Anwar *et al. Animal Diseases* (2024) 4:46
https://doi.org/10.1186/s44149-024-00153-8

Animal Diseases

ORIGINAL ARTICLE Open Access

Epidemiological study of lamb and kid morbidity and mortality rates and associated risk factors in an extensive management system in the Dalocha district, Silte Zone, Central Ethiopia

Redwan Anwar[1], Rahmeto Abebe[2*] and Desie Sheferaw[2]

Abstract

Small ruminants are vital to the economy of Ethiopia and significantly contribute to the livelihoods of resource-poor farmers. However, poor management practices and high mortality rates among young lambs and kids have hindered their economic potential. A prospective cohort study was conducted in three rural villages in Dalocha district with the aim of estimating morbidity and mortality rates among these animals and identifying associated risk factors. The study monitored 130 lambs and kids every 15 days from birth to three months and recorded health events and deaths. Data analysis utilized Kaplan–Meier survival analysis, log-rank tests, and multivariate Cox proportional hazard regression. The results revealed an overall morbidity rate of 0.58 and a mortality rate of 0.2 cases per 100 lamb days at risk for lambs, whereas the rates of morbidity and mortality for kids were 0.27 and 0.1 cases per 100 kid days, respectively. Respiratory issues were the leading health problem, accounting for 35.9% of morbidity cases, whereas diarrhea accounted for 38.5% of deaths. The hazard of morbidity was 2.1 times greater for lambs than for kids (HR = 2.1; $p = 0.039$). Additionally, the morbidity hazard was significantly greater in lambs and kids from multiparous dams (HR = 3.8, $p = 0.017$) but 89% lower in vaccinated flocks (HR = 0.11, $p = 0.001$). The identified risk factors for mortality included litter size and maternal behavior. Twin-born lambs and kids presented a mortality hazard that was 6.31 times greater than that of singletons (HR = 6.31; $p = 0.025$), whereas offspring from dams with poor mothering presented a mortality hazard that was more than 24 times greater (HR = 24.56; $p = 0.006$) than that of offspring from normal mothers. This study underscores the need for improved maternal care, access to colostrum, better bonding, and suitable environments for multiple births to reduce morbidity and mortality rates among lambs and kids. Further research into the specific causes of these issues is recommended.

Keywords Ethiopia; Incidence, Kids, Lambs, Morbidity, Mortality, Risk factors

Handling editor: Chang Cai

*Correspondence:
Rahmeto Abebe
rahmetoabe@gmail.com
Full list of author information is available at the end of the article

Introduction

Small ruminants play a critical role in agricultural livelihoods in low- and middle-income countries, with approximately 80% of the global small ruminant population found in these regions (Simpah et al., 2023). They contribute to the food supply, serve as a source of income and employment, function as a store of value, improve soil fertility, and support agricultural diversification and sustainable production. These animals are especially beneficial to impoverished communities in Africa because of their low maintenance needs (Kumar and Roy 2013). However, high preweaning mortality rates pose significant economic challenges and hinder productivity in sheep and goat farming globally (Abdelqader et al. 2017; Chauhan et al. 2019; Allan et al. 2023; Chen et al. 2024).

The mortality rates of young lambs and kids can be quite high, particularly in areas with extensive grazing systems. Globally, preweaning mortality for lambs averages 15-20% (Flinn et al. 2020). However, in the tropical rangelands of Africa, India, and Australia, these rates can exceed 30% for goats (Chen et al. 2024). In sub-Saharan Africa, lamb mortality varies from 9 to 76% among different sheep populations and is influenced by age, breed, and production system. There is an urgent need to improve sheep production efficiency in low-input farming systems by reducing lamb mortality (Mthi et al. 2020). Research indicates that genetic, environmental, and management factors contribute to high lamb and kid mortality rates. These factors include low birth weight, sex, dam parity, age and body weight during lambing or kidding, inadequate colostrum immunoglobulin transfer, lambing/kidding season and year, litter size, dystocia, and poor maternal behavior (Ibrahim et al. 2020; Flinn et al. 2020; Bangar et al. 2022; Ceyhan and Kozaklı, 2023; Chen et al. 2024).

Ethiopia boasts Africa's largest small ruminant population, with an estimated 43 million sheep and 53 million goats (Central Statistical Authority (CSA), 2021). These animals are vital for the livelihoods of small-scale farmers and pastoralists in the country and are primarily used for milk, meat, wool, manure, cash, and risk management. The loss of young livestock can have severe implications for these communities. Data from 2020 indicate significant mortalities, with 6.51 million sheep (15.1%) and 8.74 million goats (16.5%) lost nationally (CSA, 2021). The mortality rates vary between 14.9–33.5% for lambs and 17.6-24% for kids in mixed crop–livestock systems. In pastoral settings, mortality rates range from 35-36% for lambs and kids (Fentie et al. 2016), resulting in substantial economic losses. Therefore, increasing the survival rates of young sheep and goats is crucial for flock sustainability and genetic improvement in the long run (Hamito 2011).

Given the large population of small ruminants in the country, there is limited information available on the preweaning mortality and morbidity of lambs and kids, as well as their causes in Ethiopia (Petros et al. 2014; Fentie et al. 2016; Hadgu et al. 2021; Dessie and Tilahun 2022; Assefa et al. 2023; Fesseha et al. 2023; Besufkad et al. 2024). Previous studies have mostly used a cross-sectional design, which only measures the prevalence of morbidity and mortality at a single time point. Additionally, these studies focused on only one species, either sheep lambs or goat kids. Prospective cohort studies are better suited for establishing cause–and–effect relationships and generating morbidity and mortality incidence rates. To address this information gap, our current study followed newborn lambs and kids until they reached three months of age-a critical period for their survival and future productivity. This study aimed to estimate the incidence rates of lamb and kid morbidity and mortality and identify the major associated risk factors via a prospective cohort study design.

Results

Lamb and kid morbidity and mortality rates

Among the 130 animals (74 lambs and 56 kids) monitored from birth to three months, 39 (30%) had clinically apparent health problems, whereas 13 (10%) died from different causes. The overall morbidity rate was 0.44 cases per 100 animal days at risk, with 0.27 and 0.58 for kids and lambs, respectively. The overall mortality rate was 0.15 cases per 100 animal days at risk, with 0.1 and 0.2 for kids and lambs, respectively (Table 1). The morbidity and mortality rates are displayed according to different age categories. The morbidity and mortality rates were higher in the first month of life and then tended to decrease with increasing age of the lambs and kids (Table 2).

Table 1 Morbidity and mortality rates of lambs and kids in the study area according to the species of animals

Species	Animals at risk	Time at risk in days	Cases	IR/100 animal days	95% CI for IR
Morbidity					
Kids	56	4012	11	0.27	0.15 – 0.5
Lambs	74	4866	28	0.58	0.4 – 0.8
Total	130	8878	39	0.44	0.3 – 0.6
Mortality					
Kids	56	4012	4	0.1	0.04 – 0.3
Lambs	74	4866	9	0.2	0.1 – 0.4
Total	130	8878	13	0.15	0.1 – 0.3

Table 2 Morbidity and mortality rates by age group for lambs and kids in the study area

Age interval (days)	Animal-time at risk (days)	Cases	Incidence rate/100 animal days	[95% Conf. Interval]	
				Lower limit	Upper limit
Morbidity					
0-30	3778	18	0.48	0.3	0.76
31-60	3031	13	0.43	0.25	0.74
61-90	2069	8	0.39	0.19	0.77
Mortality					
0-30	3778	8	0.21	0.11	0.42
31-60	3031	2	0.066	0.017	0.26
61-90	2069	3	0.14	0.047	0.45

Cumulative incidence of morbidity and mortality

In addition to morbidity and mortality rates, we also calculated the cumulative incidence of all-cause morbidity and mortality in lambs and kids via the K–M life table approach. The cumulative incidence of morbidity was 33.8%, and the cumulative incidence of mortality was 13.56% during the follow-up period. This finding indicates that the probabilities of lambs and kids surviving morbidly and dying during their first 3 months of life were 66.2% and 86.44%, respectively. During the course of the study, a total of 18 lambs and kids were lost to follow-up. Of these, 13 were lost due to mortality, whereas the remaining five were sold along with their dams. These lost animals were classified as censored, and these censored data were taken into account in the incidence rate calculation to ensure unbiased and accurate results (Table 3). In terms of animal species, the cumulative incidence of all-cause morbidity was 43.8% (95% CI: 32.06-57.66%) in lambs and 20.86% (95% CI: 12.01-34.8%) in kids. Moreover, the cumulative incidence of all-cause mortality was 15.96% (95% CI: 8.2-29.77%) in lambs and 10.36% (95% CI: 3.89–26.02%) in kids (Supplementary file, SF1).

To better visualize the cumulative survival probability of lambs and kids from birth to 3 months, we plotted the survival data via K–M curves. Notably, lambs had a lower survival probability for mortality than did kids during the follow-up period (Fig. 1).

Causes of morbidity and mortality

Among the health events observed during the follow-up period, respiratory problems were the leading (35.9%) cause of morbidity, whereas diarrhea was the leading (38.5%) cause of mortality. The various disease events responsible for morbidity and mortality are shown in Table 4.

Risk factors associated with morbidity and mortality rates

This study assessed the impact of 18 distinct host and management factors on lamb and kid morbidity and mortality via the log-rank test. Variables with p values less than 0.25 were selected for multivariable analysis,

Table 3 Cumulative incidence of all-cause morbidity and mortality in lambs and kids based on age in the Dalocha district

Age interval (days)	Animals at risk	Cases	Lost	Cumulative incidence (%)	[95% Conf. Int.]	
					Lower limit	Upper limit
Morbidity						
0-30	130	17	0	13.08	8.34	20.19
31-60	113	14	3	23.99	17.52	32.33
61-90	96	8	68	33.80	25.65	43.67
91 -	20	0	20	33.80	25.65	43.67
Mortality						
0-30	130	7	10	5.60	2.71	11.39
31-60	113	2	15	7.39	3.91	13.74
61-90	96	4	72	13.56	7.85	22.88
91 -	20	0	20	13.56	7.85	22.88

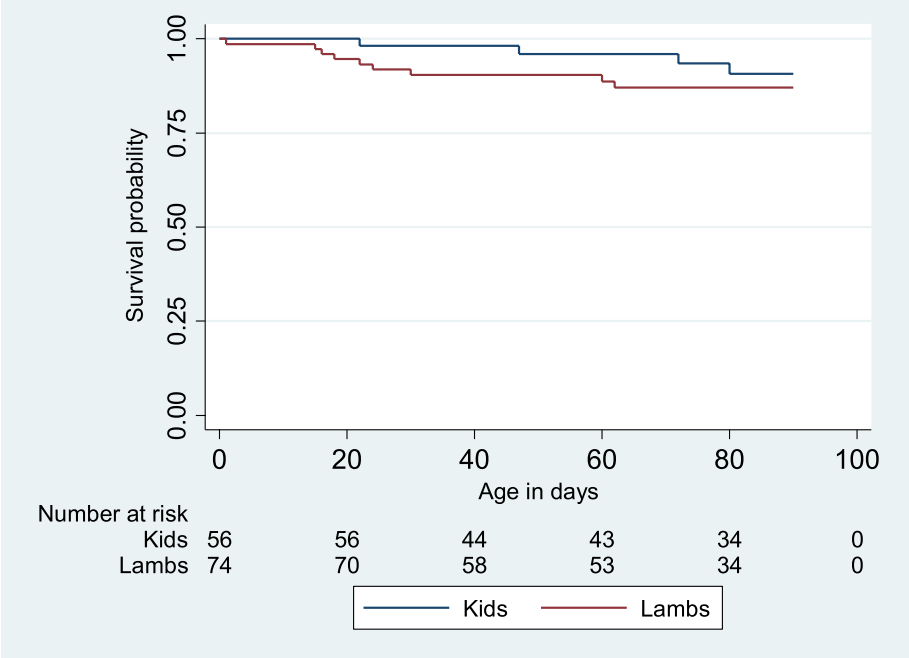

Fig. 1 Kaplan-Meier mortality survival estimates of lambs and kids from birth to three months

Table 4 Major causes of morbidity and mortality in the 130 lambs and kids monitored in the study

Disease events	Morbidity (N = 39)		Mortality (N = 13)	
	No. of cases	Percentage (%)	No. of cases	Percentage (%)
Diarrhea	10	25.6	5	38.5
Respiratory problem	14	35.9	3	23.1
Emaciation	13	33.3	1	7.7
Circling	2	5.1	1	7.7
Accident	-	-	3	23.1

resulting in nine factors for both morbidity and mortality (Table 5).

Morbidity rate

In a multivariable Cox regression analysis, nine variables were evaluated to determine their associations with the morbidity rates of lambs and kids. The host species, parity, and flock vaccination history were significantly associated with the morbidity rate ($p < 0.05$). The final model indicated that the risk of morbidity was 2.4 times greater in lambs than in kids. Moreover, lambs and kids born to multiparous dams presented a hazard that was 3.8 times greater than those born to primiparous dams. Additionally, lambs and kids from vaccinated flocks experienced an 89% reduction in hazard compared with those from unvaccinated flocks, while all other factors remained constant (Table 6). Importantly, the final model met the proportional hazards assumption, as the p values were greater than 0.05 for the global test and for each covariate considered (Table 7).

Mortality rate

In the final multivariable Cox hazard regression analysis, litter size and maternal behavior significantly affected the mortality rates of the lambs and kids ($p < 0.05$). The hazard of mortality was found to be 6.31 times greater for twins than for singletons ($p = 0.025$). Additionally, lambs and kids born to dams with poor mothering behavior had a hazard of mortality that was 24.56 times greater than that of those with adequate mothering ($p = 0.006$), while the effects of other variables remained constant (Table 8). The final model was validated for the proportional hazards assumption, with all p values exceeding 0.05, confirming that no violations occurred (Table 9).

Table 5 Univariate analysis of risk factors for lamb and kid morbidity and mortality via the log-rank test

No	Variable	Morbidity		Mortality	
		χ^2	*P*	χ^2	*P*
1	Kebele (Enqatagam, Golecheba, Wanjashola)	1.13	0.5675	0.30	0.8612
2	Flock size (≤ 10/ > 10)	1.32	0.2515	0.36	0.5470
3	Species (kid/lamb)	4.50	0.0340	1.03	0.3105
4	Sex (male/female)	0.34	0.5576	2.63	0.1047
5	Litter size (single/two)	3.27	0.0707	5.07	0.0243
6	Birth condition (by self/assisted)	0.17	0.6804	1.94	0.1640
7	Birth time (day/night)	2.97	0.0849	5.30	0.0214
8	Place of birth (indoor/outdoor)	1.10	0.2941	3.23	0.0723
9	Floor type (smooth and dry/rough and dusty)	1.99	0.1584	3.89	0.0486
10	Colostrum feeding (self/assisted)	0.13	0.7197	2.63	0.1048
11	Mothering behavior (poor/normal)	1.68	0.1954	7.27	0.0070
12	Parity (primiparous/multiparous)	2.54	0.1110	0.00	0.9903
13	Vigor (poor/good)	0.01	0.9344	0.93	0.3343
14	Care to dams (neglected/care given)	0.28	0.5939	0.09	0.7624
15	Knowledge about colostrum (no/yes)	2.11	0.1461	0.26	0.6133
16	Flock keeping (near homestead/left free)	0.02	0.8818	0.60	0.4388
17	Lamb/kid housing (together with the dam/apart from the dam)	0.00	0.9490	0.93	0.3342
19	Flock vaccination (no/yes)	6.72	0.0096	0.81	0.3683

Table 6 Risk factors associated with lamb and kid morbidity according to the final Cox regression model

Factors	Category	Morbidity rate/100 animal time	Hazard Ratio (HR)	[95% Conf. Interval]		z value	*P* value
Host species	Kids	0.27	1				
	Lambs	0.58	2.4	1.24	4.97	2.54	0.015
Parity	Primiparous	0.24	1				
	Multiparous	0.50	3.8	1.26	11.21	2.48	0.017
Flock vaccination	No	1.47	1				
	Yes	0.41	0.11	0.03	0.39	−3.46	0.001

Table 7 Test of the proportional hazards assumption of the Cox regression model for morbidity

Variable	rho	chi2	df	Prob > chi2
Species	0.14704	0.92	1	0.3378
Parity	0.09842	0.44	1	0.5070
Flock vaccination history	−0.17291	1.44	1	0.2296
global test		1.97	3	0.5788

Discussion

This prospective cohort study evaluated the incidence rates and cumulative incidence rates of morbidity and mortality in lambs and kids under extensive management systems. While several studies in Ethiopia have employed similar designs (Petros et al. 2014; Fentie et al. 2016; Hadgu et al. 2021; Dessie and Tilahun 2022; Yitagesu and Alemnew 2022; Assefa et al. 2023; Fesseha et al. 2023; Besufkad et al. 2024), most have focused on calculating morbidity and mortality rates as simple proportions of all examined animals, treating morbidity and mortality as binary outcomes. Additionally, the calculation methods for morbidity and mortality rates vary globally, with inconsistent operational definitions. According to strict definitions, a "rate" should describe metrics on the basis of animal-time units, specifically as a ratio where the denominator is the total animal-time units at risk (Dohoo et al. 2009). Our estimates of morbidity and mortality rates align with this standard definition. However, since previously published

Table 8 Risk factors for the mortality rates of lambs and kids according to the final Cox regression model

Factors	Category	Mortality rate/100 animal time	Hazard Ratio (HR)	95% CI for HR		z value	*P* value
				Lower limit	Upper limit		
Litter size	Single	0.048	1				
	Two	0.24	6.3	1.26 –	31.53	2.24	0.025
Mothering behavior	Normal	0.14	1				
	Poor	1.2	24.6	2.51	240.33	2.75	0.006

Table 9 Test of the proportional hazards assumption of the Cox regression model for mortality

Variable	rho	chi2	df	Prob > chi2
Litter size	−0.24786	1.01	1	0.3141
Mothering behavior	−0.17093	0.39	1	0.5338
global test		1.10	2	0.5774

studies used different calculation methods, we could not directly compare our results with those studies (Gebremichae et al. 2023).

This study revealed that lambs had a significantly greater morbidity hazard than did kids. While lambs also presented a higher mortality rate, the difference was not significant. These findings support the general belief among farmers that goats are hardier and survive better than sheep. However, these findings contrast with some studies that state that goats may be more susceptible to certain infections, especially gastrointestinal parasites (Bishop and Morris 2007). In contrast to our study, a higher mortality rate was reported in kids than in lambs in Jordan (Al-Khaza'leh et al. 2019). Thus, we recommend further studies to verify genetic variations in morbidity and mortality rates between lambs and kids in Ethiopia through controlled experiments.

Lambs and kids born to multiparous mothers had greater hazards of morbidity than those born to primiparous mothers did. This finding contradicts other studies, which generally indicate that first-parity goats (female goats) tend to have higher mortality rates among their offspring (Chauhan et al. 2019; Singh et al. 2022). It has been reported that first parity may be associated with low milk production and colostrum quality. They may also have less maternal experience and ability to care for their kids, especially if they have multiple births (Chen et al. 2024). This discrepancy between the present study and other studies regarding the association of parity with preweaning morbidity in small ruminants may be due to variations in flock management and environmental conditions. However, the present findings must be elucidated in future studies.

The association between flock vaccination and morbidity in lambs and kids was significant in the multivariable Cox regression model, which revealed that vaccinated flocks had notably lower morbidity rates. This lower morbidity is likely linked to enhanced immunity against diseases that can adversely affect young lambs and kids. Research suggests that vaccinated mothers produce higher-quality colostrum, which is vital for the survival and health of newborns. As a result, this leads to reduced morbidity and mortality rates. In one study, the morbidity and mortality rates in the early life of offspring were nearly nonexistent in vaccinated flocks compared with those in unvaccinated flocks (Burezq and Razzaque 2018).

This study revealed a strong association between litter size and mortality rates in lambs and kids, with twins experiencing a 6.31-fold greater hazard of mortality than single-born offspring. This finding is consistent with other research showing that single-born lambs and kids generally have lower mortality rates (Ahmed et al. 2010; Ceyhan and Kozaklı, 2023) or kids (Chauhan et al. 2019; El-Raghi and Hashem 2022; Yitagesu and Alemnew 2022; Singh et al. 2022; Chen et al. 2024). These findings suggest that increased litter size is correlated with higher mortality rates, likely due to lower birth weights in multiple generations, which hinders their resilience against environmental stressors and affects their ability to nurse colostrum. Additionally, competition for access to teats can limit colostrum intake among multiple births (Chen et al. 2024). Multiple plants typically exhibit lower energy levels, making them less vigorous, slower to stand, and less likely to suckle frequently, which increases their risk of starvation and death. Moreover, mothers take longer to care for multiple young people (Ahmed et al. 2010; Chauhan et al. 2019; El-Raghi and Hashem 2022). These issues underscore the need for targeted care and management for multiborn lambs and kids, especially those with low birth weights, to increase their survival and growth.

The current study identified poor maternal behavior as a significant risk factor for the mortality of lambs and kids, increasing their hazard for death by 24.56 times. This finding corroborates earlier research by Petros et al. (2014) and emphasizes the vital role of maternal

care in sheep and goat populations. Insufficient nurturing behaviors, such as failing to clean newborns, encouraging nursing, or providing warmth and protection, are linked to lower survival rates (Mora-Medina et al. 2016; Lévy 2022). This highlights the essential role of maternal behavior in the survival and welfare of newborn animals. Effective maternal practices not only improve offspring survival but also enhance their overall health and quality of life. Addressing poor maternal behavior should be a priority in efforts to improve the well-being and productivity of these livestock populations. By enhancing maternal care, we can reduce the significant mortality risks faced by lambs and kids, leading to more sustainable breeding outcomes.

The inclusion of age in the Cox regression model was challenging because the outcome event was age dependent. However, analyzing morbidity and mortality rates by age separately revealed higher rates in the first month of life, which then declined as lambs and kids grew older. Similarly, previous studies in Ethiopia reported the greatest risk of lamb and kid morbidity and mortality in the first month of life, regardless of the production system, which then decreased with increasing age (Fentie et al. 2016; Chauhan et al. 2019; Fesseha et al. 2023).

This investigation revealed that respiratory problems, specifically pneumonia, are the primary causes of morbidity and mortality in young stock, with diarrhea being the leading cause of death among lambs and kids. These results align with findings from several studies in Ethiopia and elsewhere (Sharif et al. 2005; Fentie et al. 2016; Todd et al. 2019; Al-Khaza'leh et al., 2019; Fesseha et al. 2023). In contrast, Hadgu et al. (2021) identified malnutrition as the primary cause of lamb mortality, followed by diarrhea and respiratory problems. Martella et al. (2015) noted that diarrhea in lambs and kids is a complex syndrome associated with various infectious agents, emphasizing the importance of identifying these pathogens for effective treatment and control. Future research in the study area or throughout Ethiopia should focus on isolating the specific agents responsible for diarrhea. While pneumonia is typically linked to common respiratory pathogens, it can also stem from decreased immunity in lambs and kids due to environmental stress or management changes. Improving health management practices—such as maternal nutrition, ventilation, and disease prevention—could reduce mortality from respiratory infections (Swarnkar and Sonawane 2024). The primary causes of illness and death in small ruminants appear to vary by age: 60% of diarrhea cases occur in the first month of life, whereas 71.4% of respiratory issues arise at later ages. Our findings corroborate those of Bangar et al. (2022), who reported that digestive diseases predominated as causes of death in the first month, whereas respiratory diseases became more common as lambs aged.

Limitations

The study had a duration of only four months, which limited our follow-up to a small number of newborn lambs and kids until weaning. A longer study period would have enabled us to track more animals into their yearling age, yielding more valuable data. This is the main limitation of our research. During the study, only 13 cases of lam and kid death were recorded, which is an insufficient sample size for developing a robust risk model; this represents another limitation of our study. Research has indicated that birth weight and seasonal variations are significant factors impacting the survival of lambs and kids during the preweaning period (Bangar et al. 2016; Abdelqader et al. 2017; Besufkad et al. 2024; Chen et al. 2024). However, these factors were not addressed in our study, adding to the limitations. Additionally, we could not determine the specific causes of morbidity and mortality in young small ruminants due to inadequate diagnostic facilities, which further restricts the scope of our findings.

Conclusion

The study revealed the morbidity and mortality rates of lambs and kids in the extensive production system of Dalocha District, central Ethiopia, on the basis of standard metrics. The morbidity hazard was significantly greater in lambs than in kids and among lambs and kids from multiparous dams but lower in vaccinated flocks. Additionally, mortality hazards were notably greater in twin-born lambs and kids, as well as in offspring from dams with poor mothering behavior. Therefore, we recommend a comprehensive approach to managing sheep and goat health in the district, which includes vaccination for ewes and does near parturition against prevalent infectious diseases, improved care for twin-born lambs and kids, and strategies to increase their rearing success. This study also emphasizes the need for careful selection of maternal traits in breeding programs to improve the health and survival rates of young livestock. Educating farmers on maternal care practices is crucial to foster bonding between mothers and offspring and to create a suitable environment, especially for ewes, who give birth to multiple offspring. Furthermore, future studies should consider isolating the specific causes of lamb and kid morbidity and mortality.

Methods

Study area

The study was conducted in Dalocha District, Siltie Zone, Central Ethiopia. Geographically, the district is situated

at 7°46′60" N and 38°15′0" E, with altitudes ranging from 1500–2400 m.a.s.l. The study area's location is illustrated in Fig. 2. The climate of the area is classified as semihumid ("moist woina dega"), with annual rainfall between 900 and 1400 mm and annual temperatures ranging from 24–29 °C. The livelihood of people is based on a mixed crop–livestock production system. Livestock reared in the area include cattle, sheep, goats, chickens, horses, mules and donkeys (Lagiso and Geta 2019). According to unpublished data from the Silte Zone Plan Commission, in 2023, the Dalocha district had 149,815 cattle, 76,987 sheep, 73,686 goats, 960,712 chickens, 565 horses, 70 mules, and 22,902 donkeys.

Study design and study population

This study conducted a prospective cohort analysis of lambs and kids for morbidity and mortality from birth to three months of age every 15 days between February and May 2023. In the Dalocha district, local sheep and goat breeds were predominant, with some Bonga and Doyogena sheep introduced from other Ethiopian regions by the local government and Boar and Toggenburg goats donated by nongovernmental organizations, especially in Enqatagam kebele. Flock sizes ranged from 2 to 31 animals per household. In Dalocha District, similar to other parts of the country, sheep and goat management practices are predominantly traditional and extensive. These practices encompass shared housing with humans, free-ranging for grazing and foraging, and water sources from homes and rivers. The breeding system employed is also traditional, where estrous females are mated with uncastrated mature males.

Sample size determination and sampling technique

The study district and Kebeles were purposively selected on the basis of their potential for small ruminant production and transport accessibility. Kebele is the smallest administrative unit in Ethiopia. Three Kebeles, Wanjashola, Golecheba and Enqatagam, were selected from the Dalocha district.

The sample size needed for the prospective cohort study to assess lamb and kid morbidity/mortality rates and investigate potential risk factors was determined via Epi info V. 7 software. It was based on a 95% confidence level, 80% power (ability to detect the factor of interest), a 1.74 ratio of the outcome of interest in the unexposed group to the exposed group (mortality rate ratio between the two), a 63.492% estimated mortality proportion in the exposed group (preweaned kids), and a 36.51% estimated mortality proportion in the nonexposed group (weaned kids) from prior research by Dessie and Tilahun (2022). Therefore, following this method, a sample size of 130 kids and lambs was deemed necessary. The sample size was proportionally distributed among the three kebeles. To start the study, households (farmers) were selected via systematic random sampling. One lamb or kid was then chosen from each household to maximize participation, given the small flock sizes. If multiple lambs or kids

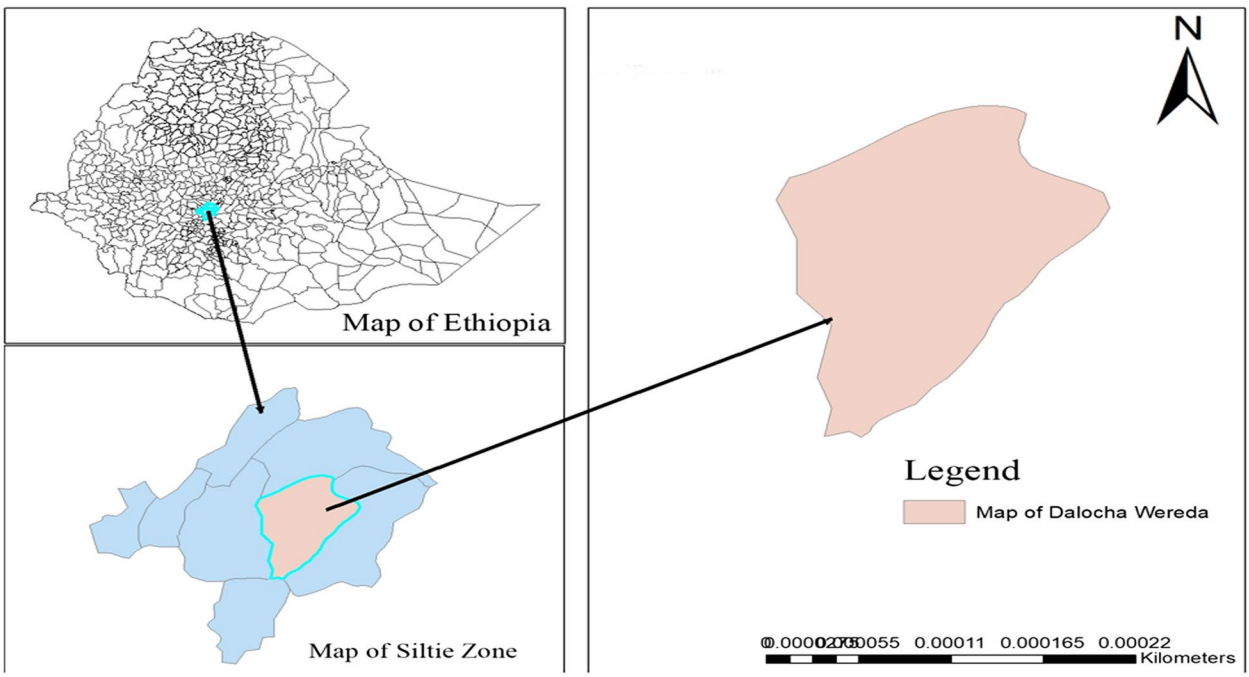

Fig. 2 Map of Ethiopia showing the study area

were present, one was selected through simple random sampling.

Inclusion and exclusion criteria

Inclusion criteria: The study included lambs and kids born within the last 14 days with known birth history and date, as well as those that were healthy at birth or had been treated and stabilized for any initial health issues.

The exclusion criteria were as follows: animals born significantly premature, those with severe congenital defects likely to impact survival or health outcomes, and those with a history of serious illness or conditions that could confound the study results.

Monitoring of lambs and kids

The lambs or kids recruited from each household were identified by coat color, sex, birth date, and birth type. All selected newborn lambs and kids were visited twice per month until they reached three months of age. Each lamb or kid was monitored a maximum of six times throughout the study period. All cases of illness and mortality among lambs and kids were recorded during each visit in a unique data-recording notebook developed for each individual. During the study, disease conditions were identified on the basis of their common symptoms (i.e., clinical signs). The date and reason for withdrwal was recorded when a lamb or kid was lost to follow-up.

During our initial visit to the selected household, we collected information on potential risk factors for lamb and kid morbidity and mortality. This included flock size, animal species, sex, birth date, litter size (single/multiple), birth condition (self/assisted), birth time (day/night), place of birth (indoor/outdoor), colostrum feeding (self/assisted), mothering behavior (poor/normal), parity (primiparous/multiparous), vigor (poor/good), care for dams (neglected/cared for), knowledge of colostrum (no/yes), flock management (near homestead/free range), lamb/kid housing (with dam/apart from dam), and flock vaccination history (no/yes).

Statistical analysis

Data collected from a questionnaire survey and monitoring of lambs and kids were organized, refined, and encoded in Microsoft Excel 2010 spreadsheets. The data were subsequently transferred to Stata V. 14.2 (Stata Corp. TX, USA, 2006) for statistical analysis. The crude cumulative incidence and incidence rates were used to estimate morbidity and mortality events. The morbidity or mortality rate was computed by dividing the number of morbidity events or deaths during the observation period by the total risk period. The periods at risk, presented as lamb/kids-days at risk, represent the complete days the animals were present during the study without experiencing disease-related incidents or perishing. The rate was expressed as per 100 lamb/kids days at risk. K-M life table analysis was used to calculate the cumulative incidence of morbidity or mortality. The survival function of the lambs and kids was also estimated via the K-M method. A log-rank test at $P<0.05$ was conducted to evaluate the likelihood of generating the observed survival curves and to test the null hypothesis, suggesting that "K-M curves are similar for different factors with no difference between them." A multivariable Cox proportional hazard model was employed to examine risk factors linked to lamb and kid morbidity or mortality rates. The final model was developed by stepwise backward elimination of nonsignificant variables. The hazard ratio (HR) along with its 95% confidence interval was utilized to demonstrate the impacts of various predictors on the outcome variable. We used the Schoenfeld and scaled Schoenfeld residuals to assess the assumption of proportional hazards in the Cox model across time with various predictors. $P<0.05$ was taken into account for significance across all statistical analysis levels.

Abbreviations

HR	Hazard ratio
CSA	Central Statistical Agency of Ethiopia
K–M	Kaplan–Meier
CI	Confidence interval

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s44149-024-00153-8.

Supplementary Material 1. Cumulative incidence of all-cause mortality in lambs and kids from birth to 90 days of age

Acknowledgements

The authors are grateful to all the farmers involved in the study for their cooperation during data collection.

Authors' contributions

RED ANW conceptualized and designed the study, was involved in data collection, and wrote the draft manuscript. RA conducted the data analysis and interpretation and was the major contributor to writing the manuscript. DS supervised the data collection and critically reviewed the manuscript. All the authors reviewed and approved the final manuscript.

Funding

Not applicable.

Data availability

The datasets used and/or analyzed during this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study received approval from the Institutional Research Ethics Committee of Hawassa University (CNCS-REC 030/2023, September 23, 2023). All methods adhered to relevant guidelines and regulations. Prior to the study, verbal informed consent was obtained from all the participating farmers.

Consent for publication
All the authors agreed with the publication of their data.

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author details
[1]College of Agriculture and Natural Resources, Department of Animal Science, Werabe University, Werabe, Ethiopia. [2]Faculty of Veterinary Medicine, Hawassa University, P.O. Box 05, Hawassa, Ethiopia.

Received: 5 August 2024 Accepted: 30 November 2024
Published online: 23 December 2024

References

Abdelqader, A., R. Irshaid, Mohammad J. Tabbaa, M. Abuajamieh, H. Titi, and A.R. Al-Fataftah. 2017. Factors influencing Awassi lambs survivorship under fields conditions. *Livestock Science* 199: 1–6. https://doi.org/10.1016/j.livsci.2017.03.007.

Ahmed, A., G.O. Egwu, H.S. Garba, and A.A. Magaji. 2010. Studies on risk factors of mortality in lambs in Sokoto, Nigeria. *Nigerian Veterinary Journal* 31 (1): 56–65. https://doi.org/10.4314/nvj.v31i1.68939.

Al-Khaza'leh, J.F., B. Megersa, and B. Obeidat. 2019. Constraints and risk factors contributing to young stock mortalities in small ruminants in Jordan. *Small Ruminant Research* 183: 106033. https://doi.org/10.1016/j.smallrumres.2019.106033.

Allan, F.K., J.T. Wong, A. Lemma, C. Vance, M. Donadeu, S. Abera, B. Admassu, V. Nwankpa, J.K. Lane, W. Smith, et al. 2023. Interventions to reduce camel and small ruminant young stock morbidity and mortality in Ethiopia. *Preventive Veterinary Medicine* 219 (12): 106005. https://doi.org/10.1016/j.prevetmed.2023.106005.

Assefa, A., A. Bahiru, and A. Tibebu. 2023. Epidemiological study on incidence and major causes of preweaning kid morbidity and mortality of Abergelle goats in Waghimra Zone, Amhara region, Ethiopia. *Blue Nile Journal of Agricultural Research (BNJAR)* 4 (1): 1–10.

Bangar, Y., S. Pachpute, and R. Nimase. 2016. The survival analysis of the potential risk factors affecting lamb mortality in deccani sheep. *Journal of Dairy, Veterinary & Animal Research.* 4 (2): 266–270. https://doi.org/10.15406/jdvar.2016.04.00114.

Bangar, Y.C., A. Magotra, P. Gaur, Z.S. Malik, and A.S. Yadav. 2022. Investigation of cause-specific pre-weaning mortality in Harnali sheep. *Tropical Animal Health and Production* 54 (5): 256. https://doi.org/10.1007/s11250-022-03255-y.

Besufkad, S., A. Abebe, T. Getachew, S. Goshme, A. Bisrat, A. Abebe, T. Zewdie, L. Nigat, A. Kebede, and S. Gizaw. 2024. Survival analysis of genetic and non-genetic factors influencing lamb survival of different sheep breeds. *Small Ruminant Research* 232: 107206. https://doi.org/10.1016/j.smallrumres.2024.107206.

Bishop, S.C., and C.A. Morris. 2007. Genetics of disease resistance in sheep and goats. *Small Ruminant Research* 70 (1): 48–59. https://doi.org/10.1016/j.smallrumres.2007.01.006.

Burezq, H.A., and M.A. Razzaque. 2018. Effects of immunizing pregnant ewes and does on the humoral immune response of secreted colostrum. *The Journal of Animal & Plant Sciences* 28 (1): 341–347. https://doi.org/10.5555/20173379381.

Ceyhan, A., and Ö. Kozaklı. 2023. The survival analysis of some environmental factors associated with lamb mortality in Awassi sheep. *Tropical Animal Health and Production* 55 (6): 409. https://doi.org/10.1007/s11250-023-03821-y.

Chauhan, I.S., S.S. Misra, A. Kumar, and G.R. Gowane. 2019. Survival analysis of mortality in pre-weaning kids of Sirohi goat. *Animal* 13 (12): 2896–2902. https://doi.org/10.1017/S1751731119001617.

Chen, L., W. Foxworth, S. Horner, M. Hitit, N. Kidane, and E. Memili. 2024. Risk factor analysis and genetic parameter estimation for pre-weaning mortality traits in Boer, Spanish, and crossbred goat ids. *Animals (Basel)* 14 (7): 1085. https://doi.org/10.3390/ani14071085.

CSA (Central Statistical Authority), 2021. Agricultural Sample Survey 2020/21 (2013 E.C). Report on Livestock and Livestock Characteristics. Volume II, Statistical Bulletin 589, Central Statistical Authority, Addis Ababa, 13. Available at: https://www.statsethiopia.gov.et/wp-content/uploads/2021/05/2013.LIVESTOCKREPORT.FINAL_.pdf

Dessie, A.S., and G.N. Tilahun. 2022. Factors affecting pre-weaning kid mortality in Boer goats and their cross with native Ethiopian goats under an intensive management. *Acta Scientific Veterinary Sciences* 4 (5): 03–11. https://doi.org/10.31080/ASVS.2022.03.0241.

Dohoo, I.R., W. Martin, and H.E. Stryhn. 2009. *Veterinary Epidemiologic Research*, 2nd ed. Charlottetown: VER Inc.

El-Raghi, A. A., Hashem, N. M., 2022. Maternal, postnatal, and management-related factors involved in daily weight gain and survivability of suckling Zaraibi goat kids in Egypt. *Animals*, 12 (20). https://doi.org/10.3390/ani12202785.

Fentie, T., Temesgen, W., Melaku, A., Assefa, G., Tesfaye, S., Fufa, F., Adane, Z., Niguse, A., Alemu, B., Wahild, F. Z., et al. 2016. Assessment of young stock mortality in major livestock production systems of Ethiopia: Feed the future USAID. University of Gondar, Ethiopia. Retrieved from https://www.researchgate.net/publication/313389765.

Fesseha, H., G. Gebremichael, I. Asefa, and T. Edaso. 2023. 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. *Animal Diseases* 3 (1): 11. https://doi.org/10.1186/s44149-023-00074-y.

Flinn, T., D.O. Kleemann, A.M. Swinbourne, J.M. Kelly, A.C. Weaver, S.K. Walker, K.L. Gatford, K.L. Kind, and W.H.E.J. Van Wettere. 2020. Neonatal lamb mortality: Major risk factors and the potential ameliorative role of melatonin. *Journal of Animal Science and Biotechnology* 11 (1): 107. https://doi.org/10.1186/s40104-020-00510-w.

Gebremichae, G., G. Gebremichae, I. Asefa, and T. Edaso. 2023. Study on incidence of lamb morbidity and mortality and associated risk factors in the mixed croplivestock production system of Gewata District, Kaffa zone, southwestern Ethiopia. *Animal Diseases* 3:11. https://doi.org/10.1186/s44149-023-00074-y.

Hadgu, A., A. Lemma, T. Yilma, and H. Fesseha. 2021. Major causes of calf and lamb mortality and morbidity and associated risk factors in the mixed crop-livestock production system in Jamma district, South Wollo, Ethiopia. *Veterinary Medicine International* 2021: 1–14. https://doi.org/10.1155/2021/6689154.

Hamito, D. 2011. Prevention of lamb and kid mortality. *Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP)*17. Technical Bulletin No.46. Available at: http://www.esgpip.org

Ibrahim, N.H., M.T. Badawy, I.A. Zakzouk, and F.E. Younis. 2020. Kids' survivability as affected by their body weight, blood biochemical indices and maternal and kids' behavior in Baladi and Shami goats under semi-arid condition. *World's Veterinary Journal* 10 (1): 105–117. https://doi.org/10.36380/scil.2020.wvj15.

Kumar, S., and M.M. Roy. 2013. Small ruminant's role in sustaining rural livelihoods in arid and semiarid regions and their potential for commercialization. In *New paradigms in livestock production from traditional to commercial farming and beyond*, 57–80. Rajasthan: Agrotech publishing academy (https://hdl.handle.net/20.500.11766/5255).

Lagiso, D., and E. Geta. 2019. Technical efficiency of red pepper production: The case of Dalocha district, southern Ethiopia. *Asian Journal of Agricultural Extension, Economics & Sociology* 37 (1): 1–8. https://doi.org/10.9734/ajaees/2019/v37i130257.

Lévy, F. 2022. The onset of maternal behavior in sheep and goats: Endocrine, sensory, neural, and experiential mechanisms. *Advances in Neurobiology.* 27: 79–117. https://doi.org/10.1007/978-3-030-97762-7_3.

Martella, V., N. Decaroa, and C. Buonavoglia. 2015. Enteric viral infections in lambs or kids. *Veterinary Microbiology* 181 (1–2): 154–160. https://doi.org/10.1016/j.vetmic.2015.08.006.

Mora-Medina, P., A. Orihuela-Trujillo, E. Arch-Tirado, P. Roldan-Santiago, A. Terrazas, and D. Mota-Rojas. 2016. Sensory factors involved in mother-young bonding in sheep: a review. *Veterinární medicína - Czech* 61 (11): 595–611. https://doi.org/10.17221/255/2014-VETMED.

Mthi, S., J.M. Rust, C.T. Mpendulo, V. Muchenje, W.J. Goosen, and Z. Mbathsa. 2020. Basic factors influencing lamb mortality under low input production systems in the Eastern Cape Province, South Africa. *Applied Animal Husbandry & Rural Development* 13: 60–68. https://doi.org/10.5555/20210168863.

Petros, A., K. Aragaw, and B. Shilima. 2014. Pre-weaning kid mortality in Adamitulu Jedokombolcha district, Mid Rift Valley, Ethiopia. *Journal of Veterinary Medicine and Animal Health* 6 (1): 1–6. https://doi.org/10.5897/JVMAH13.0211.

Sharif, L., J. Obeidat, and F. Al-Ani. 2005. Risk factors for lamb and kid mortality in sheep and goat farms in Jordan. *Bulgarian Journal of Veterinary Medicine.* 8 (2): 99–108.

Simpah, A.A.-J., P. Sasu, C. Bosch, F.P. Mabiki, Y.O. Frimpong, M.N. Emmambux, and H.M.R. Greathead. 2023. Sustainable small ruminant production in low- and middle-income African countries: Harnessing the potential of agroecology. *Sustainability* 15 (21): 15326. https://doi.org/10.3390/su152115326.

Singh, M.K., R. Pourouchottamane, S.P. Singh, R.A. Kumar, N.I. Sharma, A.K. Kumar, G.O. Dass, and R.K. Pundir. 2022. Non-genetic factors affecting pre-weaning growth and survival rate in Barbari kids under semi-intensive management system. *Indian Journal of Animal Research.* 92: 1081–1087. https://doi.org/10.56093/ijans.v92i9.124839.

Swarnkar, C.P., and G.G. Sonawane. 2024. Risk factors associated with neonatal mortality in lambs: An overview. *Indian Journal of Small Ruminants (The)* 30 (1): 1–17. https://doi.org/10.5958/0973-9718.2024.00036.9.

Todd, C. G., B. Bruce, L. Deeming, and G. Zobel. 2019. Short communication: Survival of replacement kids from birth to mating on commercial dairy goat farms in New Zealand. *Journal of Dairy Science* 102:9382–9388. https://doi.org/10.3168/jds.2019-16264.

Yitagesu, E., and E. Alemnew. 2022. Mortality rate of Boer, central highland goat and their crosses in Ethiopia: Nonparametric survival analysis and piecewise exponential model. *Veterinary Medicine and Science* 8 (5): 2183–2193. https://doi.org/10.1002/vms3.876.

Publisher's Note