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Estimating the Economic Burden and Cost-benefit of Human Brucellosis Management under a One Health Framework in Occupationally Exposed Populations of Gujarat, India

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ABSTRACT

The investigation was conducted during May–June, 2023 in 27 villages of Anand District, Gujarat, India to study the direct, indirect, and intangible costs associated with human brucellosis and evaluate the cost-benefit of a free treatment intervention implemented under a One Health framework. A retrospective, cross-sectional cost-of-illness study was conducted involving 50 individuals diagnosed with brucellosis. Participants were selected from four occupational categories: farmers, veterinarians, artificial insemination (AI) workers, and village resource persons (VRPs). Data were collected through structured interviews and categorized into direct costs (e.g., consultation, diagnostics, medicines, transportation), indirect costs (e.g., productivity losses), and intangible costs (e.g., mental stress, isolation), with all estimates reported in Indian Rupees (INR). Cost-benefit ratios (CBRs) were calculated using both average and median cost scenarios. Direct costs totalled to ₹ 319,598, with farmers incurring the highest burden. Indirect costs, largely due to productivity losses, amounted to ₹ 357,844, accounting for over half of the total disease burden. Mental distress was reported by 56% of respondents, highest among farmers (85.71%). Misdiagnosis was universal (100%) among those who sought initial treatment. The average CBR for the free treatment program was 2.9, indicating significant economic benefit. Median-based CBRs revealed the highest benefit for farmers (4.3) and VRPs (2.0), with lower returns for AI workers and veterinarians (1.1 each). Brucellosis imposes a substantial and uneven burden on rural occupational groups and this One Health model demonstrated strong cost-effectiveness and equity benefits. Broader implementation, along with early diagnosis and awareness efforts, is essential for effective disease control and livelihood protection.

KEYWORDS: Brucellosis, cost-benefit analysis, economic burden, occupational health

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1. INTRODUCTION

Brucellosis is a significant zoonotic disease that affects both livestock and humans, with substantial public health and economic implications (Singh et al., 2015). Caused by bacteria of the genus *Brucella*, the disease primarily impacts food-producing animals such as cattle, sheep, goats, and pigs. Transmission to humans occurs through direct contact with infected animals or their secretions, consumption of unpasteurized dairy products, or inhalation of aerosols containing the pathogen (Corbel, 1997; Fiori et al., 2000; Gruner et al., 1994; John et al., 2010). Despite global control efforts, brucellosis remains endemic in many low- and middle-income countries (LMICs), where veterinary public health systems are often under-resourced and awareness is limited. Although brucellosis has been eradicated or well-controlled in many developed nations, it continues to be a neglected zoonosis in much of the developing world, including India. In the Indian context, the disease is widely prevalent in livestock populations (Renukardhya et al., 2002; Dhand et al., 2005; Shome et al., 2025; Gonuguntla et al., 2023), resulting in reproductive losses, reduced productivity, and chronic infections that cause significant economic damage to the dairy and meat industries (Singh et al., 2015). The zoonotic nature of the disease makes it an occupational hazard, especially among individuals engaged in livestock handling, veterinary services, animal husbandry, and meat processing. Multiple seroprevalence studies in India have reported high rates of infection among veterinarians, animal attendants, dairy farmers, abattoir workers, and shepherds (Bedi et al., 2007; Deepthy et al., 2013; Priyadarshini et al., 2013). In humans, brucellosis manifests primarily as undulant fever, joint and muscle pain, night sweats, fatigue, and headaches (Dean et al., 2012). In many cases, symptoms persist for weeks to months and can evolve into chronic conditions such as spondylitis, chronic fatigue syndrome, or neuropsychiatric complications like depression and anxiety (Castano and Solera, 2009). The vague and non-specific symptomatology often leads to clinical misdiagnosis, with brucellosis commonly mistaken for other conditions such as tuberculosis, malaria, or viral fevers (Pappas et al., 2005). This diagnostic ambiguity contributes to delayed treatment, prolonged suffering, and increased personal and societal burden. The National Dairy Development Board implemented a One Health approach to manage brucellosis in both humans and animals, in partnership with Shree Krishna Hospital Karamsad, a medical institution. This initiative was aimed at raising awareness among dairy farmers and the medical community regarding brucellosis and its effects on human health. The project encompassed several elements, including awareness campaigns, calf-hood vaccinations, disinfection and disposal of contaminated materials, screening of dairy stakeholders, as well as counselling and treatment for infected individuals. The objective of this project was to unify efforts in animal and human health for more efficient disease management. As part of this programme, individuals who were occupationally exposed and whose animals tested positive for brucellosis were screened, and those who tested positive were given free counselling and medical treatment by Shree Krishna Hospital, Karamsad, in accordance with the recommendations of the World Health Organization (WHO). The purpose of this paper was to evaluate the economic impact of this intervention through a cost-benefit analysis. The primary objective of this analysis was to identify, categorize, and quantify both the monetary and non-monetary costs borne by individuals due to human brucellosis. This data emphasized the need for awareness creation, early diagnosis and treatment, and supporting policy advocacy for brucellosis control using a One Health strategy.

2. MATERIALS AND METHODS

2.1. Study area

The study was carried out in 27 villages of Anand District, Gujarat, India, where NDDB has implemented a brucellosis control programme with special emphasis on the "One Health" approach. The villages have been identified based on the brucellosis-affected patients and subsequently treated at Shree Krishna Hospital, Karamsad, Gujarat, India.

2.2. Study design

A cross-sectional, retrospective cost-of-illness study was conducted to assess the direct, indirect, and intangible costs associated with human brucellosis among occupationally exposed individuals. The objective was to estimate the economic burden of the disease before diagnosis and free treatment provided under a One Health intervention project and to conduct a cost-benefit analysis of the public health response.

2.3. Study population and sampling

The study included 50 individuals diagnosed with brucellosis and treated under the project. This included participants from 27 different villages of Gujarat. Participants were selected based on occupational exposure and laboratory-confirmed diagnosis. The study cohort included individuals from four primary occupational categories: Farmers (14 Nos), Veterinarians (18 Nos), Artificial Insemination (AI) Workers (12 Nos) and Village Resource Persons (VRPs) (6 Nos). The demographic profile of the study participants is given in Table 1. All participants had received treatment following diagnosis and consented to participate in the survey. Individuals with incomplete medical or occupational histories and who did not consent to the study were excluded.

2.4. Data collection

A structured, pre-tested questionnaire was shared with all participants through face-to-face interviews. Interviews were conducted by trained personnel to ensure consistency and minimize recall bias. Respondents were asked to provide information about: awareness of brucellosis, medical history and duration of illness, number and type of healthcare providers consulted, Expenditure on diagnostics, treatment, transport, and alternative medicine, Workdays lost, changes in occupational duties and income losses, mental distress and perceived disease burden (used to estimate intangible costs). Respondents who had not incurred actual medical expenses were asked to estimate expected out-of-pocket costs in the absence of free treatment.

2.5. Cost categorization

The purpose of this study is to gain an insight into the economic burden due to brucellosis, and therefore, the cost calculation was simplified. The total economic burden is the costs that an individual is likely to incur after contracting human brucellosis. This includes three major cost components: Direct cost, indirect cost and intangible cost.

2.5.1. Direct costs

This includes the out-of-pocket expenses such as doctor consultation fees, diagnostic tests, medications, costs of alternative/traditional treatment, transport to health facilities, etc. For the calculation of direct costs, the actual amount in INR paid by the respondents was considered.

2.5.2. Indirect costs

These include costs that the patient was likely to incur as a result of loss in productivity and burden on household income due to Human Brucellosis. This includes loss of income due to work absenteeism, reduced work hours, reduction in livelihood options, change in work responsibilities, any possible health loans taken, etc. For the calculation of indirect cost, the human capital method was adopted, which views individuals as investments, not just as labour. The productivity/production potential value is based on the wages they earn and any associated benefits. Therefore, in order to arrive at the monetary value of indirect costs, a simplified approach was taken: Lost Productivity=Lost Wages. For salaried respondents, wage loss was calculated based on their annual salary, whereas for farmers, it was based on the local labour wage of that village.

2.5.3. *Intangible costs*

These are those costs that cannot be directly measured in monetary terms. Intangible costs enable the quantification of the social and psychological burden from which the patients are likely to suffer. Based on medical experts' opinions, these costs were eventually reduced to only two: Individual mental anxiety and anxiety and stress costs due to the possibility of isolation from the community. The intangible cost was assessed by assessing the Willingness-to-Pay (WTP) method. Participants were asked how much they would pay to avoid a similar illness in the future. This is used as a proxy for mental and emotional distress and quality-of-life loss.

All costs were reported in Indian Rupees (INR) and referred to the period before diagnosis and treatment under the project.

2.6. Data analysis

All data were analyzed using Microsoft Excel. Ethical considerations, including informed consent and data confidentiality, were strictly observed throughout the study. Descriptive statistics were used to calculate total and average costs per individual within each occupational category. Percentages were computed to determine the proportionate contribution of direct, indirect, and intangible costs to the total burden. A Cost-Benefit Ratio (CBR) was computed as: CBR=Total Cost incurred / Cost of Treatment Provided. The CBR was calculated separately for each occupational group and for the overall sample. A CBR greater than 1.0 was considered to indicate economic benefit.

3. RESULTS AND DISCUSSION

A total of 50 individuals occupationally exposed to livestock and diagnosed with human brucellosis were enrolled in this study. All participants received free treatment under a One Health initiative and were retrospectively surveyed to document the economic burden incurred before diagnosis. The cohort consisted of farmers (28%), veterinarians (36%), artificial insemination (AI) workers (24%), and village resource persons (VRPs; 12%) (Table 1).Demographic profiling revealed that the majority of respondents (62%) were aged between 30 and 45 years and that most (86%) had no prior significant health conditions (Table 1). Comparable findings have been reported by Hai-bo et al. (2024) in China, where the majority of brucellosis patients belonged to middle and lower socioeconomic strata (85.97%), and most were farmers or herders (82.77%). Similarly, Vered et al. (2015) in Israel observed that the mean (±SD) age of brucellosis patients was 26.6±17.6 years, which is broadly consistent with the age distribution in the present study. These observations collectively indicate that brucellosis predominantly affects individuals in their most economically productive years, amplifying its financial impact at both household and community levels.

Analysis of the awareness questionnaire showed that while 82% of respondents had heard of brucellosis and 70% knew it was a zoonotic disease, only 18% had ever screened their animals for the infection. This discrepancy underscores the gap between awareness and preventive action, reflecting the need for improved communication and behaviour change

Table 1: Demographic summary of the respondents included in the study

	Number of respondents	% of total respondents
Profession		
Farmer	14	28.00%
AI worker	12	24.00%
VRP	6	12.00%
Vet	18	36.00%
Age		
18-30 years	10	20.00%
31-45 years	31	62.00%
46-60 years	8	16.00%
>61 years	1	2.00%
Gender		
Male	48	96.00%
Female	2	4.00%
Prior health conditions		
None	43	86.00%
Had prior health condition	7	14.00%
Annual household income		
<3,00,000 per annum	15	30.00%
3,00,001-10,00,000	12	24.00%
10,00,001-15,00,000	8	16.00%
>15,00,000	15	30.00%
Highest education level		
10^{th}	9	18.00%
12^{th}	12	24.00%
Graduation	23	46.00%
Diploma	3	6.00%
Masters	3	6.00%

strategies within these communities. In contrast, Ghugey et al. (2024) reported that only 4.5% of the rural population in Nagpur, Maharashtra, had ever heard of brucellosis, indicating that awareness levels in the present cohort were considerably higher, possibly due to their occupational exposure and engagement with livestock health services. Similarly, Liu et al. (2013) in Mongolia found that 58% of respondents possessed basic knowledge about brucellosis, while only 41% were aware of its prevention and control measures. These cross-country and regional comparisons suggest that awareness of brucellosis varies widely depending on occupational exposure, education, and the extent of local veterinary extension activities.

Clinically, fatigue (68%) and joint pain (62%) were the most frequently reported symptoms, followed by excessive sweating (40%), recurrent fever, headache, and malaise (36% each). Other symptoms included chills (24%) and weight loss (22%), with only isolated cases of nausea, rash, and neurological symptoms (Table 2). These findings are consistent with known clinical presentations of human

Table 2: Awareness of Brucellosis and summary of clinical symptoms recorded

	No. of respondents	%
General information		
Heard about Brucellosis disease before infection	41	82%
Had knowledge about transfer to humans from animals	35	70%
Got their animals tested for Brucellosis	9	18%
Animals infected	6	12%
Disease detection		
General		
Recurring fever	18	36%
Excessive sweating	20	40%
Chills	12	24%
Fatigue	34	68%
Headache	18	36%
Malaise	18	36%
Weight loss	11	22%
Nausea/vomiting	1	2%
Abdominal symptoms		
Stomach pain/discomfort	6	12%
Liver issue	0	0%
Musculoskeletal symptoms		
Joint pain	31	62%
Inflammation of the joints	2	4%
Muscle pain	18	36%
Back pain	26	52%
Inflammation of the spinal joints	0	0%
Inflammation of the sacroiliac joints	0	0%
Specific organ involvement		
Inflammation of the heart	0	0%
Skin-related changes/rashes	4	8%
Respiratory and neurological signs		
Respiratory symptoms	1	2%
Neurological symptoms	1	2%

brucellosis (Anonymous, 2006). However, none of these symptoms are characteristics of brucellosis, and these nonspecific symptoms often mimic common febrile illnesses such as influenza, tuberculosis, or malaria (Anonymous, 2006; Dean et al., 2012), resulting in misdiagnosis. In this study, 42% of respondents sought medical treatment for their symptoms; however, all were misdiagnosed. Diagnoses included general fever, seasonal illness, fatigue, vitamin deficiency, and other nonspecific conditions. Only one veterinarian was considered a possible case of an occupational zoonotic infection, though not explicitly brucellosis. These findings underscore the diagnostic ambiguity associated with brucellosis and reinforce earlier assertions that the disease lacks distinguishing features, making misdiagnosis common even among trained clinicians (Pappas et al., 2005). Can et al. (2014) similarly reported from Turkey that only 35% of brucellosis patients were correctly diagnosed during their first medical consultation, emphasizing the global challenge of early recognition. In Tanzania, Crump et al. (2013) found that malaria was frequently overdiagnosed among febrile patients, whereas human brucellosis-though relatively common-was often overlooked. Together, these studies reinforce the notion that the nonspecific clinical presentation of brucellosis contributes significantly to underdiagnosis and delayed treatment, thereby exacerbating the disease's health and economic burden.

The cost analysis revealed considerable variation across occupational groups and cost types. Direct costs included medical expenses (doctor visits, diagnostics, medicines), alternative treatments (e.g., Ayurveda), transportation, and lost wages due to doctor visits. On average, medicines accounted for 59.2% of the medical costs, followed by diagnostics (20.8%) and doctor consultations (19.96%). The total direct medical cost across all groups was ₹ 319,598, which only covered symptomatic relief and not curative intervention (Table 3). Comparable findings have been reported elsewhere. In a case-control study conducted in Israel, Vered et al. (2015) estimated healthcare utilization costs for human brucellosis and found that hospitalization costs were the most significant contributors to the overall economic burden. The authors reported that the total direct expenses for brucellosis patients were approximately 7.9 times higher than those of non-infected controls, largely due to prolonged hospitalization, intensive diagnostics, and medication costs. Similarly, a study undertaken in Gansu Province, China, by Lie et al. (2018) estimated the economic burden among 226 patients, reporting direct medical expenses, direct non-medical expenses, indirect economic losses, and total costs as 28,568, 5,090, 7,223, and 40,584 RMB Yuan, respectively. These studies collectively demonstrate that brucellosis imposes a substantial financial strain on affected individuals and health systems, particularly through diagnostic delays and the protracted course of treatment required for recovery.

Farmers incurred the highest direct costs (₹ 171,917), followed by veterinarians (₹ 135,300), AI workers (₹ 69,560), and VRPs (₹ 50,498). Transportation emerged as a key expense, especially for AI workers (₹ 12,950), reflecting their greater travel requirements and limited public transport in rural areas. By contrast, veterinarians reported the lowest transport costs (₹ 2,100), possibly due to institutional support, including access to official vehicles. Similar patterns have been reported in other endemic regions. For instance, Hai-bo et al. (2024) in China observed that individuals from lower socioeconomic groups, particularly farmers, incurred higher travel-related expenses, as they often had to journey from underdeveloped rural areas to urban centers for medical treatment. These findings collectively suggest that geographic and occupational disparities substantially influence the financial burden of brucellosis, with rural and field-level workers facing disproportionately higher out-of-pocket expenses.

All patients were treated at Shree Krishna Hospital, Karamsad, following WHO-recommended protocols, with doxycycline-based regimens as the standard. Treatment costs for an uncomplicated brucellosis case-including diagnostics such as ELISA-were estimated to be ₹ 11,000 per person (Anonymous, 2006; Alavi and Alavi, 2013), indicating that the intervention significantly reduced out-of-pocket costs. A study in China, highlight that brucellosis patients are predominantly from the middle and lower socioeconomic status, with high out-of-pocket expenses placing them under significant financial pressure (Hai-Bo et al., 2024).

Indirect costs, primarily productivity losses, constituted the largest proportion of the total disease burden, ranging from 52% to 58% depending on the group. Among farmers, indirect costs totalled ₹ 346,882 (58% of their total burden), driven mainly by reduced working hours (₹ 182,182) and occupational changes (₹ 103,000). Similar patterns were observed in other groups, with VRPs and veterinarians also experiencing high losses due to missed duties and shifts in work roles. Cumulatively, loss from reduced productivity alone amounted to ₹ 357,844, averaging ₹ 7,157 per respondent. These findings are consistent with previous research highlighting the predominance of indirect costs in the overall economic impact of human brucellosis. Singh et al. (2018) estimated the health and economic burden of human brucellosis in India and reported annual median losses of ₹ 627.5 million, primarily attributable to productivity losses and other indirect costs. The same study also calculated a loss of 177,601 Disability-Adjusted Life Years (DALYs), corresponding to 0.15 DALYs per thousand persons per year, underscoring the substantial socio-economic implications of the disease.

Table 3: Details of various costs (in INR) incurred by different dairy stakeholders

		Farmer			Artificial insemination worker			Village resource person			Veterinarians		
		TC	PP	OC	TC	PP	OC	TC	PP	OC	TC	PP	OC
1	Direct costs												
1A	Medical costs												
	Doctor visitation cost	28550	2039	5%	9440	787	5%	1500	250	1%	24300	1350	4%
	Medicine cost	62920	4494	10%	32070	2673	16%	6318	1053	3%	87900	4883	15%
	Diagnostic costs	9500	679	2%	5100	425	2%	40200	6700	21%	11800	656	2%
1A	Total medical costs	100970	7212	17%	46610	3884	23%	48018	8003	25%	124000	6889	21%
1B	Alternative Treatment	25000	1786	4%	2000	167	1%	180	30	0%	8000	444	1%
1C	Other costs												
	Misc. costs	900	64	0%	0	0	0%	0	0	0%	0	0	0%
	Doctor visits leave costs	38247	2732	6%	8000	667	4%	0	0	0%	1200	67	0%
	Transportation costs	6800	486	1%	12950	1079	6%	2300	383	1%	2100	117	0%
1C	Total other costs	45947	3282	8%	20950	1746	10%	2300	383	1%	3300	183	1%
1	Total direct costs	171917	12280	29%	69560	5797	34%	50498	8416	26%	135300	7517	23%
1D	Future treatment costs (for those who has not availed treatment)	55000	3929	9%	22000	1833	11%	33000	5500	17%	121000	6722	21%
2	Indirect costs												
2A	Productivity costs												
	Loss due to lesser work hours	182182	13013	30%	23712	1976	12%	56375	9396	29%	95575	5310	16%
	Loss due to lesser duty visits	0	0	0%	30000	2500	15%	14400	2400	7%	140208	7789	24%
	Loss due to lost livelihood	36000	2571	6%	24000	2000	12%	13500	2250	7%	0	0	0%
	Loss due to change in work	103000	7357	17%	12000	1000	6%	24250	4042	12%	21918	1218	4%
	Loss due to other work change	0	0	0%	0	0	0%	0	0	0%	44400	2467	8%
2A	Total productivity costs	321182	22942	54%	89712.3	7476	44%	108525	18088	56%	302101	16783	52%
2B	Household costs												

TC: Total costs; PP: Per person; OC: % overall cost; 1 US$= INR 82.29 and INR 82.20 (average value during month of May and June, 2023)

Mental health impacts were significant but varied. Overall, 56% of respondents experienced psychological distress. The burden was highest among farmers (85.71%), followed by AI workers (58.33%), veterinarians (38.89%), and VRPs (33.33%). While veterinarians did not report out-of-pocket mental health costs, they incurred the highest costs from stress related to potential isolation (₹ 21,600). Many reported social stigmas, community ignorance, and even concealment of diagnosis from family members, suggesting substantial hidden psychosocial costs. Interestingly, both farmers (100%) and veterinarians (83.33%) expressed willingness to pay for a community awareness programme, reflecting demand for broader educational outreach. The negative mental health consequences of brucellosis are increasingly recognized as an emerging area of research, given its significant impact on individuals' psychological well-being (Gregoire, 2002; Figueiredo et al., 2015).The average cost-benefit ratio (CBR) across all respondents was 2.9, meaning that for every ₹ 1 spent on treatment, ₹ 2.90 was saved in avoided costs. Farmers experienced the highest average CBR at 3.9, followed by VRPs (3.0), and both veterinarians and AI workers (1.6).Using median costs to account for skewed data, the overall CBR was recalculated at 1.3, still indicating a net benefit. Disaggregated by occupation, median CBRs were highest for farmers (4.3), followed by VRPs (2.0), with AI workers and veterinarians each at 1.1. A generalized formula was developed for application to various population mixes:

$$\text{Overall CBR}=4.3\times W_f+1.1\times W_{AI}+2.0\times W_{VRP}+1.1\times W_{Vet}$$

(where Wf, WAI, WVRP, and WVet represent the occupational proportions in the target population)

Cost burden analysis revealed important equity considerations. Median cost burdens were highest among farmers (₹ 46,910) and VRPs (₹ 21,497), and lowest for veterinarians (₹ 12,125) and AI workers (₹ 11,838). The interquartile range (IQR) was widest for VRPs (₹ 35,871), followed by farmers (₹ 44,612), suggesting greater cost variability and financial unpredictability among informal and semi-formal workers. Similar findings were reported by Hai-Bo et al. (2024) in China, where higher out-of-pocket expenditures were observed among patients from lower economic strata, including farmers. When normalized against annual income, the burden of brucellosis was highest for VRPs (14.33% of income), AI workers (6.23%), farmers (3.13%), and veterinarians (1.05%). These findings highlight the pronounced inequity in the economic impact of the disease, with lower-income and field-level workers bearing a disproportionately higher share of the cost. This pattern aligns with the observations of Singh et al. (2015), who reported that human brucellosis exerts a greater financial strain on economically vulnerable and occupationally exposed groups. The current analysis therefore underscores the strong equity-enhancing potential of targeted preventive interventions such as vaccination and occupational safety programmes. Comparable trends have been reported globally; for instance, a recent economic burden study conducted in China estimated the median direct cost per brucellosis episode at USD 688.65, with out-of-pocket expenses averaging USD 391.44, reflecting similar challenges faced by low-income rural populations.

4. CONCLUSION

The study demonstrated that human brucellosis imposed substantial direct, indirect, and psychosocial costs, particularly among low-income, high-risk occupational groups. These findings emphasized the need for targeted preventive measures, occupational safety interventions, and awareness programs to mitigate the burden. By quantifying economic and non-economic losses, the analysis provided evidence for early diagnosis, timely treatment, and informed policy advocacy. The study further highlighted the critical importance of adopting a One Health approach integrating human, animal, and environmental health for sustainable brucellosis control.

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