Seroprevalence of Brucellosis in Sheep and Goats With Owners' Knowledge, Attitudes and Practices in Garowe District, Nugal region, Somalia

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ABSTRACT: Brucellosis is an important neglected bacterial zoonotic disease in sub-Saharan Africa, including Somalia. A cross-sectional study was conducted in the Garowe district, Nugal region, Somalia, from May 2022 to January 2023 to estimate the seroprevalence of small ruminant brucellosis and assess owners' knowledge, attitudes, and practices toward brucellosis. A total of 384 sheep and goats were selected using a simple random sampling technique and screened for *Brucella* antibodies by the Modified Rose Bengal Plate Test, and positive samples were then further confirmed using an indirect enzyme-linked immunosorbent assay. For the questionnaire survey, 384 households were selected randomly, and a structured questionnaire was used to assess owners' knowledge, attitudes, and practices toward brucellosis. The overall brucellosis seroprevalence was 4.7% in small ruminants (95% CI: 2.8-7.3), and the true seroprevalence was calculated as 5.2%. According to the multivariable logistic regression analysis, sex was found to be a potential risk factor for small ruminant brucellosis ($P < .05$). More specifically, female sheep and goats were 9.13 times (aOR 9.13, 95% CI: 1.18-70.33) more likely to become seropositive than males. The owners' knowledge, attitudes, and practices toward brucellosis were found to be low, and education level was associated with owners' knowledge ($\chi^2 = 16.78$; $P < .001$), attitudes ($\chi^2 = 19.4$; $P < .001$) and practices ($\chi^2 = 34.0$; $P < .001$). There is also a significant association between owner knowledge, attitudes, and practices and seropositivity of brucellosis in sheep and goats. Moderate seroprevalence, together with insufficient knowledge, attitudes, and practices of owners, makes brucellosis a threat to animals and the entire community. Hence, raising community awareness of the disease is essential to reduce the impact on small ruminant productivity and the risks to public health.

KEYWORDS: Brucellosis, KAP study, seroprevalence, small ruminants, Somalia

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Introduction

Small ruminants constitute the largest population of domestic animals in Somalia, but the country fails to utilize these resources optimally because of different factors in which diseases stand first. One of many infectious diseases impeding small ruminant production is brucellosis.[1]

Small ruminant brucellosis is caused mainly by *Brucella melitensis* and *B. ovis* and, in sporadic cases, by *B. abortus*.[2] The disease has a major socioeconomic impact on the livelihood of communities that depend on animal production, especially in developing countries where disease control programs are either nonexistent or inadequate. These losses are associated with abortion, neonatal death, reduced fertility, decreased milk production, and trade restrictions for animals and their products.[3] The disease is transmitted from infected to susceptible sheep and goats through sexual contact, ingesting contaminated pastures, feedstuffs and water or licking infected placentae, foeti or the genitalia of infected female animals soon after abortion or delivery.[4] The prevalence of brucellosis in Somalia is 4% and 3.1% in sheep and 4.9% and 3.9% in goats according to RBT and I-ELISA, respectively.[5,6]

Brucellosis is a zoonotic, chronic, debilitating disease in humans, with an estimated half a million human annual cases reported globally.[7] The consumption of contaminated raw animal products and direct contact with contaminated tissues or secretions of infected animals are the main routes of infection in humans.[7] A very important approach to the control of brucellosis is the one health approach to control and prevent human and animal brucellosis.[8] Therefore, assessing owners' knowledge, attitudes and practices (KAPs) toward brucellosis and determining the associations between owners' KAPs and brucellosis seropositivity in their animals are important for establishing prevention and control strategies for both animals and humans. Hence, the aim of this study was to estimate the seroprevalence of small ruminant brucellosis and assess owners' KAPs toward brucellosis in the Garowe district, which is in Puntland, Somalia.

Materials and Methods

Study area and animal population

The study was conducted in Garowe district, Nugal region in Somalia. The district is situated between 8°24'N latitude and 48°29'E longitude (Figure 1). The agroecology of the district is arid, with altitudes ranging from 100 to 500 m above sea level. It receives average annual rainfall between 10.8 mm and 51 mm/year, and the temperature ranges from 23°C in the

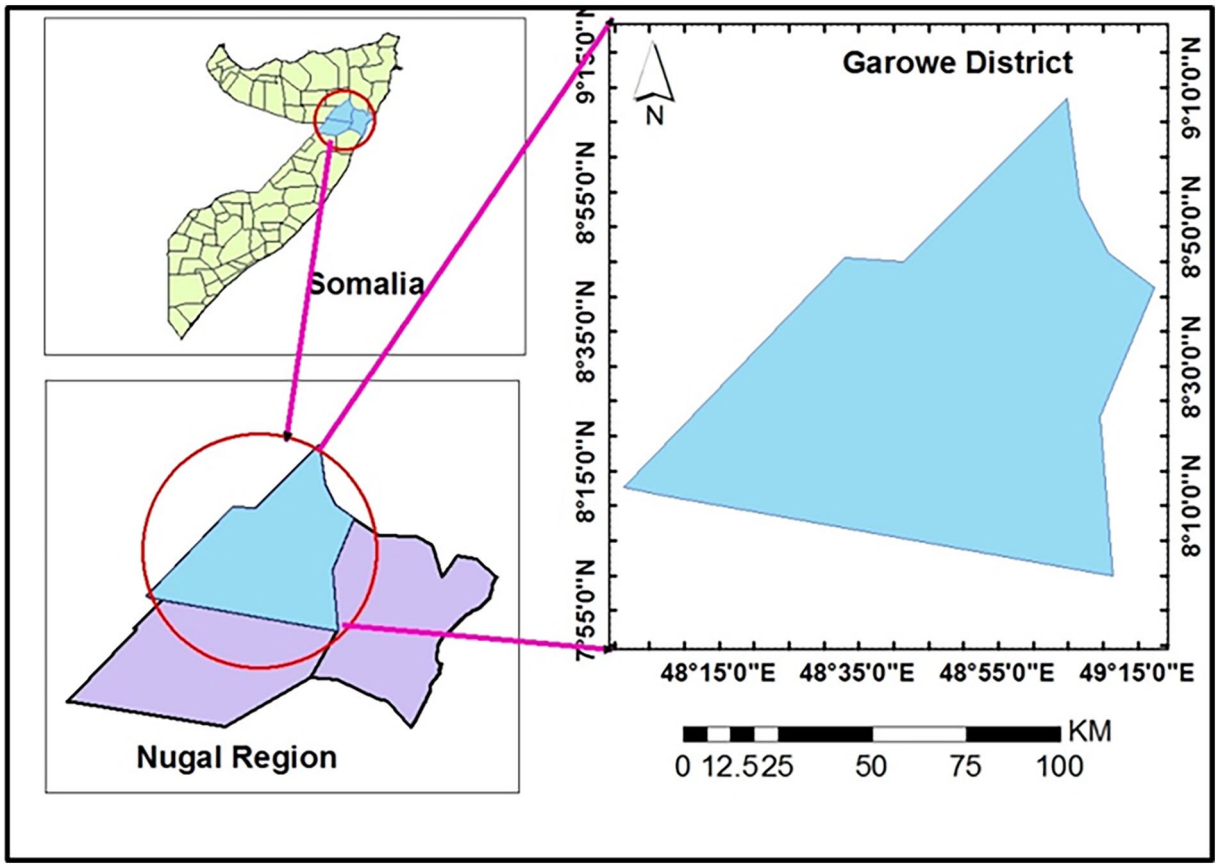

Figure 1. Study area map of the Garowe District in the Nugal region, Somalia.

winter to 41°C in the summer. Pastoral production systems are the main production systems used in the area, and livestock production, especially goat, sheep and camel production, is a major component of the livelihood of the community. The district has a total population of 3 555 266 livestock, with 1 959 593 goats, 1 217 801 sheep, and 377 872 camels. Animals are managed under an extensive management system, graze freely during the day, are kept in poorly constructed fenced barns at night, and they share common grazing and watering points. Sheep and goats found in the Garowe districts composed the source population, and all sheep and goats above 4 months of age were eligible for inclusion in this study.[9]

Study design and period

A cross-sectional study was conducted between May 2022 and January 2023 to estimate the seroprevalence and associated risk factors for sheep and goat brucellosis and to assess the knowledge, attitudes and practices of owners toward brucellosis in the Garowe district, Nugal region, Somalia.

Sample size and sampling procedures

A single population proportion formula given by Thrusfield[10] as $n = 1.96^2\, p_{exp}(1 - p_{exp}) / d^2$, where n = the total sample size, p_{exp} = expected prevalence, and d = desired absolute precision, was used to determine the minimum sample size required to estimate the seroprevalence status of brucellosis in goats and sheep in the selected area. Thus, using 5% absolute precision, a 95% confidence level, and a 50% expected seroprevalence yielded a sample size of 384 study animals. The Garowe district has 16 villages from these villages, 4 villages were selected randomly, and 384 households were selected from these 4 villages by using an online random number generator. The lists of animal owners were our study frames and were found in each village administrative office.

Questionnaire survey and data measurement techniques

To collect relevant information about owners' knowledge, attitudes, and practices toward brucellosis, a pretested structured questionnaire was administered to 384 randomly selected sheep and goats' owners after translation into a local language (**af-Soomaali)** using a face-to-face interview. The questionnaire was developed by checking the face validity (matching each item to the conceptual domain) and content validity (representativeness) by 2 senior public health and microbiology professionals, and some amendments were made on the basis of their suggestions. The construct (convergent) validity was also checked by using both the average variance extracted and the factor loading of the 3 factors, with

scores for knowledge, attitudes and practices of 0.621, 0.683, and 0.576, respectively, which was above the commonly accepted threshold of 0.50, indicating good convergent validity of the constructs. The lists of owners were obtained from each village administrative office. A pilot study of 30 individuals who were not included in the final analysis was used to test the internal consistency reliability. The results showed Cronbach's alpha scores for knowledge, attitudes, and practices of .714, .801, and .836, respectively, indicating good internal consistency and reliability. The survey comprises 8 questions pertaining to knowledge assessment, 6 questions concerning attitudes, and 7 questions about practices.

Blood sample collection and serological tests

Seven milliliters of blood were aseptically drawn from the jugular vein of each sampled animal by using needle holders, simple vacutainer tubes, and needles. The blood samples were labeled and transported to the Garowe regional laboratory by using an ice box. Each blood sample was centrifuged for 3 minutes at 10,000 rpm to extract the serum, which was then siphoned into sterile cryovials. Finally, the sera were kept in a refrigerator at −20°C until they underwent serological testing to look for anti-*Brucella* antibodies.[11]

Screening was performed using Modified Rose Bengal Plate Test (MRBPT) (concentrated suspension of *B. Melitensiss*, Weybridge strain 99; Institut Pourquier, France), and confirmatory test using Indirect Enzyme-linked immune sorbent assay (I-ELISA) (ID Vet, 310, Innovative Diagnosis, France) were performed at the Garowe regional laboratory using test protocols outlined by the World Organization for Animal Health[12] and the manufacturer's specifications for the tests. Briefly, MRBPT was performed by mixing 75 µl of serum with 25 µl of antigen suspension on a glass plate and mixing thoroughly to create a circular approximately 2 cm in diameter. The mixture was subsequently agitated by shaking for 4 minutes at ambient temperature (25°C). Samples with agglutination were recorded as positive for MRBPT, whereas samples with no agglutination were recorded as negative. Both positive and negative controls were used. The low sensitivity, particularly in long-term chronic cases, relatively low specificity in endemic areas and the possibility of biological false negative reactions are the main limitations of MRBPT.

The I-ELISA test was conducted as follows: 190 µl of dilution buffer 2 was added to all the wells, 10 µl of the negative control was added to wells A1 and B1, 10 µl of the positive control was added to wells C1 and D1, and 10 µl of sample serum was added to the remaining wells. The plate was subsequently incubated for 45 minutes at 21°C, after which each well was washed 3 times with 300 µl of the wash solution. About 100 µl of multispecies Horseradish Peroxidase conjugate was added to each well, and the plate was incubated for 30 minutes at 21°C. Each well was washed 3 times with 300 µl of the wash solution. About 100 µl of the substrate solution was added to each well, and the plate was incubated for 15 minutes in the dark. About 100 µl of stop solution (Tetra methyl Benzidine substrate) was added to each well to stop the reaction, and the optical density (OD) at 450 nm was subsequently read and recorded for each sample. If the percentage of inhibition was 110% or lower, the outcome was categorized as negative. In cases where the percentage of inhibition fell between 110% and 120%, it was regarded as uncertain or doubtful. If the percentage of inhibition was 120% or above, the result was recorded as positive. Both positive and negative control sera were used. Since the sensitivity and specificity of I-ELISA are not 100%, we calculated the true seroprevalence by considering the sensitivity and specificity of I-ELISA (sensitivity, 0.93; specificity, 0.96). The potential for cross-reactivity of the secondary antibody is the limitation of I-ELISA.

Data management and analysis

Data obtained from the laboratory results and questionnaire surveys were entered and stored in a Microsoft Excel spreadsheet. Descriptive and analytical statistics were computed using Stata version 16.0. Univariable logistic regression analysis was employed to assess the associations of small ruminant brucellosis with species, age, sex, and origin (potential predictor variables). In this model, we applied an intermethod model development approach; hence, all variables present in the univariable logistic regression analysis were also included in the multivariable logistic regression analysis, and there was no need to select independent variables since the number of available variables was limited (four). The collinearity between variables was checked by the variance inflation factor (VIF). A VIF greater than 5 indicates that there is collinearity between variables. The final multivariable logistic regression model was checked by using the Hosmer-Lemeshow test, and it was fitted for the sheep and goat datasets with χ^2 test = 3.22, Df = 7, and $P = .8639$. For all the KAPs questions, the respondent received a score of 1 if the question was answered properly and a score of 0 otherwise. The respondents were further divided into 2 groups for KAP after all the scores for correctly answered questions were added and the mean was set as the cut-off point. Individuals who scored higher than or equal to the mean were classified as possessing good knowledge, desirable attitudes, and appropriate practices, whereas those who scored lower than the mean were classified as having poor knowledge, undesirable attitudes, and inappropriate practices.[13] The chi-square (χ^2) test was used to assess the associations of owners' gender, age and education with their KAPs and owners' KAPs with the seropositivity of their animals. Throughout the data presentation, we applied the 95% confidence level $\alpha = (100 - 95) = 5\%$, which is the type 1 error (the probability of rejecting the null hypothesis when it is actually true).

Table 1. Demographic information of the respondents in the Garowe district.

VARIABLES	CATEGORIES	NUMBER	PERCENTAGE
Villages	Sinujif	93	24.2
	Awr-culus	115	30.0
	Remanti	88	22.9
	Kalabayr	88	22.9
Gender	Female	260	67.7
	Male	124	32.3
Age in years	18-30	202	52.6
	31-50	146	38.0
	51 and above	36	9.4
Education	Non educated	238	62.0
	Read and write	105	27.3
	Educated	41	10.7

Results

Demographic information of the respondents

For the assessment of the KAPs of owners toward brucellosis, a total of 384 individuals were interviewed, and most of them (67.7%) were females. The majority (52.6%) of the respondents were aged between 18 and 30 years, and most of the animal owners (62.0%) were noneducated (Table 1).

Seroprevalence of small ruminant brucellosis and associated factors

The overall seroprevalence of small ruminant brucellosis in the study area was 4.7%, and the true seroprevalence was calculated as 5.2%. Univariable logistic regression analysis revealed that sex was significantly associated with the seroprevalence of small ruminant brucellosis ($P < .05$) (Table 2).

The seropositivity of small ruminant brucellosis was independently associated with sex ($P = .034$). Accordingly, the likelihood of brucellosis seropositivity in female sheep and goats was 9.13 times (95% CI_{OR}: 1.18-70.33) greater than that in male sheep and goats (Table 3).

Knowledge, attitudes, and practices of the owners toward small ruminant brucellosis

Knowledge of the respondents toward small ruminant brucellosis. Among all of the interviewees, 23.2% had information about brucellosis, and the majority (66.3%) obtained their information from veterinarians. Even if 76.4% of the respondents knew that brucellosis affects sheep and goats, only 13.2% knew the means of transmission of the disease between animals.

From the participants, only 14.6% were aware that brucellosis is a zoonotic disease, and the majority of them (85.4%) did not know how animals may spread disease to humans (Figure 2).

The mean knowledge score was 2.5 ± 2.82, with a minimum score of 0 and a maximum score of 8. Overall, only 16.9% had good knowledge about brucellosis. The respondents' educational status was shown to be significantly associated with their knowledge ($P < .001$) (Table 4).

Respondent attitudes toward small ruminant brucellosis. Among all the participants, 14.6% believed that brucellosis is an important public health disease, and only 9.0% believed that family members are at risk of acquiring brucellosis. From all the respondents, 92.1% wanted to obtain more information about the disease. Only 3.4% and 4.5% of the participants thought that brucellosis can be avoided by cooking meat and boiling milk, respectively (Figure 3).

The mean score of participants' attitudes toward the disease was 1.05 ± 0.97. The percentage of respondents who, generally, had a positive outlook on small ruminant brucellosis was 15.7%. Educated individuals had better desirable attitudes (53.8%) toward brucellosis than noneducated individuals ($P < .001$) (Table 5).

Practices of respondents concerning small ruminant brucellosis. Goat milk and sheep milk were consumed by 71.9% of the respondents, and most of them consumed raw milk (89.1%). The majority of the participants (96.0%) assisted their sheep/goats during kidding and lambing, and most (97.7%) of them assisted without using personal protective equipment. Nearly all of the participants (97.7%) dispose the aborted/dead fetuses dropping to open dumps or giving to dogs (Figure 4).

The mean practice score of the participants was 1.02 ± 0.94. The percentage of respondents who generally had appropriate practices for small ruminant brucellosis was 3.5%. Similarly, educated individuals had better practices (17.1%) toward brucellosis than noneducated individuals ($P < .001$) (Table 6).

Association between owners' knowledge, attitudes and practices and the seroprevalence of their sheep and goats

The associations between owners' knowledge, attitudes and practices and the seropositivity of their animals were assessed by using univariable logistic analysis. There is a significant association between owners' practices and the seropositivity of their animals; hence, sheep and goat brucellosis seropositivity is significantly lower (χ^2, 37.9, $P < .001$) in owners who have appropriate practices for brucellosis than in those who have inappropriate practices. However, the knowledge and attitudes of owners are not significantly associated with sheep and goat brucellosis seropositivity (Table 7).

Table 2. Univariate logistic regression analysis of small ruminant brucellosis and associated risk factors.

VARIABLE	CATEGORIES	N	I-ELISA+ (%)	OR (95% CI)	P-VALUE
Species	Sheep	108	6.5	1	.303
	Goat	276	4.0	0.60 (0.23-1.59)	
Sex	Male	116	0.9	1	.047
	Female	268	16.3	7.79 (1.02-59.24)	
Age	Young	48	6.3	1	.586
	Adult	336	4.5	0.70 (0.20-2.52)	
Villages	Kalabayr	88	3.4	2.2 (0.69-6.97)	.180
	Sinujif	93	13.6	0.48 (0.09-2.55)	.392
	Awr-culus	115	2.2	1	
	Remanti	88	4.3	0.78 (0.18-3.34)	.734
Over all seroprevalence		384	4.7% (95% CI: 2.8-7.3)		
Calculated true seroprevalence			5.2%		

Abbreviations: I-ELISA+, positive by I-ELISA; n = number examined; OR, odds ratio; 1 = reference category.

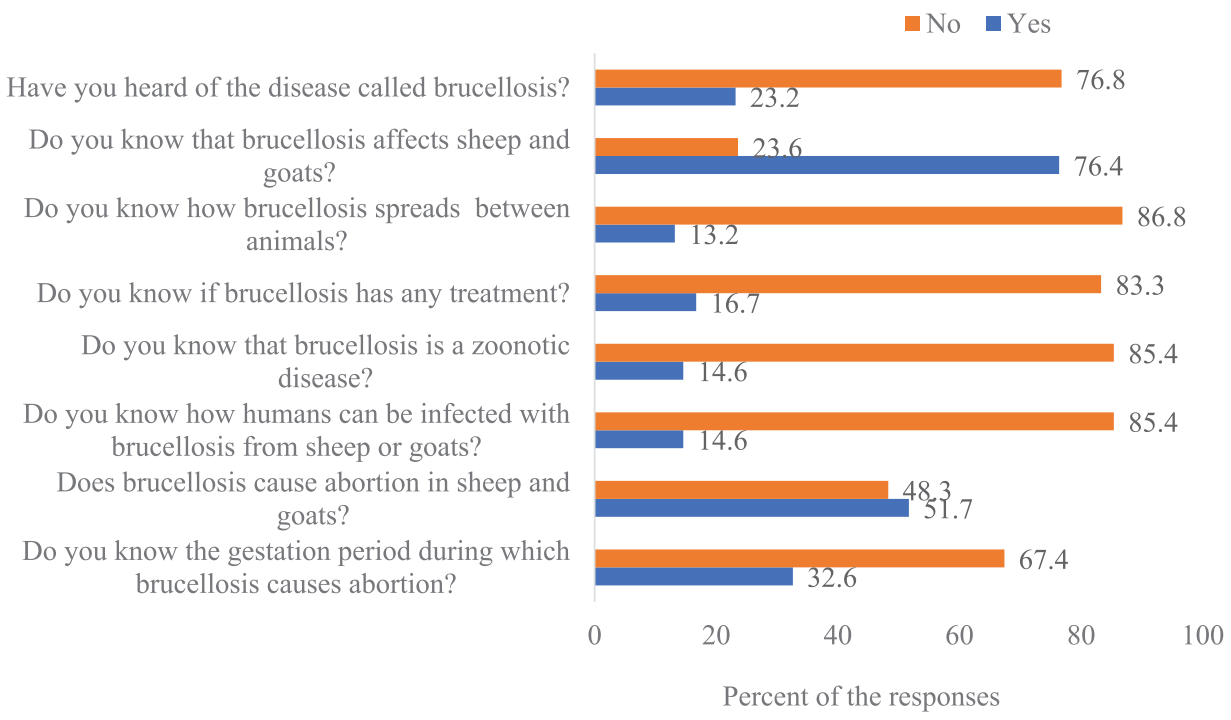

Figure 2. Respondents' knowledge regarding small ruminant brucellosis.

Discussion

Recognizing the distribution of a disease and the knowledge, attitudes and practices of the community is a basic element in implementing disease prevention and control programs.[14]

Among the 384 serum samples collected for seroprevalence investigation, 32 (8.3%) were positive for MRBPT, of which 18 (4.7%) were positive for I-ELISA. Therefore, by considering the sensitivity and specificity of the I-ELISA test, the final

Table 3. Multivariable logistic regression analysis results of small ruminant brucellosis with associated factors in the Garowe district from May 2022 to January 2023.

VARIABLE	CATEGORIES	N	I-ELISA+ (%)	AOR (95% CI)	P-VALUE
Species	Sheep	108	6.5	1	.454
	Goat	276	4.0	0.68 (0.25-1.87)	
Sex	Male	116	0.9	1	.034*
	Female	268	6.3	9.13 (1.18-70.33)	
Age	Young	48	6.3	1	.654
	Adult	336	4.5	0.74 (0.19-2.81)	
Villages	Kalabayr	88	3.4	0.91 (0.20-4.07)	.899
	Sinujif	93	13.6	0.46 (0.09-2.44)	.358
	Awr-culus	115	2.2	1	
	Remanti	88	4.3	2.48 (0.76-8.07)	.132

Abbreviations: I-ELISA+, positive by I-ELISA; n = number examined; aOR, adjusted odds ratio; 1 = reference category.
*Statistically significant.

Table 4. Knowledge level and association between knowledge and respondents' sociodemographics in the Garowe district.

VARIABLE	CATEGORIES	N	KNOWLEDGE LEVEL		χ^2	P-VALUE
			GOOD (%)	POOR (%)		
Villages	Sinujif	24	20.8	79.2	0.91	.823
	Awr-culus	32	18.8	81.2		
	Remanti	18	11.1	88.9		
	Kalabayr	15	13.3	86.7		
Gender	Female	52	17.3	82.7	0.01	.892
	Male	37	16.2	83.8		
Age	18-30	48	20.8	79.2	3.3	.190
	31-50	39	10.3	89.7		
	51 and above	2	50.0	0.0		
Education	Non educated	49	6.1	93.9	16.78	<.001*
	Read and write	27	18.5	81.5		
	Educated	13	53.8	46.2		
Over all knowledge		89	16.9	83.1		

Abbreviations: N, number of respondents; χ^2, Chi-square.
*Statistically significant.

true seroprevalence was calculated as 5.2%. Hence, the true seroprevalence of small ruminant brucellosis in the study area was 5.2%.

The current overall seroprevalence of 5.2% is in agreement with that of 4.0% in Somalia,[6] 6.4% in eastern Ethiopia,[15] and 5.82% in Karnataka in the southern province of India.[16] The similarities between these results can be explained by the fairly comparable agroecology and animal management systems. The agroecology of these 3 study areas is arid and semiarid, where there is scarcity of feed and water, and animals are managed in the extensive management system, where they share common grazing and watering points.[15-17] The types of diagnostic tests used in all of these studies are MRBT and i-ELISA, which may make the results comparable.[15-17] However, the results of

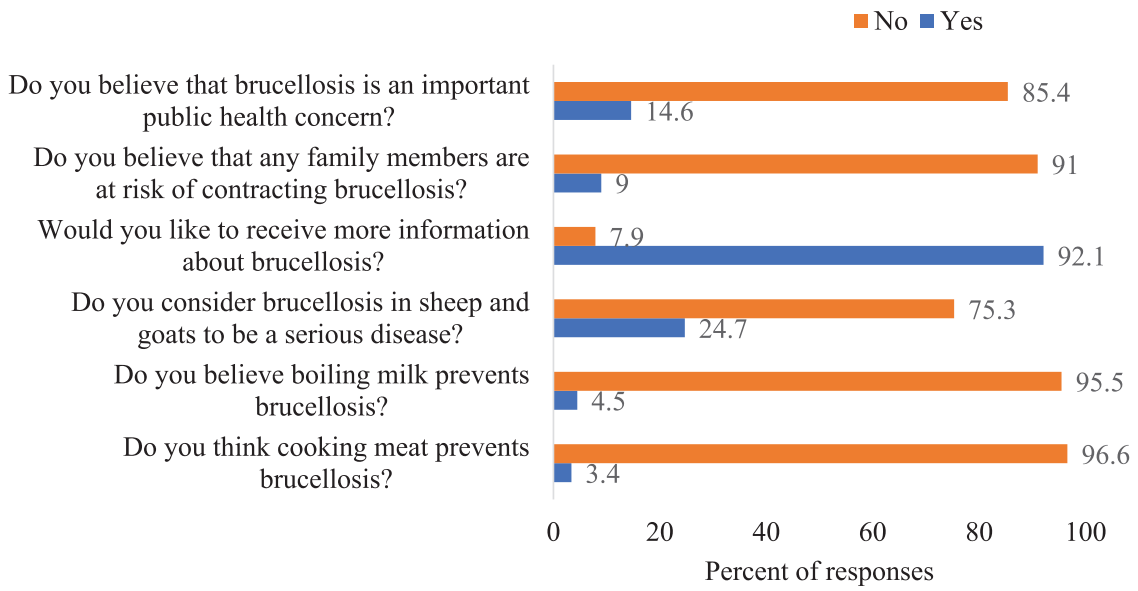

Figure 3. Respondents' attitudes toward small ruminant brucellosis.

Table 5. Attitude level and associations between attitudes and respondents' sociodemographics.

VARIABLE	CATEGORIES	N	ATTITUDE LEVEL		χ^2	P-VALUE
			DESIRABLE (%)	UNDESIRABLE (%)		
Villages	Sinujif	24	20.8	79.2	1.2	.748
	Awr-culus	32	12.5	87.5		
	Remanti	18	11.1	88.9		
	Kalabayr	15	20.0	80.0		
Gender	Female	52	17.3	82.7	0.2	.628
	Male	37	13.5	86.5		
Age	18-30	48	18.8	81.2	3.0	.225
	31-50	39	10.3	89.7		
	51 and above	2	50.0	50.0		
Education	Non educated	49	4.1	95.9	19.4	<.001*
	Read and write	27	18.5	81.5		
	Educated	13	53.8	46.2		
Over all Attitude		89	15.7	84.3		

Abbreviations: n, total number; χ^2, Chi-square.
*Statistically significant.

the current study are higher than 0.24% in West Hararghe, Ethiopia,[18] 0.40% in Kajiado County, Kenya,[19] and 1.1% in southern Cameroon.[20] The high seroprevalence of small ruminant brucellosis in our study compared with the abovementioned results might be due to environmental and animal management differences. Since the annual rainfall in our study area is low (a maximum of 123 mm/year),[17] there is a shortage of water and feed in the area because flocks move to search for feed and water, which increases the probability of direct or indirect contact between animals and may increase the risk of brucellosis transmission. In addition, there is no brucellosis vaccination program in our study area.[17] These practices of pastoralism and communal grazing, together with a lack of stable access to veterinary and public health services, can make small ruminant brucellosis endemic in the area.[21]

Compared with males, female sheep and goats were more likely to become seropositive for brucellosis ($P < .05$). This finding is in agreement with other studies conducted in

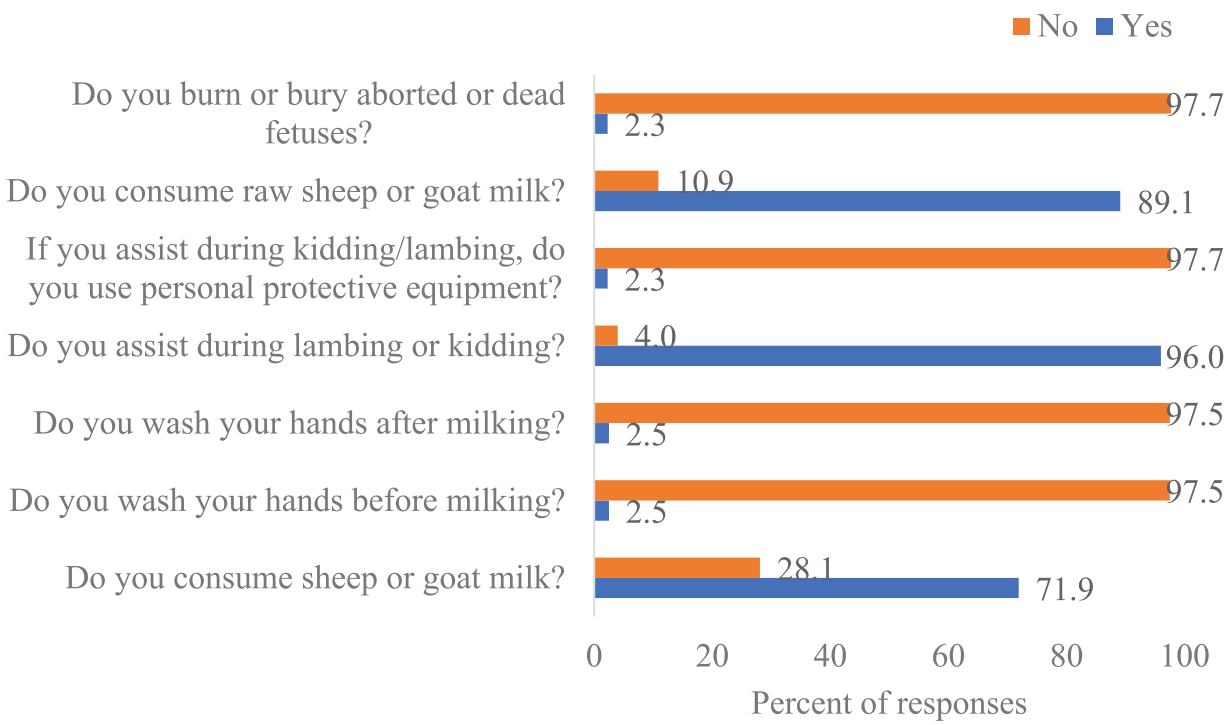

Figure 4. Respondents' practices regarding small ruminant brucellosis.

Table 6. Associations between practices and respondents' sociodemographics.

VARIABLE	CATEGORIES	N	PRACTICE LEVEL		χ^2	P-VALUE
			APPROPRIATE (%)	INAPPROPRIATE (%)		
Villages	Sinujif	93	2.2	97.8	2.9	.409
	Awr-culus	115	5.2	94.8		
	Remanti	88	3.4	96.6		
	Kalabayr	88	1.1	98.9		
Gender	Female	260	3.1	96.9	16.3	<.01*
	Male	124	3.2	96.8		
Age	18-30	202	4.0	96.0	1.0	.597
	31-50	146	2.0	98.0		
	51 and above	36	2.8	97.2		
Education	Non educated	238	0.4	99.6	34.0	<.001*
	Read and write	105	3.8	96.2		
	Educated	41	17.1	82.9		
Over all practices		384	3.1	96.9		

Abbreviations: n, total number; χ^2, Chi-square.
*Statistically significant.

different areas.[20,22,23] The high seroprevalence of brucellosis in females compared with that in males may be related to age; since most males are sold at an early age for meat purposes, young male animals are dominant than adult males. Even if animals become infected by *Brucella* at an early age, the organism localizes itself in the regional lymph nodes without provoking antibody production until the animal becomes sexually mature and produces sex hormones that stimulate the growth

Table 7. Associations between owners' knowledge, attitudes and practices and the seroprevalence in their animals.

VARIABLES	CATEGORY	NUMBER	SEROPREVALENCE IN NUMBER		χ2	P-VALUE
			POSITIVE	NEGATIVE		
Knowledge	Good	15	1	14	0.04	.85
	Poor	74	4	70		
Attitude	Desirable	14	2	12	2.4	.12
	Undesirable	75	3	72		
Practices	Appropriate	12	5	7	37.9	<.001*
	Inappropriate	372	13	359		

and multiplication of *Brucella*.[24] In addition, it may be linked with the hormone erythritol. Erythritol is a sugar alcohol present in relatively high concentrations in the placenta and fetal fluids of pregnant animals, providing a comfortable environment for the growth and multiplication of *Brucella* organisms. A higher concentration of erythritol sugar is found in females than in males, increasing the susceptibility of female animals to brucellosis.[24]

In our study, 23.2% of the interviewees had information about brucellosis. This finding is consistent with 20% in the East Wallaga Zone, Ethiopia,[25] but higher than null awareness in selected districts of the southern region.[3] However, this figure is lower than the 84% reported in Kenya[26] and 56.8% reported in Saudi Arabia.[27] The low level of knowledge of owners about brucellosis in our study compared with that in Saudi Arabia and Kenya may be related to differences in educational level and information accessibility among the study participants. For example, the majority (63.6%) of the study participants in Saudi Arabia were bachelor's degree holders and above,[27] and in Kenya, the study was conducted in Kiambu County, which neighbors Nairobi, the capital city of Kenya, which has good infrastructure with accessible medical and veterinary services.[26] Among the participants, only 14.6% were aware that brucellosis is a zoonotic disease, and the majority (85.4%) did not know how animals may spread disease to humans. This implies that there may be a shallow and insufficient level of understanding of brucellosis in these regions.

The majority (97.7%) of the participants assisted their ewes and did so during parturition without using personal protective equipment. Similar findings have been reported in the Nugaal region of Somalia[28] and the southern region of Ethiopia.[3] The reason behind this may be the poor knowledge of the animal owners about the risk of this practice and the lack of access to protective clothing such as gloves. If humans assist animals without the use of personal protective equipment and handle aborted tissue and retained placenta incorrectly, human contamination may increase, and brucellosis may spread farther.[29]

Approximately 98% of the respondents disposed of aborted fetuses by either feeding them to dogs or depositing them in open landfills. This finding is higher than the 55.5% reported in Egypt.[30] Feeding aborted fetuses to dogs may increase the transmission and persistence of infection in the flock since dogs could play a role in the mechanical transmission of the infection when they drag aborted material across the ground.[31] Additionally, discarding aborted materials into open landfills and waterways increases the chance of disease transmission to animals and humans.[32]

The majority of the respondents (89.1%) were consuming raw milk, which is greater than the 79% reported in Kenya[26] but lower than the 94.5% reported in districts in southern region[3] and the 97.6% reported in Afar region[33] of Ethiopia. The findings revealed that the consumption of raw milk, which is a known risk factor for animal-to-human brucellosis transmission, is high in the area. This could be because owners of animals believe that raw goat milk tastes better and has therapeutic benefits, such as aphrodisiac qualities.[26]

The level of owners' knowledge, attitudes and practices toward brucellosis were found to be independently associated with the education level of the respondents ($P < .001$), which is in line with findings reported in Saudi Arabia.[27] The findings demonstrated that inadequate education is a significant factor linked to poor understanding of brucellosis and that education has broader implications for health-related awareness and perceptions. This finding is consistent with existing research in health education, which demonstrates that a higher level of education tends to equip individuals with improved access to information and a greater ability to understand and retain health-related knowledge.[34,35]

The seropositivity of small ruminant brucellosis was significantly lower in owners who had appropriate (good) practices than in their counterparts. This finding is consistent with reports in Mali, Kenya, and Jordan,[35-37] but seropositivity was not associated with knowledge or attitudes. These findings indicate that knowledge and attitudes without proper practices are not sufficient to reduce the transmission of brucellosis. Therefore, improving owners' practices related to aborted fetuses and fetal membrane management, the consumption of pasteurized or boiled milk and cooked meat, the use of personal

protective equipment while assisting delivery, and the maintenance of personal and environmental hygiene are crucial for reducing brucellosis in both animals and humans.

Limitations of the study

Although parallel tests are preferable for all samples, which could help to explore the concordance of MRBPT and I-ELISA, owing to financial constraints in the purchase of I-ELISA kits for all samples, only those positive samples with MRBPT were checked using I-ELISA. Despite the fact that a pilot study involving thirty participants was conducted and efforts were made to ensure that participants understood the questions before responding, the honesty and recall ability of individuals were not independently assessed due to a lack of standardized instruments. A thorough understanding of participants' brucellosis-related knowledge, attitudes, and practices may be hampered by the use of quantitative methods that dichotomize data into binary categories. Importantly, both qualitative and quantitative methodologies should be used in future research.

Conclusions

According to the current serosurvey investigation, small ruminant brucellosis is moderately prevalent in the study area, and sex was significantly associated with brucellosis seropositivity. The knowledge, attitudes and practices of animal owners toward brucellosis were found to be low, and educational level was found to be significantly associated with this low level of owners' knowledge, attitudes and practices. The seropositivity of sheep and goats was significantly associated with owner practices; hence, poor practices were positively associated with the seropositivity of animals. Therefore, brucellosis is a public health threat in the Garowe district; however, it is important to encourage behavioral changes concerning the handling of animals and discharges during abortion and parturition, and the consumption of pasteurized/boiled milk and cooked meat is equally important. In addition, comprehensive epidemiological investigations employing one health approach are necessary to identify and characterize the circulating species of *Brucella* in humans and livestock to determine the transmission dynamics of the organism.

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CRediT Authorship Contribution Statement

Mustafe Mohamed Bile: Writing original draft, Conceptualization, Methodology Data curation, **Ambachew Motbaynor Wubaye**: Writing – review and editing, Writing – original draft, Formal analysis, Methodology, **Yihenew Getahun Ambaw**: Writing – review and editing, Formal analysis, Data curation, **Shihun Shimelis**: Writing – review and editing, Conceptualization, and Supervision. **Simegnew Adugna Kallu**: Conceptualization, Methodology, Formal analysis, Supervision.

Data Availability Statement

All the raw data generated, analyzed, and presented in this article are available from the corresponding author upon reasonable request.

Ethics Statement

This research was approved by Haramaya University, College of Veterinary Medicine Ethics Committee (Ref. No: HU/IEC/21/2017/2022). Each participant who decided to participate in this study provided written informed consent, and the information collected was kept confidential and utilized solely for this research.

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