least

seroprevalence among the three tested animal species (camels, sheep, and goats) using RBT, c-ELISA, and CFT. It was observed that female animals and older animals had a higher seroprevalence of brucellosis compared to male and younger animals, respectively [11]. This research highlights the significant presence of brucellosis in the livestock population of the Al-Qassim region and underscores the importance of continuous surveillance and preventative measures to control the spread of this zoonotic disease [11]. Another study done by Babiker *et al.*, 2022 aimed to ascertain the prevalence of *Brucella* infection in Saudi camel herds and evaluate measures for its control [35]. Babiker *et al.*, 2022 categorized the herds into two groups, Group 1 (H1) and Group 2 (H2), along with a combined group of seronegative animals from H1 and H2 (Hc) [35]. Serum and milk samples were collected from these groups and subjected to analyses. The results indicated a *Brucella* seroprevalence of 18% and 60% in H1, 3.6% and 4.6% in H2, and 62% and 29.7% in Hc in the first and second tests, respectively [35]. *Brucella melitensis* was the only species detected through rtPCR in milk samples but not in vaginal discharge samples; specifically, in H1, the prevalence of *Brucella melitensis* in milk was 67% in the first test and reduced to 3% in the second test, [35]. EL-RAHIM & AH (2014) conducted a study in 2012 in the western region of Saudi Arabia, encompassing Makkah and Al-Madinah, reported a 9.3% incidence of brucellosis in small ruminants; they found that the incidence rates were significantly different between the two cities, with Makkah reporting a higher incidence of 14.2% (70/492) compared to Al-Madinah's 1.8% (6/326). When EL-RAHIM & AH (2014) examined the incidence by animal species, sheep had a notably higher incidence rate of 15.6% (59/377) compared to goats at 3.9% (17/441). All animal sera that tested positive for *Brucella* antibodies using the Rose Bengal Test (RBT) also yielded positive results in the indirect enzyme-linked immunosorbent assay (ELISA). In terms of human brucellosis, the incidence in Makkah was found to be 2.7% (3/113), as determined by the agglutination test; and the seropositive human cases were likely infected through close contact with living or slaughtered infected sheep and goats, aligning with their occupational exposure. The findings of this study underline the significant risk *Brucella* infection poses to both animal and human health in Saudi Arabia [20]. The research advocates for the strict implementation of the existing vaccination program for ruminants, emphasizing the importance of numbering and recording vaccinated animals [20].

4. Limitations

For the current review, several limitations were encountered, including the lack of research for brucellosis in Saudi Arabia for both human and animal sectors, as well as some regions have not been covered in research yet, and others get excessive focus, thus may be led to bias in results and understating of epidemiological picture of the disease. There are ample limitations in research on environmental and agricultural factors related to brucellosis in Saudi Arabia, which may reflect weak application of one health concept. Some critical populations were not covered in

this review due to limited studies, such as moving lamb breeders, or unregistered breeders; there is a lack of behavioral research related to the prevalence of brucellosis in Saudi Arabian society.

5. Recommendations

As a result of this review, we recommend increasing investment in innovative and diverse methods for One Health research and intervention to control and prevent brucellosis, building an integrated database with an interaction platform to support decision-making and a better understanding of epidemiologic distribution for the disease, and setting national integration plan for brucellosis prevention address all difficulties and obstacles in monitoring and follow up, and increase collaboration with stakeholders and gatekeepers to design and reform intervention to include subgroups or unregistered groups.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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