Foot and mouth disease in selected districts of western Ethiopia: seroprevalence and associated risk factors

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Summary

A study was conducted in western Ethiopia – in two districts of Oromia state and four districts of Beneshangul Gumuz state – to determine the seroprevalence of foot and mouth disease (FMD) and the associated risk factors, using multistage random sampling. A 3ABC blocking enzyme-linked immunosorbent assay (ELISA) was used to measure antibody against the non-structural protein (NSP) of

foot and mouth disease virus (FMDV) to differentiate between vaccinated and infected animals. A total of 1,144 sera from 181 herds were collected and examined. The overall seroprevalence at animal level and herd level was 9% (95% CI 7.2–10.6) and 38.1% (95% CI 29.1–47.1), respectively. Statistically significant differences ($p<0.05$) were recorded among different species, with 13%, 5% and 3% seropositivity in cattle, sheep and goats, respectively. Statistically significant differences ($p<0.05$) in herd seroprevalence were observed among districts, with 52%, 50%, 50%, 44%, 21%, 11% in Gidami, Begi, Tongo, Bambasi, Mange and Asosa districts, respectively. In univariable and multivariable logistic regression, the variables that had a positive relationship with seroprevalence at herd level ($p<0.05$) were herd size, contact of livestock with ungulate wildlife, and contact of animals with animal/herds of a different peasant association. Univariable and multivariable logistic regression analysis indicated that at the animal level, age and species had a statistically significant association ($p<0.05$) with seropositivity. In conclusion, herd size, contact of livestock with ungulate wildlife, contact between herds from different peasant associations, and the age and species of the animals were the main risk factors for virus circulation in the study area.

Keywords

Beneshangul Gumuz – Cattle – Enzyme-linked immunosorbent assay – Ethiopia – Foot and mouth disease – Goat – Oromia – Seroprevalence – Sheep – Western Wollega.

Introduction

Ethiopia has a huge livestock population (1). Livestock contributes 30–40% to the agricultural component of the gross domestic product (GDP), 16–20% to the national GDP and 14–16% to foreign trade (2). Of the total livestock population, 4.09 million cattle die every year, of which 3.45 million die from diseases. Thus, diseases of livestock cause significant economic losses in Ethiopia (1). More than seven transboundary animal diseases that restrict Ethiopia's ability to participate in international trade are prevalent in the country (3).

Foot and mouth disease (FMD), which affects domestic and wild cloven-hoofed animals and causes significant economic losses, is one of the most contagious transboundary diseases in the world (4, 5). It is caused by foot and mouth disease virus (FMDV), which belongs to the genus *Aphthovirus* of the family *Picornaviridae*. There are seven serotypes of FMDV (A, O, C, Asia1, SAT1, SAT2 and SAT3) (SAT = South African Territories) (6, 7, 8). All but one of these serotypes (Asia1) are present in sub-Saharan Africa, and the epidemiology of the disease is further complicated by the presence of carrier animals (in particular African buffalo) and susceptible wildlife (9). Immunity produced against one serotype does not protect the host against another serotype. In some species of wildlife, mortality can be high, as was observed in South Africa in impala, *Aepyceros melampus,* and in Israel in mountain gazelles, *Gazella gazelle* (10).

The presence of FMD in Ethiopia and the risk factors for spread of the viruses have been described before (7, 11, 12). The commonly occurring FMD serotypes are serotype O, A, SAT1 and SAT2 (11, 12). According to a 2007 report from the Food and Agriculture Organization of the United Nations (5), the last outbreak of FMD caused by serotype C in East Africa was the 2005 outbreak in Kenya. Data obtained from the world reference laboratory for FMD in 2013 indicate that, from 2010 to 2013, FMD outbreaks in East Africa were caused by serotypes O, A, SAT1 and SAT2, with type O being the dominant serotype in Ethiopia (13). The prevalence of FMD in the country ranges from 5.6% to 26% in cattle (11, 12, 14, 15, 16, 17, 18), 11% in small ruminants (18) and 30% in ungulate wildlife (18). Production system, geographic location, age of animals, contact with wildlife and season of the year were the risk factors identified for spread of the disease in Ethiopia (11). In the South Omo zone of Ethiopia (a zone in the Southern Nations, Nationalities and Peoples' Region [SNNPR]), a higher seroprevalence was reported for herds that had frequent contact with wildlife compared to herds that rarely had contact with wildlife (17). A previous study conducted in the Benchimaji zone of SNNPR reported that herds with a history of transboundary movement had a prevalence of 20%, while herds with no history of cross-boundary movement had a prevalence of 6%,

which confirms that there is transboundary disease transmission from neighbouring countries (7).

Beneshangul Gumuz state and the Western Wollega zone of Oromia state lie on the border between Ethiopia and Sudan and it is possible for animals to cross in both directions. There is a wide distribution of wildlife in the area, so contact with livestock is common and frequent outbreaks are reported. These border regions of the country have the potential to become livestock production areas but, with the exception of a few reports on the disease (18), there is no information on the epidemiology of FMD or on its risk factors. Therefore, the objective of this study was to determine risk factors for the disease and its seroprevalence at animal and herd level in cattle, sheep and goats in selected districts of the Western Wollega and Kelem Wollega zones of Oromia (one from each zone) and four districts of Beneshangul Gumuz.

Materials and methods

Description of study area

The study was conducted in two regional states of Ethiopia: Oromia and Beneshangul Gumuz, which are located in the west of the country.

In Oromia, the study area included two administrative zones, namely Western Wollega and Kelem Wollega zones, which are located in the west of Oromia. The study area is located between latitude 8º12′–10º03′ N and longitude 34º08′–36º10′ E. The altitude ranges from 500 m to 2,576 m above sea level (asl). Annual temperature in the area varies from 15ºC to 25ºC. Broadleaf forest, grasslands and wetland (marshes and swamps) are the most common type of vegetation in Western Wollega and Kelem Wollega. The mean annual rainfall of the area ranges from 1,200 mm to 2,000 mm. Maize, sorghum, teff, finger millet (dagusa) and wheat are commonly produced crops, while coffee is the most highly cultivated cash crop in the area. One district was included from each zone: Begi district in Western Wollega and Gidami district in Kelem Wollega. The districts chosen were districts that were easily accessible by road, had a history

of outbreaks of FMD, were close to Beneshangul Gumuz and had mixed-species farming systems (cattle, sheep and goats). The livelihoods of a large percentage of the population in the study area depend on livestock and the production of coffee and other crops. The livestock production system of the area is extensive and of a sedentary type.

From Beneshangul Gumuz a total of four districts were selected: Asosa, Bambasi, Mange (in Asosa zone) and Tongo special district ('special districts' are overseen directly by regional governments rather than being governed by the zone in which they are located). The region has a single rainy season of variable length between May and October. The annual rainfall ranges from 1,130 mm to 1,146 mm. The non-cultivable land of the area is covered with grassland, shrubland and woodland, with extensive areas of closed (dense coverage) and open (scattered coverage) bamboo forests. Livestock are kept for draught purposes, milk production and as a token of wealth. Finger millet (dagusa), Niger seed (noug), sorghum and maize are the most common crops produced in the area. All the study sites share a border with Sudan (Fig. 1).

Study design

A cross-sectional study was carried out from November 2011 to April 2012 to determine the seroprevalence of FMD and associated risk factors. A semi-structured questionnaire was administered to herd owners for the assessments of animal- and herd-level risk factors.

Study herds and animal selection

The study population consisted of 160,555 cattle, 61,252 sheep and 82,104 goats in extensive production systems. These animals comprised around 1,815 herds in Asosa, Bambasi, Mange, Gidami, Begi and Tongo special district. For the purposes of the study, a herd was defined as any group of livestock grazing together, e.g. sheep and goats grazing together on communal land, or cattle and sheep grazing together on their owner's land. Irrespective of the grazing system, all herds in the study consisted of more than one species. Multistage

random sampling was employed to determine sample size by taking district as the 1st stage, peasant association as the 2nd stage, herd as the 3rd stage and individual animals as the 4th stage. Districts were purposively selected and the districts chosen were those that had a mixed-species farming system (cattle, sheep and goats), access to transportation, a history of outbreaks, and neighbouring areas which had also experienced outbreaks. From each district, 4 to 6 peasant associations (20% of the total number within the district) were randomly selected. From each peasant association, 5 to 8 herds (10% of the herds of each peasant association) were randomly selected. From each herd, 3 to 12 animals (10%) were randomly selected (19). Accordingly, 30 peasant associations, 181 herds and 1,144 animals were included in the study (Table I).

Study variables

Animal-level variables

There were three animal-level variables: species (cattle, goat and sheep), age (young, adult and old) and the sex of the animal (see Table II).

Herd-level variables

Herd size was categorised into three groups (<40 animals, 40–75 animals and >75 animals) (Table III). Herds were further categorised on the basis of whether or not they had contact with one or more ungulate wildlife (buffalo, kudu, warthog and wild pigs) and whether or not they had contact with animals/herds of different peasant associations at grazing areas/watering points. Herds were also divided into those that were found in peasant associations in areas close to livestock markets and those that were reared in peasant associations in areas in which there were no livestock markets. Herds that graze on communal land and have frequent contact with herds of different household-owners were considered as ‘herds grazing on communal land’, while herds that graze on household-owned land without mixing with the livestock of other households were considered as ‘separately grazing herds’. Based on Geographic Positioning System (GPS)

technology, altitude was recorded and categorised as <1,500 m asl or ≥1,500 m asl.

Outcome variables

The outcome variables were categorised based on the results of a 3ABC blocking enzyme-linked immunosorbent assay (ELISA). Sera with a percent colour inhibition greater than 50%, based on the PrioCHECK® FMDV 3ABC blocking ELISA (Prionics, Switzerland), were considered as seropositive to FMDV. A herd was considered as positive if one or more animals in the herd was seropositive. The 3ABC ELISA has an advantage over the conventional serological diagnosis of FMD as it has the ability to identify vaccinated animals from infected animals based on the detection of the non-structural protein (NSP) that is secreted during infection but not during vaccination (20).

Data and serum sample collection

Questionnaire

A questionnaire was administered to herd owners face to face. The questions were interpreted into Afan Oromo, Bertha and Arabic. The questionnaire for herd-level risk factor assessment was administered to 181 randomly selected herd owners.

Serum sample collection

Serum samples were collected for serological tests from individual animals of the selected herds. The samples were collected from a jugular vein, using 10 ml sterile vacutainer tubes, from 1,144 randomly selected individuals (589 cattle, 246 sheep and 309 goats) showing no clinical signs of disease. Animals of more than six months of age were included for blood sample collection to reduce the effect of maternally derived antibody, which circulates in calves for about five months (21). The age of the animal was recorded by interviewing the herd owners. If the farmers did not know the age of the newly introduced animals (those that had been bought from market or those that were a gift from a relative), the age of the animals was determined

by dentition (22, 23). The blood samples were transported from the field to the Asosa regional laboratory. They were centrifuged in a laboratory for 2–3 minutes. Serum was harvested and transferred to sterile cryovial tubes and stored at –20°C. Each tube was labelled with a serial number, a herd code, the age and sex of the animal, and details of the peasant association to which it belonged.

Serological tests

The PrioCHECK® FMDV NS (non-structural) was used to detect antibody against FMDV NSP in serum samples collected from cattle, sheep and goats. The test was carried out according to the manufacturer's instruction. The test principle is the blocking of plate-bound NSP antigen by antibodies present in the serum samples so that the conjugate (a monoclonal antibody to FMDV NSP, conjugated with horseradish peroxidase) can no longer bind – which is indicated by the absence of a colour change in the substrate in the subsequent incubation step.

Data management and analysis

Collected data were entered into an Excel spreadsheet and descriptive statistics and proportions were calculated. Individual-animal prevalence was calculated by dividing the number of animals with positive ELISA tests by the total number of tested animals and the herd prevalence was determined by dividing positive herds by the total number of herds. Herds were considered positive if one or more animals in the herd had a positive ELISA test. Within-herd prevalence was calculated by dividing the number of ELISA-positive animals in the herd by the total number of animals in the herd (19, 24).

The data were analysed using the software package SPSS Statistics (Statistical Package for Social Science) (25). The level of statistically significant association between the risk factors and seroprevalence was determined using the chi-square test. Nine potential risk factors were screened using univariable logistic regression analysis (26) ($p<0.15$). The risk factors included three animal-level risk factors (Table II and Table IV) and six herd-level risk factors, five of which

were statistically significant ($p<0.05$) (Table III and Table V). Spearman correlation coefficients were used to check the variables for co-linearity. Then, multivariable analysis was conducted and non-significant variables were removed sequentially using backward elimination at $p<0.05$. Confounding was assessed at each step of model development by inspecting changes in parameter estimates. Any changes >25% were considered to indicate confounding.

Results

Seroprevalence

A total of 9% (95% CI = 7.2–10.6, n = 102) of the 1,144 animals examined (589 cattle, 309 goats, and 246 sheep) were positive for FMD antibody using the 3ABC blocking ELISA test. From a total of 181 herds studied, 38% (n = 69) were seropositive due to the presence of at least one or more seropositive animals in the herd. The within-herd seroprevalence varied from 0% to 60%.

The herd seroprevalence was statistically significantly different between Oromia region and Beneshangul Gumuz region. A statistically insignificant association was observed with individual-animal seroprevalence ($\chi^2 = 2.49$, $p>0.05$) between Oromia and Beneshangul Gumuz. There was a statistically significant difference ($\chi^2 = 17.1$, $p<0.05$) between the seroprevalences of each zone. Individual-animal seroprevalences of 15%, 11%, 10% and 6% were recorded in Tongo special district, Western Wollega zone, Kelem Wollega zone and Asosa zone, respectively. The lowest seroprevalence at animal level was recorded in Mange district followed by Asosa district, while the lowest herd seroprevalence was recorded in Asosa district followed by Mange district (Table I). The animal and herd seroprevalences of the disease at regional, zonal and district level are summarised in Table I.

Animal-level seroprevalence

Statistically significant differences among the three species were recorded after descriptive analysis ($\chi^2 = 33.5$, $p<0.05$), univariable

logistic regression and multivariable logistic regression. The highest level of seropositivity was seen in cattle (14%; 95% CI = 10.8–16.4, n = 80); the second-highest level was found in sheep (5%; 95% CI = 3.8–6.7, n = 13) (Table II). There was a direct relationship between age and seropositivity to FMD. Statistically, no significant difference was observed between sex groups (Table II). The animal-level univariable logistic regression revealed that cattle were five times (95% CI = 2.6–10.6) more likely to be infected with FMDV than goats. For sheep and goats, the difference in the probability of becoming infected with the disease was not statistically significant. In cattle, the risk of seropositivity increases every year as the animal gets older: for the adult age group (3.5–5.5 years old) the risk increases 2.7 times with every advancing year, while in the old age group (>5.5 years old) the risk increases 3.4 times (Table II).

Herd seroprevalence

The multivariable logistic regression analysis demonstrated that the herds with the highest odds of FMD seropositivity were those that were large, those that grazed on communal land, those that had contact with ungulate wildlife, those that had contact with herds/animals of another peasant association and those situated close to livestock markets (Table VI).

Discussion

Previous studies from different parts of Ethiopia have indicated that prevalence of the disease in domestic ruminants varies from 6% to 26% (11, 12, 14, 15, 17, 18, 27). The 9% overall seroprevalence in this study is consistent with previous reports; for example, Molla *et al*. reported a seroprevalence of 8.1% in cattle from South Omo zone (17) and, similarly, Megersa *et al*. reported a 10% seroprevalence in the cattle population of three selected zones of the SNNPR (11). In the present study, the prevalence of FMD in cattle was 14%. The same seroprevalence in cattle (14%) was reported in the Somalia Region of Eastern Ethiopia (27) and a seroprevalence of 12% has been reported in the Benchimaji zone of the SNNPR (7). However, higher seroprevalences of 21% and 24% have been reported in two zones in

Oromia, namely Borana zone and Guji zone (12, 14, 16). The higher seroprevalence in Borana and Guji in comparison to the current study might be due to the pastoral production system in these zones, which is characterised by a high level of herd mobility, intermingling of animals at watering points, large herd sizes and frequent contact with the livestock of neighbouring countries through cross-border contact (7, 11).

The present study indicated that there is statistically significant variation among administrative areas. This is in line with previous reports (11, 15). This might be due to differences in the movement and distribution of livestock, the level of contact between herds and ungulate wildlife, and the grazing type in each administrative structure. The higher seroprevalence in Tongo special district is related to the coexistence of cattle, sheep and goats and contact of livestock with other herds at the border. In the Norther Kordofan, River Nile and Gedarif states of South Sudan, a lower seroprevalence of FMD was reported in separately grazing herds of small ruminants than in those that were intermingled with cattle herds (28). Gelaye *et al*. reported higher seroprevalence in districts and peasant associations where cattle could cross the border with Sudan and come into contact with other livestock (7).

In the Begi district of Western Wollega zone, the higher seropositivity was related to the large cattle population and contact of livestock with wildlife such as buffalo, wild pigs, kudu and warthog. A previous study reported a high seroprevalence in the Bennatsemay and Hammer districts of the South Omo zone, where cattle have frequent contact with ungulate wildlife (17). The factors behind the high seroprevalence in the Gidami district of Kelem Wollega zone are probably the large livestock population, the mixed-species farming system and regular contact between livestock and ungulate wildlife. Information obtained from herd owners in the Bambasi district of Asosa zone indicated that the coexistence of small ruminants with cattle and contact of livestock with livestock of other peasant associations and other districts, particularly Manasibu district in the

Western Wollega zone could be the possible reason for the high prevalence in this study.

The seroprevalence of FMD in small ruminants in this study was lower than in a previous study in which samples were collected from all corners of the country (18). However, in that study, the samples collected from small ruminants in the lowlands of Beneshangul Gumuz were non-seroreactive (18). The current report of 4% in Western Wollega and Beneshangul Gumuz was a clear indication of the expansion of the disease in Ethiopia. The statistically significant difference ($p<0.05$) between cattle and small ruminants and the absence of significant variation between sheep and goats might be due to differences in the carrier status of the animals (25). After recovery from acute infection, African buffalo harbour the virus for a minimum of five years, cattle for three years, and sheep and goats a maximum of nine months (23). This is in agreement with a study conducted in Nigeria (29). A report from neighbouring Sudan indicated that, after an active outbreak of the disease, seroprevalence of FMD was 79% in cattle, 22% in sheep and 28% in goats, which indicated a significant variation in seropositivity among cattle and small ruminants, but no significant difference between sheep and goats (13).

In the current study, the seropositivity of both small ruminants and cattle increased with age. Previous studies reported a similar positive relationship of seroprevalence of FMD and age in Ethiopian cattle under extensive production systems (7, 12, 14). The difference of seropositivity among age groups was most probably related to long periods in which animals produced antibody against the non-structural protein of FMD virus, ranging from six months in small ruminants to more than three years in cattle (6, 30). However, the absence of statistically significant differences between different age groups of small ruminants might be related to management factors. In the study area, after the age of two months, all small ruminants were kept together with adult groups. In contrast, young calves and adult animals were kept separately, which may have reduced the exposure of young cattle to the virus (17).

In this study, although higher prevalence was recorded at low altitudes, there was no statistically significant difference in seroprevalence between midland and lowland areas. This is possibly due to unrestricted livestock movements, which allow interaction between livestock in lowland areas and those in midland areas. Previously, studies conducted in different parts of the country had reported statistically significant variations across altitude, with a higher seroprevalence in lowlands than in midlands and highlands. However, these differences were not related to altitude but to the pastoral production system implemented in the lowlands, which was characterised by intermingling of animals at watering points, a high degree of herd mobility and large herd sizes (7, 11, 18).

The role of wildlife in the epidemiology of FMD under Ethiopian conditions has not been extensively investigated, but studies report an association between frequent contact with wildlife and high levels of seropositivity in livestock. The univariable and multivariable logistic regression analysis in the present study showed a statistically significant ($p<0.05$) association of FMD seropositivity and contact between livestock and ungulate wildlife. Similarly, in South Omo zone in the SNNPR, there was a higher seroprevalence in herds which regularly had contact with ungulate wildlife than in herds which rarely had contact with wildlife (17). Sahle reported a seroprevalence of 30% in ungulate wildlife, with the highest antibody titres being recorded in buffalo. According to Bronvoort *et al*., contact between ungulate wildlife and livestock at watering points and grazing areas is the main risk factor for FMDV circulation and it is a challenge for disease control in East Africa (31).

Statistical analysis using the chi-square test and univariable logistic regression showed that herds in communal grazing areas were 3.2 times more likely to become infected with FMDV than herds that grazed separately. On the other hand, multivariable logistic regression showed that grazing type had no statistically significant relationship with the seropositivity of the animals. It was a confounding factor in the relationship between seropositivity and herd size, and between seropositivity and the age of the animals.

In the assessments of risk factors for FMD in selected districts of western Ethiopia, 55% of herds had a history of contact with herds/animals of another peasant association or another district at grazing/watering points. These herds were 3.4 times more likely to be seropositive for FMD than herds that did not have a history of contact with other herds. Most of those herds and animals were found in Tongo special district, Bambasi district in Benshangul Gumuz and Begi district in Oromia. Farmers who responded to the questionnaire indicated that contact between animals of different peasant associations occurs during the dry season. Vosloo *et al*. reported that the movement of livestock without restriction in East Africa, which results in frequent intermingling of animals, is among the main risk factors for the endemicity of the disease in the region (32). Direct contact with herds from other peasant associations as a result of crossing state and national borders is one of the most common ways that FMDV is spread (8, 30).

Studies of cattle in extensive production systems in different regions of Ethiopia have reported a direct association between FMDV infection and herd size (7, 14). The present study also found that there was a positive relationship between FMD seroprevalence and herd size: as herd size increased, the risk of there being seropositive animals in the herd increased. This direct association might be an indication of the nature of disease transmission.

In this study, univariable logistic regression and the chi-square test showed a statistically significant association between FMD seroprevalence and the presence of a livestock market, but multivariable logistic regression showed no such association. Previous studies in Ethiopia have also established a positive relationship between the presence of a livestock market and the seropositivity of animals (11, 14, 33). In the current study, the proximity of a livestock market was the confounding factor in the relationship between seropositivity and livestock movements, and between seropositivity and mixed-species farming systems.

Conclusions

This study revealed an overall FMD seroprevalence of 8.9% (14% in cattle and 4% in small ruminants). This confirms the presence of the disease in the study area. Based on multivariable logistic regression analysis, the statistical association between the risk factors and seropositivity was ranked as follows:

– herd size, with an odds ratio of 17.5

– age of animals, with an odds ratio of 5.1

– contact with ungulate wildlife, with an odds ratio of 3.3

– contact with herds/animals of different peasant associations, with an odds ratio of 2.8

– species type, with an odds ratio of 1.73.

There are currently no programmes for strategic or emergency vaccination for FMDV in the study area and their development is recommended. To develop strategic control and scheduled vaccination programmes it will be necessary to increase community awareness of FMD transmission and control measures and to engender a commitment to vaccination among the community. It will also be necessary to carry out serotyping and strain characterisation to ensure that vaccine strains match field strains. The use of purified vaccine is also recommended in order to avoid contamination with the non-structural protein of FMDV during vaccine production process, which would create false-positive results in an NSP diagnostic assay.

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Conflicts of interest statements

None of the authors has any financial or personal relationships that could inappropriately influence the contents of the paper.

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Table I
Individual animal and herd seroprevalence of foot and mouth disease in regions, zones and districts of Ethiopia

	Individual-animal seroprevalence					Herd-level prevalence				
	Animals tested	**Prevalence (%)**	**95% CI**	**χ^2**	**p-value**	**Herds tested**	**Prevalence (%)**	**95% CI**	**χ^2**	**p-value**
Region				**2.5**	**0.115**				**6.9**	**0.009**
B/Gumuz	700	55 (8)	5.9–10.1			65	33 (50.8)	33.5–68.1		
Oromia	444	47 (11)	8.1–13.9			116	36 (31)	20.9–41.1		
Zone				**17**	**0.001**				**13**	**0.003**
Asosa	527	29 (6)	3.8–8.0			84	20 (23.8)	13.4–34.2		
K/Wollega	197	20 (10)	5.8–14.2			38	19 (50)	27.5–72.5		
W/Wollega	247	27 (11)	6.86–14.7			27	14 (51.9)	24.1–79.1		
Tongo	173	26 (15)	9.7–20.3			32	16 (50)	25.5–74.5		
District				**23**	**0.001**				**20**	**0.001**
Asosa	193	8 (4)	1.2–6.7			35	4 (11.4)	0.2–22.6		
Bambasi	159	16 (10)	5.3–14.7			25	11 (44)	18–70		
Begi	247	27 (11)	6.9–15.1			27	14 (51.9)	24–79		
Gidami	197	20 (10)	6.0–14.0			38	19 (50)	27.5–72.5		
Mange	175	5 (3)	1.9–4.2			24	5 (20.8)	2.6–39		
Tongo	173	26 (15)	9.7–20.3			32	16 (50)	25.5–74.5		
Total	**1,144**	102 (8.9)	**7.2–10.6**			**181**	**69 (38.1)**	**29.1–71.**		

B/Gumuz: Beneshangul Gumuz
K/Wollega: Kelem Wollega
W/Wollega: Western Wollega
CI: Confidence interval
χ2: chi-square

Table II
Descriptive statistics of animal-level risk factors for foot and mouth disease

Risk factor	Sample tested	Prevalence (%)	95% CI	χ^2	p-value
Species				**33.5**	**0.001**
Cattle	589	80 (13.6)	10.8–16.4		
Goats	309	9 (2.9)	1–4.8		
Sheep	246	13 (5.3)	3.8-6.7		
Sex				**0.105**	**0.746**
Female	746	68 (9.1)	7.1–11.1		
Male	398	34 (8.5)	5.8–11.2		
Age (cattle)				**13.9**	**0.001**
<3.5	200	13 (6.5)	3.1–9.8		
3.5–5.5	217	34 (15.7)	10.7–20.7		
>5.5	172	33 (19.2)	13.2–25.2		
Age (small ruminant)				**1.76**	**0.42**
<2	209	6 (2.9)	0.6–5		
2–3.5	184	7 (3.8)	1.2–6.6		
>3.5	162	9 (5.6)	2–7.1		

CI: Confidence interval

Table III
Descriptive statistics of herd-level risk factors for foot and mouth disease

Risk factor	Herds tested	Prevalence (%)	95% CI	χ^2	p-value
Herd size (number of individuals)				**35.2**	**0.001**
<40	104	21 (20.2)	11.6–28.8		
40–75	60	35 (58.3)	39–77.7		
>75	17	13 (76.5)	34.9–118		
Grazing type				**11.9**	**0.001**
Separate	68	15 (22.1)	10.9–33.2		
Common	113	54 (47.8)	35.0–60.5		
Contact with ungulate wild life				**15.3**	**0.001**
No	99	25 (25.3)	15.4–35.2		
Yes	82	44 (53.7)	37.8–60.9		
Contact with herds/animals of different peasant associations				**14.9**	**0.001**
No	106	28 (26.4)	16.6–36.2		
Yes	75	41 (54.7)	38–71.4		
Close to livestock markets				**3.9**	**0.047**
No	156	55 (35.3)	6.5–9.7		
Yes	25	14 (56.6)	10.4–17.8		
Altitude (above sea level)				**0.6**	**0.45**
<1500 m	72	30 (41.)	26.8–56.6		
≥1500 m	109	39 (35.8)	24.6–47		

CI: Confidence interval

Table IV
Univariable logistic regression analysis of animal-level risk factors for foot and mouth disease

Factors	β	SE	OR	95% CI	p-value
Species					
Goats	Ref.				
Sheep	0.63	0.4	1.9	0.78–4.4	0.16
Cattle	1.66	0.4	5.2	2.6–10.6	0.001
Cattle age (years)					
<3.5	Ref				
3.5–5.5	0.98	0.3	2.7	1.4–5.2	0.004
>5.5	1.23	0.4	3.4	1.7–6.7	0.001

B: Beta

CI: Confidence interval

OR: Odds ratio

SE: Standard error

Table V
Univariable logistic regression analysis of herd-level risk factors for foot and mouth disease

Factors	β	SE	OR	95% CI	p-value
Herd size					
<40	Ref.				
40–75	0.89	0.39	2.4	1.3–5.2	0.023
>75	2.5	0.46	13.2	5.4–32.5	0.001
Grazing type					
Separate	Ref.				
Common	1.17	0.34	3.2	1.63–6.4	0.001
Contact with ungulate wild life					
No	Ref.				
Yes	1.23	0.32	3.4	1.8–6.4	0.001
Contact with herds/animals from different peasant associations					
No	Ref.				
Yes	1.2	0.33	3.4	1.8–6.3	0.001
Close to livestock markets					
No	Ref.				
Yes	0.85	0.44	2.3	0.99–5.4	0.052

B: Beta
CI: Confidence interval
OR: Odds ratio
Ref: Reference category
SE: Standard error

Table VI
Multivariable logistic regression

Parameters	β	SE	OR	95% CI	p-value
Constant	2.33	0.48	–	–	–
Herd size	2.86	0.62	17.50	5.2–58.8	0.001
Contact with herds/animals of different peasant associations	1.05	0.46	2.80	1.2–7.1	0.001
Contact with ungulate wildlife	1.20	0.44	3.30	1.4–7.9	0.007
Species	1.70	0.55	1.73	1.1–3.78	0.001
Age	1.63	0.42	5.10	2.24–11.62	0.001

CI: Confidence interval

B: Beta

SE: Standard error

OR: Odds ratio

Fig. 1
Map of study area in western Ethiopia