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Study on incidence of lamb morbidity and mortality and associated risk factors in the mixed crop-livestock production system of Gewata District, Kaffa zone, southwestern Ethiopia

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Abstract

Lamb morbidity and mortality cause significant loss in a smallholder production system. A longitudinal prospective survey was conducted on 408 randomly selected farmers located in six purposefully selected kebeles in Gewata woreda from June 2020 to July 2021 to determine the incidence of morbidity and mortality in lambs and to identify risk factors. For this purpose, 408 lambs from the Gewata district's mixed crop-livestock production system were examined every day from birth to three months of age. The data was analyzed using the Kaplan-Meier (K-M) method, the log-rank test, and Cox proportional hazards regression. Results showed that the cumulative incidence of all-cause of morbidity and mortality at the end of three month was 12.86% (95% CI: 10.26–16.13%), and 6.86% (95% CI: 5.03–9.35%), respectively**.** Diarrhea was the leading cause of morbidity and mortality, accounting for 49.33 and 50% morbidity and mortality, respectively. Pneumonia was the second most frequent cause of morbidity and death. In the K-M hazard analysis, the greatest risk of lamb morbidity and mortality was observed during the first month of life, and then the risk decreased significantly as the lamb grew. Of the 17 potential risk factors studied, the multivariable Cox proportional hazards regression model showed that lamb sex, birth weight, umbilical care, time and method of colostrum feeding were the five predictors that were significantly associated with a higher risk of morbidity, whereas birth weight, lambing difficulty, dams' parity, method and time of colostrum feeding were the five predictors that were significantly associated with a higher risk of mortality. Moreover, a higher risk of morbidity was observed in lambs with methods of colostrum feeding after birth (HR = 3.158; $p = 0.000$) and with variations in birth weight (HR = 1.418; $p = 0.003$). Similarly, the mortality risk was 4.926 ($p = 0.047$), 4.023 ($p = 0.012$), and 3.206 ($p = 0.000$) times higher in lambs with lambing difficulties, at the time of colostrum feeding, and by the method of colostrum feeding, respectively. According to this research, lamb morbidity and mortality rates in the study area are significantly high which has a great impact on the replacement stock and production. Hence, awareness should be created among farmers concerning improved lamb management practices.

Keywords Gewata, Incidence, Lamb, Morbidity, Mortality, Ethiopia

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Introduction

Ethiopia has approximately 30.7 million heads of sheep and is Africa's second-largest sheep population (Central Statistical Agency 2019). Sheep breeds are widely spread across the country's diverse ecosystem, ranging from subalpine to dry lowlands, as well as production practices (Gizaw et al. 2007; Tibbo 2006). Short-tailed, long-tailed, thin-tailed, and fat-tailed sheep are among the 14 traditional sheep populations of the country and are divided into four major groups based on tail type (Galall 1983). Additionally, using a microsatellite DNA marker, Ethiopian researchers found nine breeds and six genetically diverse sheep breed groupings that are scattered across the nation in various agroecology and production methods (Gizaw et al. 2007; Solomon et al. 2008).

In Ethiopia, mixed crop-livestock production accounts for 75% sheep population, while pastoral and agro-pastoral farming accounts for the remaining 25%. They operate on a large production system with minimal effort and produce the lowest carcass weight compared to other East African countries (Solomon et al. 2008). Due to ecological, economic and cultural variations, the aim of maintaining sheep varies from place to place. They are, however, by and large, save for exceptional makes use of together with earnings generation, meat, milk, skin, wool, manure, security, gifts and non-secular rites (Edea et al. 2010).

One of the major production challenges affecting sheep and goat productivity is the high pre-weaning mortality of young lambs and kids (Singh et al. 2009). The term "preweaning mortality rate" (PWMR) refers to the number of lambs that die between birth and weaning, including neonatal mortality (International livestock center for Africa 1998), especially in the neonatal stage (from birth through the first 28d of life), which is the most essential for lambs (Gokce et al. 2014). The study on Ethiopian highlands revealed that a high level of neonatal lamb mortalities was recorded both on-station (46.3%) and on-farm (51.5%) (Bekele et al. 1992a), whereas the study of Rift Valley areas of Ethiopia showed that 46.8% preweaning kids death and 30.3% neonatal kid death, especially till 1 month of age (Fentie et al. 2016).

In Ethiopia and other parts of the world, lamb mortality can only be reduced by recognizing and addressing the underlying causes (Kirk and Anderson 1982), such as infectious conditions (pneumonia, liver fluke, diarrhea and pneumo-enteritis) and non-infectious conditions (starvation/chilling exposure complex, stillbirths/dystocia, mismothering, low birth weight, breed, ewe's age, neonate's immunity gained through colostrum, dam's parity and lamb's sex, injury and poisoning) (Fentie et al. 2020; Hadgu et al. 2021; Islam et al. 2015; Lorenz et al. 2011; Mohammed et al. 2020; Binns et al. 2002; Hordofa et al. 2021; Khan et al. 2006). To completely appreciate the causes of lamb morbidity and mortality, it is also necessary to comprehend the associated risk factors (Fentie et al. 2016; Hadgu et al. 2021; Mohammed et al. 2020; Hordofa et al. 2021). Genetic, environmental and management factors were the most important determinants of lamb mortality and morbidity. These include lamb's birth weight, sex, dam parity and age, colostrum immunoglobulin transfer, lambing season and year, dam body weight during lambing, and litter size (Hadgu et al. 2021; Fogarty et al. 2000; Dalton et al. 1980; Sawyer et al. 1977; Wiener et al. 1983).

The Kaffa zone has a large potential for a small ruminant population kept by smallholder farmers as a sole or supplementary source of cash income (Ortiz 1983). Although small ruminant production provides food security for sheep producers, disease, poor nutrition, poor animal production systems, reproductive inefficiency, management constraints, inadequate veterinary care, and lamb mortality have a great impact on smallholder producers. Lamb morbidity and mortality are one of the most evident constraints to sheep producers' profitability in most countries, resulting in a shortage of replacement stock. The rate of survival of lamb produced determines the success of any breeding program, as well as the future of sheep production. For farmers and cattle herders to get the most out of their livestock resources, it's critical to develop efficient livestock production that can prevent losses of young stock. Hence, the major cause of lamb stock morbidity and mortality should be identified and estimated to develop a sustainable control program. Keeping these aspects in view, the current study was conducted to assess the incidence of morbidity and mortality from birth to weaning and potential risk factors in lambs of the Gewata district, Kaffa zone, southwestern Ethiopia.

Results

Descriptive epidemiology

In this study, 408 farmers in a mixed crop-livestock production system with at least one lamb less than 3 months of age in their flock were interviewed from six kebeles of Gewata district, Kaffa Zone, Southwest Ethiopia. Of the 408 respondents, 81.86% were men, while 18.14% were women. The age categories of the respondents in the 18–30 years, 31–40 years, and 41–50 years age groups were 46.32, 33.58, and 15.20%, respectively. The remaining age groups were above, and regarding this age distribution of the respondents, the majority were grouped by productive age. The level of education is the most basic criterion for determining a society's standing. A literate community is more capable of comprehending and completing various agricultural activities. The findings revealed that 17.16 and 27.94% respondents were

illiterate and read and write, respectively. Others, 28.18 and 12.75% had completed elementary and secondary education levels, respectively, and the remaining 4.17% were above secondary (Table 1).

Of the total sampled lamb, 54.17% were male and 45.83% were females. A significantly high number of owners care for umbilical (66.91%) and fed colostrum by suckling (56.13%) within 6h (51.72%). Regarding the birth type, the highest number (57.87%) were born twice, and the least number was born triple (2.94%). Moreover, 60.78% lambs were born with lambing difficulty, 85.54% dams' parity was multiparous, and the highest number of lambs was weighted between 3.1–3.5 kg (34.80%). In this study, 78.68% were sampled in the wet season, 54.17% were managed under poor hygiene, and 72.55% was mixed with other weaned lamb in the flock (Table 1).

Lamb morbidity and mortality rate

Of the 408 lambs that were observed in this study, disease incidences and deaths in the study lamb were recorded up to three months of age, after which no morbidity or mortality events were noted. As a result, the data were truncated after three months and accordingly the overall morbidity and mortality rates are calculated as 12.86 cases per 100 lamb months and 6.86 cases per 100 lamb months at risk, respectively. The highest morbidity and mortality (18.60 and 8.69) were observed in Bako-Shuta and Wodiyo, respectively. Similarly, the lowest morbidity and mortality (4.17 and 0) were observed in Buta, and Bako-Shuta, respectively. Besides, morbidity and mortality of lamb based on origin or kebele were presented in Table 2.

Kaplan-Meier survival analysis

The cumulative survival probability of lamb to all-cause morbidity by colostrum intake time and mortality by dams' parity is showed in Figs. 1 and 2, respectively. To better visualize the cumulative survival probability or incidence of morbidity or mortality from birth to three months of life, the same data were also presented using the K-M life table (Table 3). The K-M survival curves show a significant decrease at end of each month with a constant across respective months in the survival probability of lamb with increasing age. Disease events were recorded in all age groups.

Using the Kaplan-Meier method, we calculated the risk of morbidity and mortality at the end of each month until the lambs were three months old. As a result, the greatest risk (hazard) of morbidity and mortality was observed during the second and third months of life, and then the risk decreased significantly as the lamb grew older (Table 3).

Causes of morbidity and mortality

Diarrhea was the leading cause of morbidity and mortality accounting for 49.33 and 50.00% morbidity and mortality, respectively. Pneumonia was the second most frequent cause of morbidity and death. Table 4 lists the other prevalent causes of lamb morbidity and mortality.

Risk factors for lamb morbidity and mortality

Univariable analysis

In this study, the effect of six kebeles host and management factors on lamb morbidity and mortality was assessed using the Log-rank test, and potential predictors for the final multivariable analysis were selected based on the results. From there, the variables with p-values less than 0.25 were selected for the multivariable analysis of the risk factors, totaling 12 variables for morbidity and 11 variables for mortality (Table 5).

Multivariable analysis

Lamb morbidity rate The incidence rate of lamb morbidity was found to be significantly ($p < 0.05$) impacted by lamb sex, birth weight, Umbilical care, method and time of colostrum feeding in the final multivariable Cox regression analysis model. Accordingly, compared to their counterparts, lamb sex (HR = 0.265), and umbilical care (HR = 0.473) had a lower risk of morbidity. In contrast, the method of colostrum feeding had the highest risk of morbidity (HR = 3.158) (Table 6). The final model was tested for the proportional hazards assumption and found not to violate the assumption (global test: Chisq = 10.77; df = 16; $p = 0.8235$).

Lamb mortality rate The final multivariable Cox hazard regression analysis model revealed that among the assessed potential risk factors, such as birth weight, lambing difficulty, dams' parity, method, and time of colostrum feeding all had a statistically significant ($p < 0.05$) impact on the lamb mortality rate. In comparison to their counterparts, the mortality risk was lower in the birth weight of lamb (HR = 0.379), and dams' parity (HR = 0.223). On the other hand, lamb from a ewe with lambing difficulty exhibited a higher mortality risk (HR = 4.926) (Table 6). The final model was tested for the proportional hazards assumption and found not to violate the assumption (global test: Chisq = 7.37; df = 16; $p = 0.9656$).

Table 1 Respondents' feedback on their demography, lambs' health, and management in the mixed crop-livestock production system of Southwest Ethiopia

Variable	Category	Frequency	Valid percent (%)
Origin/Kebele	Wodiyo	115	28.19
	Imicho	89	21.81
	Dumo	62	15.20
	Boka-Shuta	28	6.86
	Alargeta	46	11.27
	Buta	68	16.67
Owner age (years)	18–30	189	46.32
	31–40	137	33.58
	41–50	62	15.20
	>50	20	4.90
Sex (owner)	Male	334	81.86
	Female	74	18.14
Education status	Illiterate	70	17.16
	Read and write	114	27.94
	Elementary	155	28.18
	Secondary	52	12.75
	Above	17	4.17
Flock size	2–4	136	33.33
	5–7	145	35.54
	>8	127	31.13
Lamb sex	Male	221	54.17
	Female	187	45.83
Birth type	Single	160	39.22
	Twice	236	57.84
	Triple	12	2.94
Birth weight (kg)	≤2	28	6.86
	2–2.5	39	9.56
	2.6–3	97	23.77
	3.1–3.5	142	34.80
	≥3.6	102	25.00
Lambing difficult	Yes	160	39.22
	No	248	60.78
Dams' parity	Primiparous	59	14.46
	Multiparous	349	85.54
Season of birth	Wet	321	78.68
	Dry	87	21.32
Hygiene	Poor	221	54.17
	Good	187	45.83
Mixing of different weaned lamb	Yes	296	72.55
	No	112	27.45
Umbilical care	Yes	273	66.91
	No	135	33.09
Method colostrum feed	Suckling	229	56.13
	Hand feed	98	24.02
	Not feed	81	19.85
Time of colostrum feeding	≤6 hrs	211	51.72
	6-12 hrs	164	40.20
	≥12 hrs	33	8.09

Participatory investigation of causes of lamb morbidity and mortality in the study area

During the focus group, key informants' discussion was local names, in order of importance, experience with lamb health problems and methods of prevention and control, key health issues for each level, and diseases or conditions that cause illness and death in lambs. Identifying and ranking area sheep production limits, ranking or prioritizing morbidity and mortality causes, and discussing sheep morbidity and mortality time trends (seasonal calendar). In terms of lamb health concerns, the research area's preventative and control methods were not thoroughly tested. The participants stated that during lamb diseases, they did not pay attention to sick lambs due to a lack of knowledge and the distance to an animal health facility where the sick lamb might be treated.

As discussed during focus group discussion (FGD) and key informants, major health problems in the study area were infectious diseases and insufficient facilities for veterinary services were major animal health problems in the area. Diseases or diseases causing factors and death in lambs were identified and ranked in the study area. Importance and local name: Diarrhea (#1), Pneumonia (#2), Dysentery (#3), endoparasites (#4), and conception. (#5) (Table 7). Diseases, shortage of animal health professionals, shortage of drugs, and vaccination time were enumerated as constraints of sheep production in the study area.

According to FGD and key informants, infectious disease (1st), mismothering starvation exposure (2nd), predator (3rd), management (4th), and unknown causes (5th) were identified and ranked as the causes of lamb morbidity and mortality in the study area. The wet season and dry season were responsible for lamb morbidity and mortality in the research region, according to temporal patterns (seasonal calendar). The causes of lamb morbidity and mortality in the study area were discussed by focus group discussants and key informants during the dry season because of a lack of available feeds for ewes to produce enough milk for lambs. In the wet season, the pasture was contaminated by floods and the season was favorable for microorganism multiplication (Table 7).

Discussion

The mortality and morbidity of lambs before weaning are major factors in reducing profitability by causing significant losses in sheep production, which negatively affects sheep and livestock production (Hadgu et al. 2021). In the current study, the cumulative incidence of all-cause of morbidity and mortality observed was 12.86 and 6.86%, respectively. This finding is the first incidence report on lamb morbidity and mortality in the study area.

Table 2 Morbidity and mortality rate of lamb in the mixed crop-livestock production system of Southwest Ethiopia based on origin

Origin	No. of lamb at risk	No. of cases	Time at risk (months)	IR /100 lamb month	95% CI for IR
Morbidity					
Wodiyo	115	24	161	14.91	9.99–22.24
Imicho	89	19	129	14.73	9.39–23.09
Dumo	62	10	88	11.36	6.11–21.12
Boka-Shuta	28	8	43	18.60	9.30–37.20
Alargeta	46	10	66	15.15	8.15–28.16
Buta	68	4	96	4.17	1.56–11.10
Total	**408**	**75**	**583**	**12.86**	**10.26–16.13**
Mortality					
Wodiyo	115	14	161	8.69	5.15–14.68
Imicho	89	11	129	8.53	4.72–15.39
Dumo	62	4	88	4.55	17.06–12.11
Boka-Shuta	28	–	43	–	
Alargeta	46	3	66	4.55	1.47–14.09
Buta	68	8	96	8.33	4.167–16.66
Total	**408**	**40**	**583**	**6.86**	**5.03–9.35**

IR Incidence rate, *CI* Confidence Interval

Additionally, there are methodological differences between earlier studies conducted in Ethiopia and other studies when estimating the lamb morbidity or mortality rate. It is challenging to link differences in the cumulative incidence of morbidity and mortality between the current study and previous studies to variations in geographic and management conditions because of methodological differences in the calculation of the cumulative incidence. This means that the current study looked at a wide range of potential risk factors for lamb morbidity and mortality. As a result, multivariable Cox regression analysis revealed that lamb sex, birth weight, Umbilical care, method, and time of colostrum feeding were risk factors for lamb morbidity, while birth weight, lambing difficulty, dams' parity, method and time of colostrum feeding were risk factors for lamb mortality.

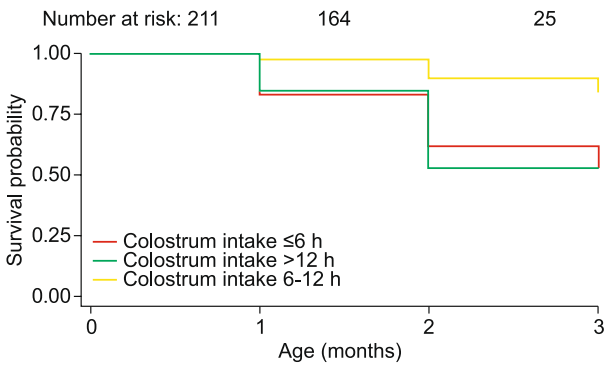

Fig. 1 K-M survival curve of all-cause morbidity in lamb based on colostrum intake time

According to the K-M hazard analysis, the risk of morbidity and mortality in lamb varied concerning the potential risk factors considered. As a result, the lambs with different colostrum feeding methods had the highest risk of morbidity (HR = 3.158), followed by variations in birth weight (HR = 1.418), umbilical care (HR = 0.473), lamb sex (HR = 0.265), and colostrum intake time (HR = 0.251). Similarly, lambs with difficult lambing had the highest risk of mortality (HR = 4.926) compared to lambs born normally at all follow-up times, followed by the first time of colostrum intake (HR = 4.023), method of colostrum feeding (HR = 3.206), birth weight (HR = 0.379), and dams' parity (HR = 0.223). Delay in consuming colostrum, help with lambing, and other factors are all responsible for the higher risk of morbidity and mortality in the first month.

This research showed that the mortality rate was higher in lambs who give birth to three lambs than in twins and single births. This research was supported by previous findings that showed that the kind of birth had a substantial impact on lamb survival, with single births exceeding multiple births (Ortiz 1983; Ricordeau et al. 1990; Gizaw et al. 1995). Lambs of recurrent births as a result of physiological starvation of the uterus are often fragile and underweight, and this condition is even more problematic if the female does not produce enough milk (Awgichew 2000).

Similarly, the effect of lamb birth weight on lamb mortality was consistent with several previous works by Gizaw et al. 2007 and Mukasa-Mugerwa et al. (Gizaw

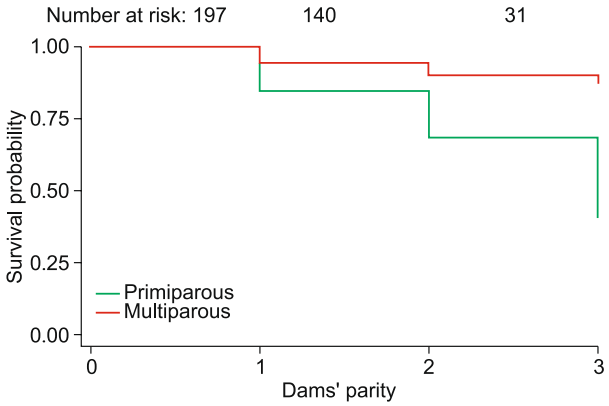

Fig. 2 K-M survival curve of all-cause mortality in lamb based on Dams' parity

et al. 2007; Mukasa-Mugerwa et al. 1994), who reported that the likelihood of survival decreases significantly when a lamb weighs less than 2 kg. Lambs with low birth weight cannot survive in harsh climates because of their low energy storage and reduced ability to regulate body temperature. Heavier lambs have increased chances of early survival (Morel et al. 2008). Mukasa-Mugerwa and his colleagues, (Mukasa-Mugerwa et al. 1994) investigation showed that a neonatal survival rate can increase up to 90% if lambs were born with a birth weight of 2 kg or more.

Early-age/parity ewes are not matured, and they require nutrition for ewe growth and lactation requirements. The lambs' mammary development is also not complete, which will result in poor mothering capacity and survivability. These results coincided with the findings of Mukasa-Mugerwa et al., (Mukasa-Mugerwa et al. 1994), who reported that the survival rates of lambs were higher in the fifth and sixth parities, with a trend toward an increase in survival from the first to the sixth parity, and the general trend for increasing survival rate with increased parity may be due to an increase in dam weight and, as a result, a large quantity of milk produced in ewes with increased parity. While the ewe's milk supply and mothering skills improve with parity, there is a point at which the dam's conditions and ability to nurture the lamb decrease (Mukasa-Mugerwa et al. 1994). On the other hand, Gizaw et al., 1995 revealed that parity did not have a significant role in lamb survival (Gizaw et al. 1995).

In this study, sex was not a risk factor for morbidity and mortality in lambs. The higher mortality in male lambs than in female lambs in this research was comparable with the previously reported studies (Vatankhah and Talebi 2009; Ahmed et al. 2010; Abdelqader et al. 2017).

Table 3 Kaplan-Meier estimate of the hazard of morbidity and mortality in lamb from birth to three months

Age interval (months)	Number of lamb at risk	No. of cases	Censored number	Hazard	Survival probability	Cumulative incidence	Std. error	95% CI for Hazard
Morbidity								
0–1	211	44	0	0.1618	0.8503	0.1497	0.0243	0.1141–0.2094
1–2	164	27	0	0.**3086**	0.6230	0.3770	0.0587	0.1936–0.4236
2–3	25	4	0	0.2051	0.5071	0.4929	0.1020	0.0052–0.4051
Mortality								
0–1	197	28	0	0.1029	0.9021	0.0979	0.0194	0.0649–0.1410
1–2	140	9	0	0.1029	0.8138	0.1862	0.0342	0.0357–0.1700
2–3	31	3	0	0.**1538**	0.6976	0.3024	0.0886	0.0000–0.3274

Table 4 Major causes of morbidity and mortality in the 408-lamb monitored in southwestern Ethiopia

Causes	Morbidity ($N = 75$)		Mortality ($N = 40$)	
	No. of cases	Percentage (%)	No. of cases	Percentage (%)
Diarrhea	37	49.33	20	50.00
Pneumonia	22	29.33	13	13.25
Mismothering exposure	6	8.00	–	–
Management problem	2	2.67	4	10.00
Unknown cause	5	6.67	3	7.50
Predator	3	4.00	–	–

Table 5 Univariable analysis of risk factors for lamb morbidity and mortality using Log-rank test

No	Variable	Morbidity		Mortality	
		Chisq	*p*	*Chisq*	*p*
1	Address (Wodiyo/Imicho/Dumo/Boka-Shuta/Alargeta/Buta)	9.21	0.1009	6.16	0.2910
2	Owner age (18–30/31–40/41–50/> 50)	18.75	0.0003	0.86	0.8342
3	Sex (owner, Male/Female)	0.01	0.9152	1.49	0.2229
4	Education status (Illiterate/Read and write/Elementary/Secondary/Above)	17.59	0.0015	7.52	0.1109
5	Flock size (2–4/5–7/> 8)	4.97	0.0835	0.72	0.6989
6	Lamb sex (Male/Female)	0.09	0.7603	2.42	0.1195
7	Birth type (Single/Twice/Triple)	6.69	0.0352	28.50	0.0000
8	Birth weight (kg) (≤2/2–2.5/2.6–3/3.1–3.5/≥3.6)	12.13	0.0164	95.04	0.0000
9	Lambing difficult (Yes/No)	6.14	0.0132	2.65	0.1035
10	Dams' parity (Primiparous/Multiparous)	3.02	0.0821	18.08	0.0000
11	Season of birth (Wet/Dry)	3.34	0.0677	0.16	0.6853
12	Hygiene (Poor/Good)	0.09	0.7603	2.42	0.1195
13	Mixing of different weaned lambs (Yes/No)	0.14	0.7035	1.43	0.2320
14	Umbilical care (Yes/No)	0.53	0.4647	0.14	0.7063
15	Method colostrum fed (Suckling/Hand feed/Not feed)	86.25	0.0000	50.87	0.0000
16	Time of colostrum feeding (< 6 hrs vs 6-12 hrs vs > 12 hrs)	26.86	0.0000	7.55	0.0229
17	Causes of morbidity and mortality (Diarrhea/Pneumonia/Mismothering exposure/Management problem/Unknown cause/Predator)	14.08	0.0151	6.09	0.2971

Table 6 Risk factors associated with the incidence of all-cause morbidity and mortality in lamb under three months of age in multivariable Cox proportional hazard regression model

Risk factor	Morbidity			Mortality		
	HR	*p*	95% CI for HR	HR	*p*	95% CI for HR
Lamb sex (Male/Female)	0.265	0.000[b]	0.137–0.510	–	a	–
Birth weight (kg) (≤2/2–2.5/2.6–3/3.1–3.5/≥3.6)	1.418	0.003[b]	1.127–1.784	0.379	0.000[b]	0.257–0.557
Lambing difficult (Yes/No)	–	a	–	4.926	0.047[b]	1.024–23.700
Dams' parity	–	a	–	0.223	0.007[b]	0.075–0.668
Umbilical care (Yes/No)	0.473	0.028[b]	0.243–0.921	–	a	–
Method of colostrum feeding (Suckling/Hand feed/Not feeding)	3.158	0.000[b]	2.202–4.528	3.206	0.000[b]	1.900–5.407
Time of colostrum feeding (< 6 h/ 6-12 h/12 hrs)	0.251	0.000[b]	0.138–0.457	4.023	0.012[b]	1.361–11.887

NB: a: $p > 0.05$; b < 0.05

Table 7 Identified lamb disease during FGD in the study area

Local name (Kafficho)	Amharic name	English name	Signs of the disease	Rank
Oshiyoo	Yesambamich	Pneumonia	Coughing, labor breathing	1st
Goociyee biiyo	Tekimat	Diarrhea	Watery diarrhea	2nd
Michichino	Yemiyasimit	Dysentery	Bloody diarrhea	3rd
Kashingito	Tilatil	Internal parasite	Emaciation, eggs on feces	4th
Maace shuuiyoo	Hod dirket	Constipation	Dry feces	5th

Rank Ranking of lamb diseases based on the frequency of occurrences by animal owners

However, Turkuson et al. (Turkson and Sualisu 2005) in Ghana reported higher mortality for female lambs. This disparity has been attributed to sex-related variables that have yet to be identified according to Mandal et al. (Mandal et al. 2007).

The lambing season has an insignificant ($p > 0.05$) effect on the lamb morbidity and mortality rate in all age intervals and higher lamb mortality was recorded during the dry season (11.54%) than in the wet season (10.69%). In line with the current study, previous research found that lambs born during the rainy season have lower mortality than lambs born during the dry season (Armbruster et al. 1991). The lower lamb mortality rate during the rainy season may be owing to better feed supplies along with better shelter, whereas the higher death rate during the dry season may be due to increasing disease pressure and feed shortages.

The value of colostrum was recognized by a large percentage of respondents (64%) who allowed unrestrained nursing of lambs, while a minor percentage of respondents (36%) restricted suckling. After 6 to 12h after delivery, the neonate's ability to absorb immunoglobulin begins to deteriorate (Radostits et al. 2007). To ensure a successful transfer of passive immunity and colostrum immunoglobulins, it is suggested that the lamb be allowed to properly drink the dam's colostrum within the first 2 days after delivery (Singh et al. 2009). The mortality rate of lambs was reduced through the use of separate lambs, care for the lambs, administration of colostrum within 12 h of age, and early supplementation of the young. Used, but the mortality rate is still higher than in other studies. However, this is lower than the previously reported prevalence of 40% in the Ebinat woreda National Regional State of Amhara in northwestern Ethiopia (Woldemariam et al. 2014).

In this study, keeping neonates and ewes near the home garden away from the rest of the herd for 1 week had a significant effect on mortality rates in pre-weaning lambs ($p > 0.05$), and in herds with newborn sheep and ewes, more deaths were found. It was kept with the rest of the herd. This may be due to the high risk of poor care, injury, exposure to predators, and insufficient intake of colostrum. When the newborn lambs are not immunologically competent, there is a greater risk of contracting contagious diseases by running with the flock. This result is in agreement with Sharif et al. (Sharif et al. 2005), who reported that if lambs were not segregated from adult animals, they were more likely to die. The isolation of diseased animals from the flock aids lamb survival by reducing the danger of infectious disease transmission.

Diarrhea was the most important cause of morbidity (49.33%) and mortality (50.00%) in lambs. In line with the current study, Hadgu 2021 reported that lamb morbidity and mortality were 27.3% and 32.5%, respectively (Hadgu et al. 2021). In contrast to the current study, malnutrition (31.3%) followed by diarrhea (24%) and respiratory problems (21.3%) was the most common cause of lamb mortality. Neonatal diarrhea in lambs is considered a cause of lamb death, and Pasteurella spp., Salmonella spp., *E. coli,* and Helminthes are possible causative agents of these diseases (Smith 1977).

Diarrhea was the leading sign of death in lambs in approximately 50% cases. Pneumonia is the second most important disease responsible for morbidity and mortality in lambs. This result is in agreement with the findings of Mukasa-Mugerwa, Njau and Gama, who reported that respiratory infections represented 54% causes of neonatal lamb mortality, (Mukasa-Mugerwa et al. 2000; Njau et al. 1988; Gama et al. 1991). Moreover, a study carried out by Tibbo (Tibbo 2006) indicated that respiratory disease is the single most important cause of sheep mortality in the Central Highlands of Ethiopia. In other studies by Bekele, (Bekele et al. 1992a; Bekele et al. 1992b), the etiologies involved were multifactorial, and 100 % respondents in the study area were not measured to treat and prevent the disease due to less attention given to lambs and a lack of awareness and distance of veterinary service to bring sick lambs in the study area.

FGD was conducted with key informants, and the participants identified and ranked the following diseases and conditions such as infectious disease (1st), mismothering starvation exposure (2nd), predator (3rd), management (4th), and unknown causes (5th) as the causes of lamb morbidity and mortality in the study area. According to Berhan, lambs born during the dry season had a greater death rate than lambs born during the rainy season (Berhan and Van Arendonk 2006). Through its effect on feed availability, the seasonal influence on lamb mortality has been well documented. This is because sheep in the tropics and Ethiopia, in particular, rely mostly on natural grassland grazing and agricultural residue, both of which are seasonal in availability and quality. In Ethiopia, feed is superior in terms of both quality and quantity during the rainy season, while the opposite is true during the dry season.

The study's main strength was that it attempted to analyze the causes of morbidity and mortality in lambs, as well as the factors that contribute to this, whereas its main drawback was that it did not determine the bacterial causes of lamb mortality and morbidity and solely based on the survey than laboratory finding support. Furthermore, because this research was conducted with a smaller sample size, a smaller geographical coverage, and over a shorter period, it was difficult to include all potential risk variables for mortality and morbidity.

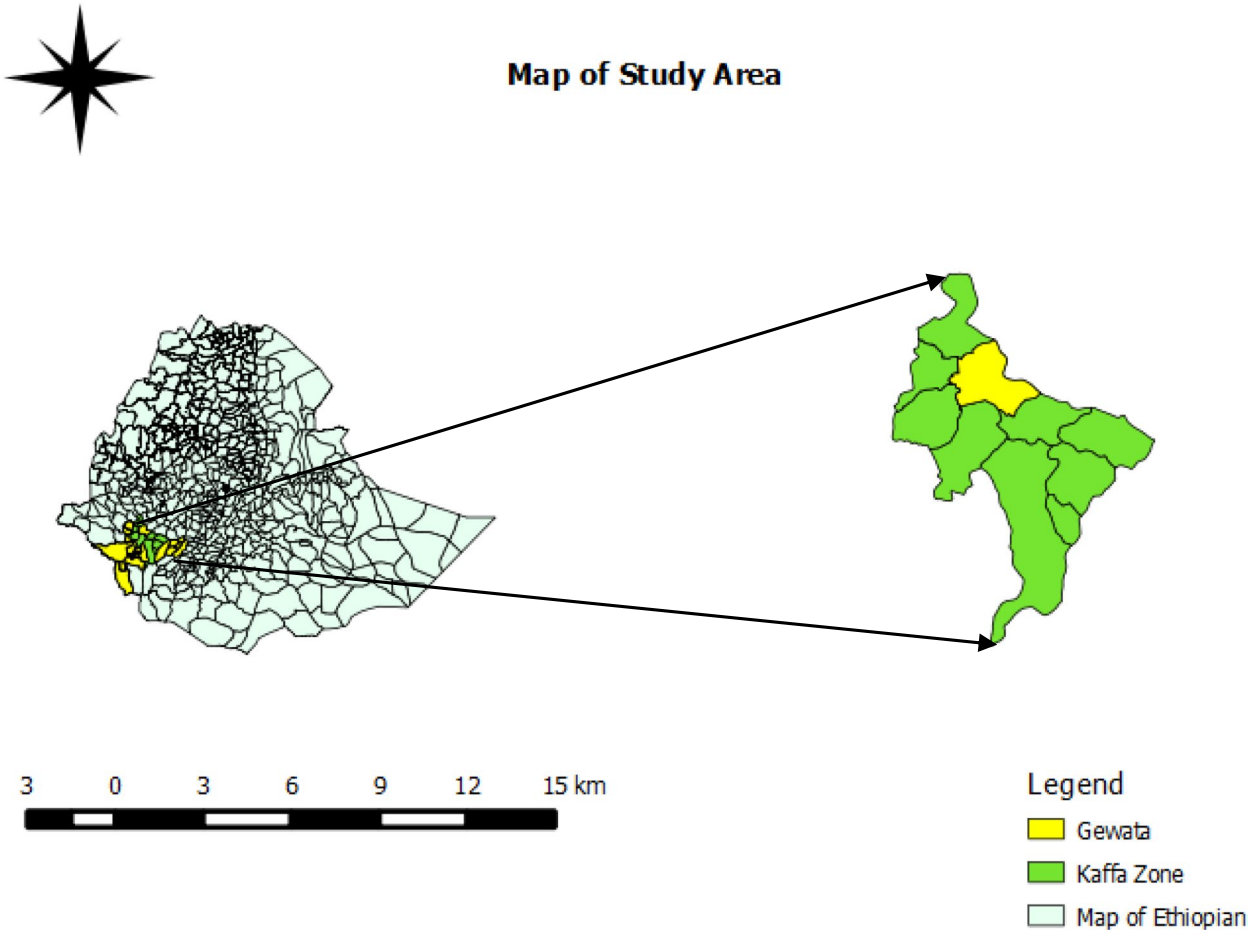

Fig. 3 Map of Gewata district, Arc GIS, 2020

Conclusion

The mortality and morbidity of lambs are the most critical production issues that severely influence sheep productivity in the study area. The current study found that lamb morbidity and mortality rates in Gewata woreda are high due to a variety of variables that influence lamb morbidity and mortality. Factors such as lamb sex, birth weight, umbilical care, method and time of colostrum feeding were risk factors for lamb morbidity, while birth weight, lambing difficulty, dams' parity, method and time of colostrum feeding were risk factors for lamb mortality at all ages, whereas birth season had did not affect morbidity. Infectious diseases such as diarrhea and pneumonia were the leading cause of lamb mortality followed by mismothering, predators, management issues, and unknown reasons. Diarrhea, pneumonia, dysentery, internal parasites, and constipation were found to be the most common lamb diseases in the study area. Diseases, a lack of animal health specialists, a lack of medications, and the period between vaccinations were all listed as restrictions to sheep production in the study area.

In conclusion, to reduce lamb mortality and morbidity, an appropriate package should be created and implemented. Husbandry strategies that can reduce the loss of young stock be made more widely known to livestock owners. It is necessary to establish and implement proper veterinarian service and disease detection mechanisms. As a result, all of these can help to lessen the various risk factors and their negative impacts. Moreover, further extensive examinations of lamb morbidity and mortality should be conducted to assess the actual effect of lamb morbidity and mortality on sheep production in the research region.

Methods

Study area

This study was conducted in the Gewata district of Kaffa Zone, southern Ethiopia, it is located about 600 km and 869 km from Addis Ababa. From an agroecological point of view, the Gewata region is 10% lowland (< 1,500 m.a.s.l), 55% mid-altitude (1,500–2,300 m.a.s.l),

and 35% highland (>2,300 m.a.s.l). The altitude is between 1400 m and 2,700 m above sea level. Gewata woreda is located between 34°45′ to 36°10′ east longitude and 5°40′ to 7°40′ north latitude (Fig. 3). The average annual temperature is 13 to 36 degrees Celsius and the annual rainfall is 900 to 1400 mm. Beekeeping and mixed crop production are the main sources of income for the majority of the population. The main crops grown in the region are grains such as wheat, barley, teff, legumes, maize, and anise. The main livestock raised in the region is cattle (105,558), sheep (25,948), goats (21,748), horses (9,629), mules (1,012), donkeys (1,193), chickens (123,070), and hives (82,969) (GDLFO 2020).

Study subjects and animals

Smallholder farmers in selected districts were the target populations. They were chosen at random fashion from six kebeles (peasant associations) (PA). The Indigenous breed of sheep also known as the "Bonga" breed/type were the study animals. The study involved birth-to-weaning lambs kept under extensive, semi-intensive, traditional systems of small-scale mixed crop-livestock production. The age of the lamb was estimated from available birth records and dentition, and eight temporary incisors develop during the first month of life. Health of each lamb was determined through detailed physical and clinical examination.

Study design

A longitudinal prospective survey was employed from June 2020 to July 2021 on 408 randomly selected farmers located in six purposively selected kebeles in Gewata woreda, to determine the cumulative incidence of morbidity and mortality in lambs and to identify potential risk factors. These were intended to collect a one-year data set (June 2020 to July 2021) of lamb morbidity and mortality. Traditional survey methodologies, as well as participatory epidemiology tools and data collection and interpretation concepts, were used in the study. Lamb owners who own animals took part in determining the reasons and assessing the effect of lamb morbidity and mortality, as well as other limits on sheep productivity. Dates of birth, birth weight, sex, type of birth, and date of death of lambs were gathered from the animals' data recording book of the community-based Bonga sheep breed improvement cooperatives.

Sample size determination and sampling methods

The sample size was determined using Arsham formula (Arsham 2005).

$$N = \frac{0.25}{SE^2}$$

Where SE is the standard error.

By considering the standard error of 0.05 with a 95% coefficient interval, $N = 0.25/0.05^2 = 100$. However, 408 animal owners participated in the questionary survey from the six kebeles during the survey to increase precision.

The number of participants was selected on a household basis from the six study sites. These six sites/kebeles were selected since they were the main target site of the project of the Bonga breeding center. Moreover, the households were chosen based on criteria such as accessibility, the presence of greater than two lambs, the livestock-crop mixed production system, animal owners' experience in extension programs, and owners' willingness to participate in the study.

Data collection methods and sources

Data were obtained from primary and secondary data sources used during the study period. Primary data were collected through semi-structured interviews, FGD, farm observations and 408 purposively selected households. During the interview, major causes of lamb morbidity and mortality were assessed.

Observational study and clinical examination

The study involved monitoring lamb morbidity and mortality in selected six sites during the study period. All lambs in the selected flock were strictly monitored starting from birth to weaning age. The regular follow-up and clinical examinations were done by veterinarians who were working in the breeding center as well as animal health extension workers assigned by the District Agricultural Office. Veterinarians visited the lambs every month, and the investigators performed emergency visits in addition to routine visits when there was a need for a health evaluation of the lambs in response to a request from flock owners. Every day, animal health extension workers visited the research animals and recorded their health status using a recording format.

During the farm visit, lambs with apparent signs of ailment were subject to a detailed clinical examination. A change in vital signs (rectal temperature, heart rate, respiratory rate, the color of mucous membranes, palpation of superficial lymph nodes, skin condition, joints, and feet examination, depressed mentation, poor suckle reflex, weakness and recumbency) discovered during the examination was documented on a predetermined format. Moreover, lambs' health was evaluated *via* objective criteria of appetite, fecal consistency, hydration status, and behavior. After these detailed clinical and physical examinations, animals were categorized as "apparently healthy" or "diseased" (Hadgu et al. 2021; Mohammed et al. 2020).

Questionnaire survey and focus group discussion

A semi-structured questionnaire was developed to collect information on the potential factors associated with the risk of lamb morbidity and mortality in the study area. The questionnaire was pre-tested and administered in person to the farmer if one was available, or to an animal health worker most responsible for animal management. The information gathered includes variables at the lamb and flock levels, as well as other farm management practices.

Focus group discussion (FGD) was conducted using a purposive sampling technique with farmers having indigenous knowledge of animal disease experience to acquire relevant information. A total of 54 participants were selected (each focus group with six participants with a total of nine FGDs from six kebeles). Interviews with key informants (Site animal health assistance and animal production experts) were used purposively. Additionally, the diseases that affect lambs in the area, as well as their local names, seasons of occurrence, and traditional treatments for lamb ailments, are all discussed during the FGD. Finally, FDG were used to rate illness severity and age groups in distinct lamb diseases with recognized local names. Secondary data were also gathered from the district livestock and fishery office and extensively published data at the study site (Supplementary file).

Description of the variables

Outcome variable: The morbidity or mortality of lambs from birth to three months is the outcome (dependent or response) variable for this study. Because the variables are dichotomous (yes or no), they were labeled with a 1 if the event of interest occurred, and a 0 if it did not occur during the study's observation period.

Independent variables: The current study considers sex, lambing season, weaning age, flock size, birth weight lambing difficulty, dam's parity number, umbilical care (yes/no), a mix of the lamb of different ages, time lamb ingested their first colostrum meal, method of colostrum feeding, hygiene, and farmers' educational status as potential independent variables or predictors of lamb morbidity and mortality. The month in which the study lamb was born is referred to as the lambing season. Thus, months with short to heavy rain (April–August) are labeled "wet season," while months with no rain (September–March) are labeled "dry season."

Data analysis

Data from questionnaire interviews and focus group discussions were entered and stored in an MS Excel spreadsheet for later data management and analysis using STATA 13 statistical software. Morbidity and mortality rates were calculated using the true incidence rate, which was defined as the number of new cases of diseased cases/mortality that occurred during the follow-up period divided by the number of lamb months-at-risk (Sullivan 2016). For the morbidity rate, the time at risk was measured from the start of the study until the lamb developed a clinical sign of any illness. Furthermore, a lamb that had one illness was considered to be at risk for another. The mortality risk time was calculated from the time a lamb is enrolled in the study (soon after birth) until death from any cause occurs. A lamb with a disease condition was also considered to be at risk of death. Lamb who dropped out (lost to follow-up) from the study before the end of the observation period or who remained event-free (morbidity or mortality) at the end of the observation period were censored, which is known as right censoring.

Time-to-event data were analyzed using non-parametric and semi-parametric methods. The Kaplan-Meier (K-M) lifetable analysis, a popular non-parametric approach, was used to compute and describe in tabular form the cumulative survival probability and cumulative incidence of lamb morbidity and mortality from birth to three months of age. Furthermore, the K-M curves were used to plot cumulative survival data based on age groups and exposure factors studied. The survival probability was calculated using the K-M approach and the formula in Eq. (1)

$$St\beta 1 = St*((Nt\beta 1 - Dt\beta 1)/Nt\beta 1) \quad (1)$$

where St is survival probability past interval t; Nt is the number at-risk during interval t; and Dt is the number of disease events or deaths during interval t. The cumulative incidence, or cumulative failure probability, was easily calculated as 1-St using the K-M approach. Censoring was assumed to be independent of the likelihood of developing the outcome event, and survival probabilities were assumed to be comparable in participants recruited early and late in the study (non-informative censoring). The log-rank test was used to statistically test the hypothesis that there is no difference in the survival curves between the groups of categorical predictors studied and to determine whether the predictor should be included in the final model. To select a variable for the multivariable model, a *P* value cut off at 0.25 from the log-rank test was used as a criterion.

A multivariable Cox proportional hazards regression model, a semiparametric approach, was used to analyze risk factors associated with lamb morbidity

and mortality. The utilized Cox proportional hazards regression model is denoted by Eq. (2)

$$h(t) = h(t) ¼ h0(t) \exp (\beta 1X1 þ \beta 2X2 þ \ldots \beta pXp) \quad (2)$$

where h(t) is the expected hazard at time t, h0(t) is the baseline hazard, X1, X2, Xp are the predictors (or independent variables), and β1 þ β2 þ.... βp are the coefficients for each independent variable. The baseline hazard is the risk that exists when each independent variable is equal to zero. The Cox model analyzes the time to event about multiple factors at the same time and provides estimates of the strength of the effect (hazard ratio, HR) for each constituent factor. The final model was constructed by stepwise backward elimination of variables that were not significant at the 5% level. Potential confounders were controlled at every stage of model construction. A variable was considered a confounder if the coefficients of the remaining variables changed by 20%, and these were kept in the model even if they were not significant. The Cox proportional hazard model assumed that the hazards are proportional, which means that the relative hazard remains constant over time with different predictors or covariate levels (49). We used the Schoenfeld and scaled Schoenfeld residuals to test the proportionality assumption. We also looked at the KM curves of the predictors for the crossing to see if they were proportional. $P < 0.05$ were considered statistically significant.

Abbreviations

GWLFO	Gewata Woreda Livestock and Fishery Office
CSA	Central Statistical Agency
FGD	Focus Group Discussion
ILCA	International Livestock Center for Africa
NM	Neonatal Mortality
PWMR	Pre-Weaning Mortality Rate
SME	Starvation Mis -mothering Exposure.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s44149-023-00074-y.

Additional file 1. Questionnaire on Study on Incidence of Lamb Morbidity and Mortality and Associated Risk Factors in the Mixed Crop-Livestock Production System of Gewata District, Kaffa Zone, Southwestern Ethiopia.

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Authors' contributions
HF and GG contributed to the study conception and design, data collection, data analysis, and manuscript writing. HF, GG, IA, and TE participated in data analysis, reviewing, and manuscript editing. All authors read and approved the submission of the manuscript.

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Availability of data and materials
The data will be provided upon the request of the corresponding author.

Declarations

Ethics approval and consent to participate
The Institutional Review Board of Wolaita Sodo University (IRB) has approved the ethical approval of the current study. The purpose of the study was communicated to the participants and informed consent was obtained using oral informed consent approved by the institutional ethics committee. Throughout the investigation, identifiers such as personally identifiable information have been excluded and kept confidential. Photos and videos of study participants were kept anonymous. Participation in the study was completely optional. Those who do not want to participate or wish to end their participation have been given the freedom to do so.

Consent for publication
Not applicable.

Competing interests
All authors declare no competing conflicts of interest.

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